Infrastructure

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Infrastructures are the arteries of our contemporary world: roads, railways, airports, ports, pipelines, fibre optics cables, data, and logistics centres. Built above and below ground, they connect, channel, and, at times, halt the movement of humans, commodities, and resources that populate the earth. Infrastructures can also be immaterial: software, flows of data, and capital and the systems that organise them. A most basic definition can be gleaned from the term itself: the prefix 'infra-' means 'below', which highlights infrastructure's role as the 'underlying structure' that allows a system to function. Infrastructures are not traditional ethnographic sites, yet in recent years a growing number of anthropologists and other social scientists have started to analyse them. Ethnographies of infrastructure have shown how these overlooked objects and networks offer exciting insights into the processes that make up social life. These studies have often highlighted the paradoxical quality of infrastructures, showing how they underwrite mundane daily interactions at the same time as being sites where dreams of alternative worlds are played out. Infrastructures remind us of the past and shape ideas of the future. They are both concrete things, and also structures that enable other things to move and be brought into relation with one another. For all of these reasons infrastructures are needed, coveted, and fought for. They channel new forms of power and act as catalysts for political struggle. This entry traces a growing body of work on infrastructures and their social implications. It shows how following infrastructures has allowed ethnographers to extend their analyses across multiple scales, shedding new light on practices of statecraft, ideas of the environment, political possibilities, and conceptions of time and space. Attention to infrastructures helps us analyse past and present societies and push for a collective re-imagination of the possible forms that the future might take.

Introduction

Rarely a day passes without infrastructure being mentioned in the news, with recent crises making their importance ever clearer. Climate change raises questions over the sustainability of fossil-fuel-based energy infrastructure; the COVID-19 pandemic showed the fragility of infrastructures of health care, equipment supply chains, and the emergence of new infrastructures of care and surveillance; and the war in Ukraine and its effects on both energy and food has demonstrated the contingency and importance of the networks that enable the systems of production, extraction, and accumulation on which much of contemporary life is dependent. Pipelines, roads, railways, airports, and ports are at once fragile and ubiquitous, mundane and political, extending far beyond any one human society whilst they (re)organise the humans and objects out of which such societies are made.

In spite of the intensity of contemporary concern over infrastructure, until recently, it was not a category or class of objects that anthropologists were particularly known for studying. As a material substrate ('infra' meaning 'below') for social life proper, infrastructures tended to remain in the background as mundane, unremarkable, and technical objects rather than controversial, vibrant, and cultural forms.

However, in recent years all this has changed. What would once have been seen as a niche topic for anthropological study has blossomed into a lively comparative field which brings together political and economic anthropology, material culture studies, science and technology studies (STS), and the anthropology of the state to interrogate, in a huge range of places and contexts, what infrastructures are, how they come to be, and the role that they are playing in contemporary social life. This entry provides an orientation to this developing field, exploring why this turn to infrastructure has taken place, and what the payoff of studying infrastructures might be.

Anthropologies of infrastructure

The anthropological study of infrastructure has emerged in part from a long-running question facing anthropologists about how to study the large-scale systems within which we are all entangled (Larkin 2013, Troillot 2003). Anthropology is a discipline which specialises in understanding local experience and forms of social life that take place in particular communities. However, anthropologists are also aware that any experience in place is shaped by things and processes happening elsewhere. Understanding things like capitalism, globalisation, colonialism, and the state have been long-running concerns within the discipline, leading to the creation of key concepts such as 'scapes' (Appadurai 1990), 'friction' (Tsing 2005), 'structural violence' (Farmer 1996), and 'socio-technical networks' (Latour 1991).

Anthropologists have found infrastructures promising in this regard for they are both concrete material forms which can be studied ethnographically in particular places, but they also function as infrastructures precisely because they traverse and transgress space and place (Harvey et al. 2017). Whilst the method of ethnography may have been developed in small-scale social settings, it is nowadays invariably conducted in relation to issues like globalisation, economic exchange, global religion, media, and migration which exceed the boundaries of any one research project in any particular place (Eriksson 1995, Anand et al. 2018; Anand 2011; see also Amin and Thrift 2014). By turning their attention to infrastructures, anthropologists have shown how their systemic qualities are created through tangible activities that take place in offices, in laboratories, in communities and neighbourhoods, in debating chambers, on websites, social media platforms, and in images and documents which circulate through social networks online and offline. Many social scientists understand infrastructural systems in terms of technological progress, the pursuit of seamless connectivity, and the materialisation of geopolitical relations (cf Harvey 1989; Therbon 2007; Levinson 2006; Easterling 2014; Cowen 2014). Within the anthropology of infrastructure, the emphasis has been on *how* these ideas (of technological progress, seamlessness, and geopolitical importance) come to be attached to infrastructure. Paying attention to infrastructures allows us to account for the everyday work that goes into making, breaking, and living with systems of power, control, possibility, and inequality (see also Megoran 2006).

Another reason why anthropologists have been drawn to infrastructure is that more and more state

projects that they encounter in their field sites are now classified under this term. Things like roads and energy systems have not always been grouped together as 'infrastructure'. As Ashley Carse shows, the term has a particular history, emerging initially in English to describe the substrate that underlay railroads, rather than the railroads themselves. Over time, infrastructures have gradually come to be conceptualised as a class of things in their own right—as 'hard technical artefacts or systems, rather than processes' (Carse 2014, 11), allowing engineers and anthropologists alike to think about diverse material systems all as forms of 'infrastructure'. This is not just a matter of terminology. With the term we have seen the emergence of a much broader set of concerns about the appropriate techniques and practice of governmentality that infrastructures demand. This has particularly been the case when it comes to the relationship between infrastructures and the governance of risk.

For Stephen Collier and Andrew Lakoff (2020), the identification of infrastructure as a class of object that entails particular kinds of risks and possibilities has shaped the kinds of projects that states invest in. Specifically, Collier and Lakoff link state-led infrastructure projects to processes of securitisation, showing through a historical analysis of twentieth century military organisation how infrastructures emerged as a material response to challenges of international security. In an analysis of the emergence of the concept of 'critical security infrastructure', they trace how the problem of infrastructure for the US Army emerged first as a logistical problem of how to move troops and their resources across land, a challenge which stimulated socio-material inventions, from floating pontoon bridges to the very idea of supply chains. Over time the concern with building infrastructures to support military incursions shifted into a concern with how to protect them from attack, thus opening the way to thinking of infrastructures of production and circulation as critical sites of risk. This state preoccupation with infrastructures as subject to and technologies of risk management has stimulated investment in both national and international megaprojects, whose structural complexity and social impacts have come to shape anthropologists' field sites in profound and unavoidable ways. As a result anthropologists have found themselves exploring such issues as the place of speculation, futures, and markets in the making and reshaping of people's lives, the exclusionary quality of infrastructure megaprojects that disconnect some people even as they connect others, and the ongoing legacies of power and colonialism that are made evident when new infrastructures appear.

If infrastructures have emerged empirically as sites of contestation, politics, and social change within anthropological field sites, they have also become available as topics for study. This was the result of shifts in theoretical discussions and debates within the social sciences and humanities. Infrastructure studies is an inherently interdisciplinary field which traverses geography, science and technology studies (STS), political sciences, history, sociology, and urban studies. Across these disciplinary boundaries, scholars are held together by a range of shared theoretical approaches that foreground questions about the role of materiality, object agency, process, and form in processes of social and political change. Key influences in

this broader interdisciplinary discussion include actor network theory (ANT) (Latour 2005, Law 1999), and in particular the work of Bruno Latour and his early studies of the production of scientific knowledge and the workings of infrastructure, such as the collected essays in *Pandora's hope* (1999), and his parable about a speculative rapid transport system, *Aramis: or the love of technology* (1996). ANT helped draw attention to the active role that seemingly inert objects play in social life, and to the way that knowledge and understanding of the world is the outcome of material practices of ordering, translating, and transforming signs and matter.

One of the most well-known definitions of infrastructure is 'matter that moves matter' (Larkin 2013, 238). Infrastructures like roads and railways are tangible material forms that exist in particular places and that people use in their everyday lives. Yet infrastructures are not just material forms that exist in one location, but function precisely because they hold together a range of things—rail tracks, standards, ideas, policies, labour practices. It is this ability to connect that enables things and people to move, and societies to function. Brian Larkin therefore argues that infrastructures are not only things 'but also the relations between things' (2013, 239). Those who have sought to understand the more explicitly political implications of these mutable socio-material relations have built on the work of scholars like Langdon Winner, whose pioneering publications in the social studies of technology illustrated how artefacts can come to act violently and reproduce or rework social inequality (Winner 1986). This is most clearly articulated in Winner's discussion of the bridges built by the planner Robert Moses over the Long Island Expressway. These bridges were too low for public buses to pass under, with the effect that they kept low-income citizens away from the beaches of Long Island. Extending this attention to infrastructural power, scholars have also drawn on the work of scholars such as Susan Leigh Star, Geoffrey Bowker, and Paul Edwards who have shown how the standards, classifications, and knowledge systems that frame and shape infrastructures are both informed by, and in turn inform, relations of inclusion and exclusion (Star and Bowker 1999, Lampland and Star 2009, Star and Ruhleder 1996, Edwards 2003).

Pushing this critical attention to the political life of materials further, infrastructure studies have also been deeply influenced by the feminist STS scholars like Donna Haraway, Isabelle Stengers, and Karen Barad, whose work has sought to recover the political possibilities inherent in the hybrid, categorically transgressive, and messy work of making knowledge and making worlds (Barad 2007, Haraway 1991, Stengers 2005). In the 2010s, much of this conversation about materiality and object-agency coalesced into a field of study known as the 'new materialisms', which brought together these materialist approaches with political science to advocate for a more explicit attention to the affective properties of lively matter in shaping political relationships (Coole and Frost 2010, Braun and Whatmore 2011). Proponents of this school argued we should pay attention to the specific chemical properties of materials such as oil, gas, coal to learn about how different forms of political consciousness take shape. For example, Timothy Mitchell has demonstrated that the specific composition of coal, its heaviness, location, and the methods necessary for

its extraction have played a crucial role in shaping workers' ability to make democratic claims. This is because, unlike oil, coal extraction is predicated on the concentration of large groups of workers in one place (2011).

> Although there are tensions between these different intellectual threads, what they share is an openness to understanding human worlds as inherently entangled with material processes and properties, and a curiosity as to the implications of this entanglement in domains ranging from science to politics, religion, health, technology, and, of course, infrastructure.

As we can see, there is no single anthropology of infrastructure, nor a unique definition of what infrastructures are. Instead, the way anthropologists have come across infrastructures and sought to incorporate them into their analysis has created practical and conceptual challenges that have in turn reshaped wider debates within the discipline. The sections below outline how an attention to infrastructures have produced new perspectives on: the state, the environment, conceptualisations of space/time, and, finally, how these elusive networks have helped anthropologists to develop new understandings of politics.

Infrastructures and the state

With [ethnographic](#) studies of infrastructure frequently taking anthropologists into the offices, field laboratories, and spaces of protest associated with infrastructure projects, it is perhaps unsurprising that their study has often also been the study of the state (Harvey and Knox 2015, Von Schnizler 2010, Collier 2011). As large-scale public works projects, infrastructures are [dependent](#) on states to [finance](#) or underwrite their investment. They are also tied to states through standards, regulations, legal regimes, planning systems, and political decision-making processes (Collier et al. 2016). Arguably, large-scale infrastructures like roads, electricity networks, and railways would not be possible without the existence of modern nation states, and thereby offer a promising way into studying the everyday life of the state itself (Sharma and Gupta 2006, Gupta 2012).

One of the issues that has faced anthropologists of the state has been the challenge of actually studying the state ethnographically (Mitchell 1999). 'The state' is a concept that points to political institutions such as councils, governments, military, and the courts, but it also includes a wider range of people—[tax payers](#), [citizens](#), businesses, [charities](#)—objects and processes, such as forms, elections, referendums, consultations, policies, and standards, through which norms of appropriate behaviour and conditions of belonging are worked out (Taussig 1997, Coronil 1999). Anthropologists have found in state infrastructure a promising object through which the subjects and objects which generate 'state effects' can be traced and followed in practice (Harvey 2005).

If infrastructures are not possible without the state, then the opposite is also true: namely, that the state is

not possible without infrastructure. Infrastructures can thus be thought of as key technologies through which states enact, perform, and reproduce themselves. Ethnographies from South America to Central Asia to Europe have shown how roads, railway borders, and other structures are the crucial threads through which the limits of nation states are stitched and, indeed, unstitched (Harvey and Knox 2015, Mukerji 1997, Reeves 2014). In this sense, infrastructures have been central technologies of colonisation and machines of colonial and racial violence (Zeiderman 2020; Viatori and Scheuring 2020). The recent history of the Baku-Tbilisi-Kars railway exemplifies this infrastructural (un)stitching. In the aftermath of the first Nagorno Karabakh War in 1993, the railway was rerouted away from Armenia, creating a corridor connecting Azerbaijan with Turkey, through Georgia. This effectively and willingly materialised a logistical border to Armenia's participation in regional and international trade. Furthermore, as Tekla Aslanishvili and Evelina Gambino explore in their ethnographic film, *A state in a state* (2022), this geopolitical function and the funding structure of the train gave life to a series of borders of different kinds, exacerbating forms of marginalisation along ethnic lines and generating new insecurities amongst the populations affected by this infrastructure (Aslanishvili 2022; Gambino 2022, 2019).

Anthropologists have pointed to the frequently inherent coloniality of infrastructures, showing how rather than being just a means to an end, they have shaped the logic through which colonisation has been enacted (Cupers and Meier 2020, Vaughn 2021). Sarah Vaughn's research on water infrastructure and climate adaptation in Guyana, for example, has shown how contemporary attempts to manage the watery coastline of Guyana rests on infrastructural histories of dam construction that involved colonisation, slavery, plantation agriculture, and racial politics. Contemporary infrastructure projects demand a reckoning with these embedded histories, even as they seek at times to depart from them. In other contexts, infrastructures have enacted a politics of colonisation by enabling peripheries and frontiers to be tamed and tied into state systems of bureaucratic oversight and governmental control. They have shown how roads and supply chains, for example, link sites of extraction and allow novel forms of circulation, exchange, and profit (Tsing 2005, Scott 1998). Not content with seeing this as just a matter of domination, however, anthropologists have sought to tell more complex stories about these incursions, showing how large-scale projects of domination are domesticated and embodied by those who inhabit these infrastructural worlds. Laura Bear, for example, who studies the Indian railways, has shown how as railways travelled to corners of the subcontinent never connected before, a myriad of new relations emerged that would permanently reconfigure not just the institutional but also the intimate lives of Indian citizens (Bear 2007).

If some infrastructure projects have been a way of inserting state power over territories, people, and the environment, others have been part of a process of state *transformation* as state forms become obsolete, splinter, or are replaced over time. Stephen Collier's ethnography (2011) of the attempted neoliberalisation of Russia following the collapse of the Soviet Union charts how infrastructure becomes a means through

which such change is pursued and also thwarted. Collier's ethnography looks at the attempted privatisation of heating systems across the territories left behind by the collapse of the Soviet Union, demonstrating how communal heating systems emerged problematically as material instantiations of the Soviet political system. The author explores what happens to such infrastructures in the face of political change. Focusing on the transition from socialism to neoliberalism, Collier follows pipes and flows of heat to show how the establishment of the free market in a former Soviet town took the shape of a battle against the infrastructures of Socialist urbanism. Here, the pipes heating the USSR operated according to centralised estimates of the city's needs and could not be controlled by individual households. Similarly, Antina von Schnitzler has shown how water meters became political in the South African context of post-apartheid politics. When these meters were installed in South African townships in the 2000s, this seemingly benign technology operated as a tool of governance that sought to counter an anti-apartheid era of payment boycotts and usher in an era of neoliberal citizenship. Through the implementation of water metering, township residents were asked to become 'calculating subjects', whose civic contract with the state entailed an entrepreneurial ethos (von Schnitzler 2008). Here the water meter was a technology that helped bring into being a new form of governmentality.

If the material work of grappling with pipes and meters is one way that states transform their modes of governance, another is through the knowledge infrastructures of paperwork, bureaucracy, standards, regulations, and law. Ethnographers have shown how contracts (Appel 2019, 137–204; Tsing 2005, 69), forms of expertise (Ong 2005; Mitchell 2002, 2011; Harvey and Knox 2015; Gunel 2019) or the calculations that sustain global financial flows (Appel and Kumar 2015; Ho 2009) operate as powerful knowledge infrastructures of contemporary capitalism. Ethnographies show that infrastructures of information—such as documents—operate very similarly to the more obviously material infrastructures we can observe around us. Hannah Appel's ethnography looks at the place of contracts in establishing petro-capitalism in Equatorial Guinea. Like bridges and roads, contracts work by connecting some entities (i.e. the state and private enterprises), and, like territorial borders, they disconnect others. As juridical tools, contracts come to fix the relationship between corporations and the state, with the latter guaranteeing profits for the former. This fixing has infrastructural qualities. Hannah Knox and Penny Harvey highlight how 'a finished road makes invisible or seemingly unimportant the conditions of its construction' (2012, 529). 'There are several ways in which things can become un-noticed', says Hannah Appel, 'there are things that you don't notice because you rarely come across them, and there are the things you don't notice because you come across them so frequently' (2019, 137). In its mundane, modular form, a signed contract provides a legal coat under which the terms, parties, and negotiations brought together by a specific deal can remain unseen and therefore unquestioned (Appel 2019, 137–61; Tsing 2005, 69). As scarcely visible substrates, contracts are shown to have powerful infrastructural effects, enabling legal practices such as offshoring and sanctioning the distribution of underground oil deposits between private corporations. As such, they effectively function as key infrastructures of this particular kind of extractive capitalism, organising its

economic *and* social impacts.

Whether depicting infrastructures as public works, splintered networks, arteries of domination, or invisible substrates, they provide us with a greater understanding of state processes by allowing us to study the state in a concrete manner. In this way, ethnographies of infrastructure propose new ways to understand how state power is formed and maintained, and the shapes states take within different historical moments.

Infrastructures and space/time

Infrastructures also enable social scientists to reconsider the importance of time and temporality in social life. Time is a foundational topic for anthropologists, both in terms of understanding how time is constructed, measured, and valued in different social worlds, and in terms of an on-going reflexive critique of the temporal assumptions embedded in the socio-cultural study of society (Wolf 1982, Fabian 1983, Gell 1992, Pels 2015). Many of the questions that animated these debates about time in anthropology have been reinvigorated in recent years by studies of infrastructures.

Attention to infrastructures has revealed how shared conceptions of time are codified (Bear 2016), opened up questions about the relation between space, place, and time (Gupta 2015, 2018), and allowed an interrogation of how different ideas of time are enlisted into projects of accumulation, exploitation, and, indeed, revolution (Bear 2014, Appel 2015, Pedersen and Nielsen 2015). Crucially, anthropologists have found that infrastructures actively 'work on time' (Mitchell 2020). That is, they change and modulate basic assumptions about how societies are temporally ordered and they do so in often unexpected ways. One good example of this is the temporal effects of the introduction of the railways in the nineteenth century. Railroads revolutionised the relation between space and time, shrinking the time that travel took in ways that created not just shorter journeys but also a whole new concept of space. The arrival of trains quite literally informed a new understanding of time and landscape: the necessity to synchronise train schedules across a national territory pushed for the unification of national time under a single time zone; the speed of travel separated people from the land through which they travelled; and new railways into frontier zones materialised a sense of progress into the future (Schivelbusch 1986).

The spectacle of new infrastructures often manifests as a kind of technological sublime (Nye 1996), with infrastructure megaprojects presented as indices of progress and the presence of concrete, steel, and glass symbolising the appearance of modernity (Anand et al. 2018, Barker 2005, Laszczkowski, 2011, Schwenkel 2015). Anthropological studies of infrastructure have long been replete with examples of this, particularly in urban settings (Rabinow 1989, Graham and Marvin 2001, Joyce 2003). Today as in the past, infrastructures continue to have a powerful capacity to enact the future in the present (Mrazek 2002; Mitchell 2020). They do this in various ways. First, infrastructures provide durable structures upon which

investors can secure a revenue of capital into the near future. In this sense, they provide a concrete anchor for the promises of development made by states and international institutions alike (Abourhame and Salamanca 2016). Second, in order to attract investment, infrastructures are presented by states and corporations as promissory, enchanting, and at times almost magical tools through which politicians, speculators, and other institutional and non-institutional actors can claim to be able to secure a better future (Anand et al. 2018, Abram and Weszkalnys 2011). Yet ideas of modernity materialised by infrastructures also coexist and are entangled with other very different conceptions of time.

This is the case of the Soviet-era electrification programme in Mongolia described by David Sneath (2009). Electricity was of utmost importance to the Soviet modernising mission; Lenin famously described communism as 'Soviet power and the electrification of the whole country' (Lenin [1920] 1965). The establishment of cables and transmission lines and the extraction of hydropower and fossil fuels were key technologies through which the Politiburo (the main policymaking committee of the Communist Party) sought to tame the peripheries of the Soviet Union. A new rational and modern 'cult of light' was set to permanently eradicate the unmodern imaginaries that populated the margins of the USSR. However, rather than displacing the imaginative registers of traditional practices, as Sneath describes, electricity became domesticated by local publics and started to coexist next to the very beliefs it was set to displace. As divination remains widely practiced to this day, in Ulaanbaatar, the capital of Mongolia, one might visit a diviner famous for using 'modern technical devices' such as a pocket calculator to tell fortunes, all the while experiencing 'Lenin's light' as the glow of modernity (Sneath 2009, 88). In this case the infrastructures of electrification in Mongolia did not establish a new modern subject; instead, they contributed to a new mixed world made of imbroglios between the technical and the magical, the scientific and the prophetic.

As well as ushering in modernity, infrastructures also intervene in temporality through their promise of creating speed (Harvey and Knox 2008). The technological ideal of overcoming ever-greater distance in increasingly less time remains at the heart of contemporary ideas of progress (cf Marx [1857] 1993, Virilio 1986). Following Marx, the geographer David Harvey has famously termed this this tension 'space/time compression' (1989), which he places at the core of contemporary capitalism. Indeed in our daily lives this compressed space/time seems to be everywhere: commodities we buy arrive on our doorstep in less than 24 hours, the fruits and vegetables we eat have travelled thousands of kilometres before even becoming ripe, and fibre optics cable allows communications in seemingly 'real time' (Riles 2004). The most remote corners of our planet are interconnected through seemingly continuous flows, so that when a giant container ship became stuck in the Suez Canal in the spring of 2021, impacts were felt across markets all over the world. The complex logistical choreographies of this constant circulation and compression have been at the heart of lively debates in the social sciences about the relationship between infrastructure and time, in particular in relation to shipping, trade, and commodity flows (Cowen 2014; Khalili 2021; Chua et

al. 2018, Mezzadra and Neilson 2019).

Anthropology's original contribution to these interdisciplinary debates can be found in its unique ability to account for the frictions that populate the world of logistics (Tsing 2004, 2009; Lee and Li Puma 2002; Rofel and Yanagisako 2018; Bear et al. 2015; see also Katz 2001). Paying attention to actually-existing logistics from specific places, anthropologists have criticised the idea of space/time compression as the dominant condition of contemporary capitalism. Nicole Starosielski shows this well in her study of the cables that make possible the real-time communications sustaining financial markets and global trade (Starosielski 2015). She shows that 'thinking of time-space compression through infrastructure paradoxically draws attention to the slowness of the process of speeding up' (Anand et al. 2018, 15), the time it takes for cables to arrive in communities and the slow speeds that result once they are there. She describes how our 'wireless world' is made possible by a resolutely material undersea network of cables. These cables, made up of resources extracted from a variety of places, are laid by armies of workers and disrupt already existing environments populated by animals and people, and which are sometimes deemed as sacred by local populations. Starosielski's ethnography sheds light onto the actual temporalities of infrastructure, as well as considering what, and indeed, who, is left out from collective imaginations of the high-speed internet. The space/time compression that we experience when speaking in real time with a distant friend through the internet, thus, exists not separate from but in accretion with a host of other logics of time and space (Anand 2018).

Here, anthropological inquiry works once again 'against the grain of paradigm setting' (Navaro-Yashin 2007, 16). Ethnographic attention to the infrastructures of logistics has produced thick descriptions of the time/spaces that populate global flows, allowing anthropologists to develop a 'polyglot language' (Tsing 2009) that is capable of showing how diverse times and spaces are made by contemporary forms of circulation.

Infrastructure and the environment

If the anthropology of infrastructure cut its teeth on the study of national and global networks such as canals, fibre-optic cables, or electricity networks, the focus on infrastructure 'proper' has expanded since to include things that might not at first glance look very 'infrastructural'. Indeed, as we saw in the introduction, the field is not defined by studying a particular class of things generally called 'infrastructure' but it studies the relationships whereby some things take on the quality of being 'infrastructural'. For example, for a driver in a car travelling along a highway, we might say that the highway is 'infrastructure' in that it enables driving to happen. However, for the road maintenance worker, the road appears less as infrastructure and more as an object of repair. As Susan Leigh Star and Karen Ruhleder famously put it, we should not be asking 'what' is an infrastructure, but rather 'when' is an infrastructure (1996). Understanding infrastructures in this relational way has meant that the term has been opened up by recent

scholarship. If 'infrastructure' is merely something that enables something else to happen, a 'system of substrates' that support other forms of life (Larkin 2013), then it may make just as much sense to say that soil, or air, water, or carbon, are infrastructures as much as bridges, electricity networks, or shipping routes.

In the face of climate change, pollution, environmental degradation, and biodiversity loss, the infrastructuring qualities of environmental forms have become increasingly evident. This has linked environmental anthropology and the anthropology of infrastructure in a range of insightful studies, seeking to bring into view the role that non-human life forms play in sustaining human lifeworlds. Their broad understanding of infrastructure encompasses insects, forests, sand, and waves. Leading discussions about the entanglement of humans and non-humans in the face of environmental destruction, Anna Tsing, in her monograph *Mushroom at the end of the world* (2015) and multimedia project *Feral atlas* (2021), attends to the ways that labour, cultural practice, and the material agency of things swirl together to create world-shaping and world-breaking forms. Tackling the role of natural forms in sustaining infrastructure, a recent study of the Panama Canal draws attention to the way that engineered infrastructures always also entail a reckoning between 'nature' and technology (Carse 2014). In this case, Carse describes how the flow of water that feeds the Panama Canal is regulated by forests and their hydrological properties. Deforestation by farmers and loggers in the region not only threatens local ecosystems but also poses a threat to the infrastructure of the canal itself—thus linking local environmental dynamics to a key infrastructure of global trade. Plants, states, and citizens can also become co-implicated in environmental destruction, as a recent study of soya bean farming in Paraguay shows (Hetherington 2013). Here, attempts by monocrop agribusinesses to manage their environmental harms demonstrate the limits of government as a tool to tackle socio-natural destruction. Instead of a simple story of power (of agribusinesses) and resistance (by local people), what we find here is a more complex tale of how swathes of land in Paraguay came to be given over to soya bean farming, and how this form of agriculture persists through the everyday interactions of regulators, growers, peasant activists, migrants, and non-humans such as pesticides and the beans themselves. What these studies show is the complex imbrication of engineered infrastructures with ecological systems which become co-implicated in attempts to bring about social change (see also Knox 2020, Dewan 2022).

All of these studies of infrastructure and the environment tend to build on a tradition of research that has fundamentally dismantled the idea that nature is an inert substrate upon which human affairs are conducted (Latour 1993). Instead, by positing an infrastructural approach to the environment, they demonstrate the inherently political status of 'nature' as a space of extraction, enclosure, conservation, labour relations, and state making. Those studying environment/infrastructure have shown how landscape, environment, and matter are being imagined and created as infrastructures of consumerism and capitalism. They also draw attention to the environmental effects of engineered infrastructures from dams

to data centres, including the social and material conditions of mineral extraction, pollution, disposal, repair, and contamination (Parikka 2011). In doing so, such studies have brought discussions of infrastructure squarely into debates about the human experience of living in 'the Anthropocene', a term that denotes the entanglement of people, technology, and matter in the contemporary era. Indeed, the historical emergence of the Anthropocene epoch, particularly during the twentieth century, coincides with the spread of engineered infrastructures. Whilst the Anthropocene has been a somewhat contested concept within anthropology (Moore 2016), the issues that it raises are well served by the work that has already been conducted under the umbrella of the anthropology of infrastructure.

At the same time as the environment has become understood as inherently infrastructural, so too infrastructures have undergone their own shift to become themselves more 'environmental', in the sense that they are becoming active and responsive parts of the milieux in which people live (Gabrys 2018). This has manifested particularly through the digitalisation of infrastructure whereby existing infrastructures have undergone a transformation, with materials becoming augmented or 'informed' through the use of continuous monitoring or sensing (Barry 2005, Fortun 2004). We see this with things like urban dashboards (Mattern 2015), networks of sensors in the ocean or on trees (Helmreich 2019, Myers 2018), driverless cars (Tennant and Stilgoe 2021), and anything designated with the adjective 'smart' (Halpern et al. 2017). These studies show how, as infrastructures become augmented with sensors, digital communication, and AI, they take on cybernetic qualities. That is to say, infrastructures are no longer simply stable forms, inserted into social worlds, but are now expected to respond to and 'learn' from their milieu (think of the 'smart motorway', iteratively changing speed limits in relation to road conditions). This has led some to argue that infrastructures are in this sense becoming 'environmental' in that they are both substrate and agent, thus dismantling the figure-ground relationship upon which the very concept of infrastructure has until recently rested (Knox 2022, Gabrys 2018).

Counter-political infrastructures

A final area to highlight is the recent ethnographic attention to dynamics of resistance, repurposing, and reappropriation of infrastructures by both local and international communities of citizens and activists. One risk with the anthropology of infrastructure is that it draws too much attention to the capacity of top-down imposed socio-material change. A powerful counter to this is the extensive work that now exists on bottom-up, often counter-political forms of infrastructure development. These have emerged either as alternatives to dominant infrastructural systems, or in the gaps left by failing or crumbling infrastructure (Dalakoglou 2016, Corsín Jiménez 2014, Simone 2004, Barry and Gambino 2019, Gambino 2022). Ethnographies of squatters, activists, programmers, laborers, and migrants have explored how the centralising, exclusionary, and extractive logics of dominant infrastructural forms are being countered by alternative principles of open source, collaborative, and collective design based on principles of sharing, participation, and care

(Kelty et al. 2010, Puig de la Bellacasa 2017). The ethnographic sites for this work are diverse. Chris Kelty and Gabriella Coleman, for example, have taken as their focus the high-tech world of the free and open source software communities, community hacker spaces, and open hardware movements (Kelty 2010). Others have focused on the infrastructural work done by activist groups like the Occupy movement, 15M in Spain, and the solidarity movement in Greece (Postill 2020, Chan 2015, Corsin-Jimenez and Estalella 2017, Juris 2008, Dalokoglou 2016). This has drawn attention to much longer-running forms and methods of bottom-up civic action, bringing into the study of infrastructure an appreciation of the importance of community-based networks of social support. Here people and their social relations of exchange and mutual support are created by groups like migrants, inhabitants of informal settlements, or racially marginalised communities that are either excluded from or subjected to the violence of state-sanctioned infrastructural systems (Holston 2009, Simone 2004).

The key contribution of these studies of alternative, distributed, and bottom-up ways of making and doing infrastructure is to offer a reconfiguration of anthropological understandings of how power and politics work. AbdouMaliq Simone, for example, asks how collective will is enacted. For over three decades, Simone has observed the way in which informal urban networks come to be assembled in cities of the Global South. His work demonstrates how an attention to infrastructures refigures politics as 'a choreography of experimentation' (Simone in Bear et al. 2018, 49; Simone 2004) that binds together designs, materials, pipes, places, and relationships between urban dwellers as they seek to intervene in the worlds in which they live. It is from this makeshift (infra)structure that forms of resistance materialise. Anthropological work on these bottom-up infrastructural forms has served to counter techno-determinist analyses of infrastructures and their effects. Instead, they have shown how infrastructures are sites of political struggle, on-going negotiation, and social and cultural creativity. There is often an activist register to these studies. They illustrate how even in the face of seemingly immovable material structures put in place by states and corporations, people find ways of tinkering, reworking, and altering infrastructures to forge not only new material arrangements but also, perhaps even more importantly, alternative anticolonial trajectories of imagining possible futures. These studies deploy ethnographic description to the ends of a collective re-imagination of the possible forms that society might take (Estalella and Criado 2019, Pink et al. 2018).

Conclusion

Infrastructure has emerged as an alluring topic of study for anthropologists, but it has not been without its critics. The 2015 meeting of the UK based Group for Debates in Anthropological Theory discussed the motion: 'Attention to infrastructure offers a welcome reconfiguration of anthropological approaches to the political' (Bear et al. 2018). The discussion pivoted around the tendency of infrastructure scholars to extend the category to a bewildering array of things and topics, including affects, values, languages, ethics,

temporalities, exchanges, and culture. Those in opposition to the motion argued that this risks depoliticising and generalising the specific historical and cultural saliency of engineered infrastructures as built forms (Lazar in Bear et al. 2018). They also held that extending the category risks forcing incommensurable 'ontologies' or world-views, such as those upheld by the Indigenous communities that are so often affected by infrastructural developments, into a universalising, Western techno-political lens (Rival in Bear et al. 2018). In substance, infrastructure was criticised for being at once too vague and too narrow, risking erasing diverse ways of seeing the world as well as becoming too diluted to have any analytical purchase (Harvey in Bear et al. 2018, 4).

While the motion did not pass, many anthropologists remain committed to exploring human and non-human worlds through an attention to infrastructure. Expanding the definition of infrastructure further, some argue that it is best understood as 'the movement or patterning of social form [...] the living mediation of what organises life: the lifeworld of structure' (Berlan 2016, 393). Others highlight infrastructures' character as the 'enablers' of different systems and encourage seeing the infrastructural turn in the human sciences as a sign 'that we are conceptually re-arming ourselves for the struggle against the Anthropocene and the modernity that made it' (Boyer 2017, 226). However, rather than proliferating an endless list of things to categorise under the heading 'infrastructure', ethnographic accounts speak more importantly to the ability to detect *when and how* the infrastructural quality of things comes to matter, and to map the different kinds systems they underwrite (Star 1999).

Finally, as the study of infrastructure has become consolidated as a subfield of anthropology, it has begun to explore what role scholars might play in making and imagining future infrastructural systems and shaping people's entanglement with them (Bryant and Knight 2019, Pink 2022). This work involves awkward but necessary collaborations between anthropologists and a range of other scholars and practitioners (Aslanishvili and Gambino 2022; Knox 2022, Khandekar et al. 2021, Bremer et al. 2020, Ogden 2021). These kinds of interdisciplinary collaborations are already underway, with studies such as the *Feral atlas* (2021) coming into being at the intersection of different forms of knowledge, including history, art, architecture, engineering, and natural science. As the anthropology of infrastructure comes of age, it has thus begun to extend beyond the discipline, seeking out collaborations with local communities, artists, programmers, architects, and infrastructures themselves. Its goal of tracing and creating alternative ways of seeing, being, and organising life is all the more important in the face of challenges to come.

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