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Understanding infrastructure interfaces: common ground for interdisciplinary urban research?

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Abstract: Urban development is a complex, multidimensional process that no single discipline can understand, explain or address adequately. In the case of infrastructure, different disciplines address specific issues—technical problems, social dynamics, political power—yet in reality these often intersect. This article documents the experience of analysing the governance of infrastructure interfaces through a multi-disciplinary case study of transport and sanitation in Addis Ababa, Ethiopia. The analysis relied on combining established frameworks applied to social and technical analysis, alongside that of the analysis of institutions and integrated planning. Scholars from development studies, planning and transport studies, architecture and engineering, anthropology, geography, political science and public administration were involved. Each provided conceptual and methodological approaches of value but with some proving more synergetic than others. Overall the process itself yielded considerable benefits for the joint research endeavour and confirmed the validity and additionality of interdisciplinarity in infrastructure research.

Keywords: Addis Ababa, Ethiopia, governance, infrastructure, infrastructure interfaces, institutions, interdisciplinarity, planning, sanitation, transport, urban development.

INTRODUCTION

Disciplines are departments of knowledge or knowledge communities in which instruction in the subject matter takes place and the rules for conduct of research are defined and applied. Disciplines exist for good reason. They allow for foundational understanding and methodological know-how, as well as knowledge accumulation and depth of understanding in a particular field. However, disciplines also represent systems of rules and ways of seeing that can constrain as much as advance effective scholarship. For this reason, and specifically in urban contexts, it has been argued that

a single disciplinary approach is no longer an adequate response to contemporary complexities (Beall *et al.* 2010). On the contrary, the development of cities requires expertise in the technical aspects of infrastructure systems, in policy and planning as well as the management know-how for the functioning of cities. It also relies on an understanding of the drivers and impact of urban political economies and the social dimensions of access to and use of the amenities and infrastructures of cities.

It is now widely agreed that bounded disciplinary registers are simply insufficient for addressing the complexity of contemporary urban questions. These require broad understanding, analysis and application, often best derived from interdisciplinary research. Yet its execution can be difficult in practice. The use of different data, specialist methods, or disciplinary predilections can ensure that cross-disciplinary engagement can result in an amazing lack of reciprocal knowledge (Abbott 2010). Incomprehension, misunderstanding and disciplinary chauvinism can all act as impediments to our understanding of cities, the multiple worlds within them, as well as the various spheres of supra-urban influence under which they operate. With this in mind, Ash Amin and Nigel Thrift (2017) have advocated for a new 'science for cities' that is multi-scalar, multi-register and, of course, interdisciplinary.

Our current research on urban infrastructure in Addis Ababa contributes towards the attainment of this ambition. Our focus is on transport and sanitation infrastructure systems, recognising their fundamental role as drivers of urban growth and being critical determinants for poverty reduction and welfare. Our case-study sites are two local-scale infrastructure projects, one central and the other peripheral to the city, which nevertheless are integrated into a complex web of supply chains, technical expertise and governance arrangements that span and extend way beyond the urban scale. We examine these local-level projects both intrinsically and as part of urban infrastructure systems resulting from hard policy instruments, linked in turn to the purposive design of the capital city. We do this through an examination of infrastructural governance interfaces at different levels. This article demonstrates the indisputable value of the interdisciplinary research process, while also reflecting on some of its limitations and challenges.

TOWARDS INTERDISCIPLINARITY

As traditionally understood, disciplines constitute a coherent intellectual field of study and display a unity in their problematics, categories and techniques of investigation, usually of a singular and homogenous 'object' of enquiry: the economy, medical conditions, the biological world, society, etc. They are concerned with rigour in procedures and methods and, importantly, disciplines are asserted as being

autonomous from one another and from 'the powers or authorities that might wish to appropriate them' (Thompson 2016: 323). In reality, disciplines are not so hermetically sealed and are subject to cross-fertilisation. As a consequence, interdisciplinarity is not particularly novel (Barry & Born 2014) and in any case, disciplinary boundaries are often porous and necessarily hybrid (Osborne 2015).

Interdisciplinary research has been advocated for at least since the 1940s, especially in applied areas such as international development studies, where a fuller understanding of social phenomena is necessary (Hulme & Toye 2006). Other fields of investigation —for example, globalisation, climate change or urbanisation—also require broad understanding, analysis and application that can frequently elude bounded disciplinary registers. Yet the boundary transgressions that define interdisciplinarity can be equally elusive, leaving such efforts no more than multidisciplinary collaborations where issues are separately examined by researchers based in different disciplines, who may then come together to develop overall syntheses and conclusions. By contrast, at its most essential, interdisciplinary research involves the incorporation of novel perspectives, expanded insights, new sources, methodologies and new objects of study. It is a far more ambitious enterprise, involving a deep integration of two or more disciplinary approaches *from the outset* and throughout an entire research exercise. Interdisciplinary research does not require the development of individual polymaths but rather an openness of mind to understand the parameters of different disciplines and the light each can throw on the insights and analyses of others (Kanbur 2002: 483).

Most recent debates on interdisciplinarity have emanated out of reaction to normative calls for interdisciplinarity from funding agencies, governments, university managers and policy makers. The change this has evoked is not so much one of substance, for, as previously stated, interdisciplinary research is not new. It is rather the magnitude of change (calls for interdisciplinarity are now ubiquitous) and how interdisciplinarity is justified. Barry and Born (2014) point to two key justifications: an increased demand for science to be accountable to society (for example, through greater user involvement) and innovative for the economy, with innovation designed to contribute to growth. While Barry and Born do allow for an ontological logic in interdisciplinary research, where changes result in the nature of the researchers themselves as well as in the objects of their research, it is probably fair to say that in a broad research policy and management environment, the more instrumentalist demands prevail.

One of the effects of increased advocacy for interdisciplinary research has been growing interest in the impact on the humanities and social sciences of collaboration *across* the 'hard' and 'soft' sciences (British Academy 2016, Campaign for Social Science 2017, Michie & Cooper 2015, Nussbaum 2010, Small 2013). The dynamics of disciplinary cross-fertilisation and integration *within* the broad social sciences remained of significance in our research as well as the bringing together of engineers

and physical scientists with social scientists. We chose to categorise the researchers and professional and user participants involved in the study as either techno-policy or socio-political in their approach, recognising that some disciplines such as geography and planning can and do straddle the two.

A further category that is sometimes highlighted is transdisciplinarity, which overtly seeks to transcend or transform existing disciplinary structures and techniques of intervention to produce new orders of knowledge and intelligibility (Barry & Born 2014). Amin and Thrift's (2017) 'new science for cities' constitutes a transdisciplinary ambition that aims for epistemic convergence and knowledge validation for the urban scale. This proved to be beyond the reach of our own research endeavour, although convergence did result around the fact that our research priorities were driven by shared practical problems requiring viable solutions. The investigatory context created an interdisciplinary (if not transdisciplinary) knowledge community in a way that may not have been possible through purely technical or curiosity-driven socio-political research.

WHY ETHIOPIA?

We chose Ethiopia as an interesting case for the study of the governance of infrastructure interfaces because of the changes that have characterised the country over the last quarter century. Ethiopia's status as a transitional state with far-reaching ambitions provides an instructive case for studying urban infrastructure governance and the tensions that arise when long-term objectives for growth and wellbeing have to be balanced with short-term delivery and political legitimacy. Following the defeat of the military dictatorship in 1991 a hegemonic ruling party, the Ethiopian People's Revolutionary Democratic Front (EPRDF), introduced a new political order. Sidelining or encompassing other parties and interests, it embarked on the aggressive pursuit of bringing under control ethnic federalism at a national level, as well as a programme of state-directed development. With relatively strong state capacity under a concentrated and personalised system of decision making, Ethiopia embarked on a form of social engineering and institutional transformation that could achieve modernisation and development at the same time as securing political legitimacy (Khisa 2018). Heavy reliance on high levels of largely government-led infrastructure investment has led some to compare Ethiopia to the Asian developmental states, although without equivalent levels of domestic resource and savings (World Bank 2012). The country certainly stands alongside another high-profile reformist state in Africa, Rwanda under President Paul Kagame.

From the late 1990s onwards, Ethiopia positioned itself towards becoming at middle-income country by 2025. In terms of economic gains, while agriculture

currently makes up roughly half of the Ethiopian economy, Ethiopian cities contribute 40 per cent of the GDP of the country (UN Habitat 2017) and so, core to this vision, was a deliberate and centralised programme of urbanisation and industrialisation. Urban development was positioned as key to the country's economic advancement and investment in infrastructure was seen as a key driver for this (Dorosh & Thurlow 2012). This had obvious implications for relations between national government and the governance of the capital city, Addis Ababa.

The quest for modernisation and centralisation on the part of the EPRDF trumped approaches to infrastructure development favoured by many Western-dominated international development agencies. These tended to focus on decentralisation strategies and incremental, local or area-based responses to infrastructure and service delivery. Service networks and delivery levels are low in Ethiopian cities even by African standards (World Bank 2015) and local officials complained that the ability of metropolitan government departments to invest in the infrastructure adequate to address the evident backlog was constrained by poor revenue flows (Ministry of Urban Development, Housing and Construction 2015). Hence among the fault lines we investigated were first between national government policies and those characteristically deemed best practice by international aid agencies, and second between national and metropolitan government.

The ruling party understood only too well the political and economic gains to be derived from investment in infrastructure. It made sure that it was publicly recognised as the sole or lead promoter of all such development initiatives. Yet this has proved to be a mixed blessing. Establishing legitimacy and garnering popular political support through investment in infrastructure are contingent upon ordinary urban dwellers not only identifying the ruling party as responsible for these interventions but also finding that they actually improve the quality of their lives. In Addis Ababa, despite ubiquitous branding by foreign donors, investors and construction companies, it is difficult to miss the very visible hand of government. Hence the disruptions that processes of urban development can create, such as evictions, rising costs and growing spatial inequalities are also associated with government. As such, it is not yet clear that the ruling party's infrastructural political contract is paying off. Indeed, we found that both our research sites were infrastructure hot spots, representative of wider and multilevel governance challenges. These were associated with fault lines between national and local interests and those of foreign investors, suppliers and contractors, as well as the overall politicisation of infrastructure systems and their cognate policy agendas.

Social and political discontent became all too clear in the wake of the ill-fated election in 2015, when the EPRDF and its allies won an implausible 95 per cent of the vote and every seat in parliament. Protesters took to the streets and young men burned

foreign-owned factories. Prime Minister Hailemariam Desalegn responded harshly, leading to further riots, arrests and deaths and the declaration of a state of emergency. In April 2018, determined to end the violence and chaos, the EPRDF named as prime minister a young reformist by the name of Abiy Ahmed. He had impressive academic and military credentials and has shown himself to be an astute politician, lifting the state of emergency, ordering the release of thousands of prisoners, freeing up the media and ending the war with Eritrea. However, although very popular, his position remains fragile. The country is still fragmented and the 'Ethiopian miracle' is faltering, with the country's sustained 10 per cent growth rate beginning to slow down. Nevertheless, this critical moment in Ethiopia's recent history provided the open context in which it was possible to conduct our research and to assess the durability of Ethiopia's infrastructural political contract.

Within the broad spectrum of infrastructural investment, we chose to focus on transport and sanitation, as urban growth and poverty elimination depend on the adequate provision of both these areas. For transport, benefits ensue from the improved movement of goods and people and better connections between national hubs of economic activity and other urban centres. At the same time, a major challenge for fast-growing cities in developing countries is the provision of adequate, accessible and affordable water supply and sanitation solutions. Both are imperatives for ameliorating poverty in the immediate and medium term as well as contributing to longer-term growth and development through making cities less dysfunctional and

Figure 1. Addis Ababa's Light Rail Transport System.

more attractive places to live, visit and invest in and to contributing to better wellbeing and the development of human capital.

The article draws on research conducted in two study sites in Addis Ababa. The transport infrastructure interface was explored through an examination of the Leghar light rail transport (LTR) station and interchange (see Figure 1) in the centre of the city. The development of this ultra-modern transport solution was highly centralised and the result of top-down decision making, with the Prime Minister himself driving and enabling the whole process. National and city-level officials, including officials from the Department of Housing and Urban Development, were not involved in any meaningful way and there was no discernible public consultation. Local professional stakeholders felt excluded, not least because the LTR was more expensive than the bus rapid transport (BRT) option they had favoured and they were concerned about the over-reliance on external expertise, particularly the Chinese subcontractors who were managed almost exclusively by the national Ethiopian Railway Corporation.

Figure 2. Condominium housing in the Haile Garment area of outer Addis Ababa.

The sanitation case study was Kotari Condominium, a large housing development within the Haile Garment area on the outskirts of Addis Ababa (see Figure 2). The Ethiopian Government is intent on the rapid delivery of state-subsidised mortgage housing on the periphery as a response to the housing deficit and the rising cost of land in the city centre, rendering it unaffordable for low-income residents. Kotari forms part of a first wave of large-scale condominium development on the edge of the city and is illustrative of innovations being put in place to overcome the provision of basic services such as sanitation. Sanitation in Addis Ababa is provided by way of trunk sewers in the centre of the city. In surrounding areas too far to be affordably connected to trunk infrastructure, septic tanks are the most common form of sanitation, with vacuum trucks emptying them and disposing of the waste either via transfer stations or directly at one of a number of treatment plants.

However, the high-density peripheral housing development of Kotari was instead given a decentralised sanitation plant based on a modern membrane bioreactor (MBR) wastewater treatment system imported from Europe (see Figure 3). This sanitation option also involved central state decision makers and international

Figure 3. Kotari's membrane bioreactor (MBR) wastewater treatment system.

contractors. Local professional preferences for extending existing systems were ignored and, although lacking the high visibility and impact of the LTR in the centre of the city, Kotari nevertheless constituted a flagship housing project and high-tech decentralised sanitation system that is integral to Ethiopia's transformation and vision for Addis Ababa as a modern African capital city.

WHY INFRASTRUCTURE?

Interdisciplinarity holds the possibility of opening up fresh perspectives, raising different questions, finding new answers and indeed generating new questions. In the case of infrastructure, it is particularly interesting because it requires the bringing together of very different epistemic registers. It involves reconciling points of reference that see all technical knowledge and the material world as socially constructed, with one that requires us to determine at exactly what weight a bridge will collapse or a sewer will burst. Two key corollaries ensue. First, infrastructure research requires us to be upfront about our normative framing and to recognise prioritisation of different disciplinary registers. Second, it requires researchers to grapple with varying levels of analysis and different spatial and temporal scales. With regard to the issue of normative framing, we first identified various *infrastructural ideals* and their association with particular policy approaches. Second, we distinguished the research priorities of different disciplines, roughly categorising them as *techno-policy* and *socio-political*, and we look at how they deliberately or inadvertently get prioritised during the research process.

Infrastructural ideals

There are no uniform or uncontested conceptualisations of urban infrastructure. Some definitions focus on the 'hard' utilities and the material networks that underpin their provision (Estache & Fay 2009). Other approaches include the people, practices, discourses and imaginaries that shape urban services (Amin & Thrift 2017). All are informed as much by normativity as by disciplinary habits of thinking and it is easy to conflate the two. To avoid this, we identified four broad and stylised infrastructural ideals that inform infrastructure investment and interventions: universal networked access, connecting competitive space, ecological modernisation and new self-sufficiency. They shape how infrastructure is differentially understood and approached in policy terms: whether as a right, a commodity, a public good, a private investment or an arena for various forms of collective action.

Universal access is an infrastructural ideal that was first associated with mid-to-late-20th-century international development thought. At this time macro-level concerns about economic transformation were augmented by more micro-level concerns about the lived experience of the poor. Under the rubric of 'distribution with growth', national economic performance was seen as the means to rather than the end goal of development, the latter being an improvement in the lives of people (Beall & Fox 2009: 13). More broadly and over a similar timeframe, universal access was also the official infrastructure doxa of modernism (Coutard 2002) and still today it informs notions of inclusive urbanism and the right to the city (Marvin & Guy 2016, Parnell 2016). Broad concerns about societal wellbeing and a healthy labour force to reinforce economic productivity underpin the case for universal access (Revi & Rosenzweig 2013). As a result, ensuring basic access to infrastructure services has endured as a feature of international development policy, informing the Millennium Development Goals (MDGs) in the early 2000s and being reiterated in the more recent Sustainable Development Goals (SDGs) under the United Nations' Agenda 2030.

In practice, universal access is not associated with any one type of political economy regime. There has been undoubted and significant progress made in improving access to basic services globally, particularly in Africa, yet developmental and liberal states alike struggle to address universal provision. Even with the best political will and sense of social responsibility, delivering infrastructure nevertheless requires engaging with the hard realities of technology, economics and finance. Moreover, affording universal access can have negative impacts or unintended consequences; for example, giving rise to inequities in provision and spatial concentration across urban areas (Graham & Marvin 2001). The desire to enhance access to infrastructure informed the thinking of most of the researchers and participants in the project across the full range of disciplines. It underpinned the national government's motivation to guarantee its political legitimacy and was embedded in much of the education and training of officials and professionals at the city level.

Connecting competitive space is an infrastructural ideal that is essentially concerned with economic growth, productivity and the effective deployment of scarce resources. It follows the logic of building on strengths and prioritising infrastructure investments where they can have the most impact on growth. In effect, this means concentrating high levels of investment in those urban contexts with the greatest potential for leverage and scale economies. As the World Bank (2009: 8) has put it, 'the world is not flat', recognising the benefits of economic concentration and implicitly endorsing corresponding infrastructure policy. In stark contrast to universal access, this infrastructural ideal focuses on the alignment of infrastructure geared towards economic productivity. For urban economists it is about strategic investments that leverage the power of urban agglomeration in the context of diverse and uneven development

(Lall *et al.* 2017). For planners, the ideal of connecting competitive space follows the logic of urbanisation patterns that strengthen and prioritise higher density growth poles that incrementally and over time will extend to other areas (Friedmann 1967): a form of trickle-down urbanism that assumes temporal inequalities of infrastructure access will be mitigated over time.

Critics of connecting competitive space see the firm focus on efficiency of delivery, productivity and the leverage of infrastructural investments as representing a departure from social justice and infrastructure as public good (Coutard 2002, Graham 2000). The concept of 'splintering urbanism' has been applied to the process whereby the networked urban fabric is broken up through uneven and differential provision and concentrated investments (Graham & Marvin 2001). In fast-growing and globally connected cities, exclusive areas are equipped with new or retrofitted infrastructures to enhance their global rather than local economic competitiveness and connectivity (Parnell 2016). High-speed rail terminals, hub airports, global logistics centres and ultra-high-capacity fibre-optic cable access are part of the infrastructure inventory of such spaces, as is bottled water for the inhabitants of high-income enclaves, shielded from sanitation challenges and the vagaries of popular transport. The areas outside these zones, nodes and corridors are left to fend for themselves, often receiving minimal, informal and substandard, and invariably very costly, infrastructure (Swilling 2011).

In practice, these trends are reinforced through privatisation and competition in the provision and operation of infrastructure utilities, where 'cream skimming' or 'cherry-picking' by providers means serving the most profitable consumers and areas (Murthy 2013). Private provision also serves to eliminate the cross-subsidies that support low-income areas. This in turn leads to price increases, disproportionately affecting the less well off (Clarke & Wallsten 2002). Some commentators challenge the assumption that the unbundling of networked infrastructure utilities leads to greater socio-spatial disparities in access to infrastructure services, particularly in contexts where the ideal of universal access has been elusive (Coutard 2002) or where investing in service delivery in densely settled urban concentrations can extend reach and achieve economies of scale. Clearly the urban infrastructure approach of Ethiopia's national government has been very much informed by the ideal of connecting competitive space, although not at the expense of seeking better access and wellbeing. On the part of international partners, such as Chinese investors and contractors, this was unequivocally their world view.

Ecological modernisation takes as its point of departure the global environmental crisis. It is linked to the notion of *infrastructure transitions*, a concept that also emerged during the 1980s and 1990s, which refers to putting infrastructure at the heart of securing sustainable ecological urban futures (Bulkeley *et al.* 2014, Geels 2012, Hajer 1995, Silver & Marvin 2016). The reframing of the environment as a public good is a

central tenet of ecological modernisation, accompanied by critical analyses of the flows and consumption of natural resources alongside ecological degradation. Urban infrastructure is a critical part of broader ecological modernisation and transition (Bulkeley *et al.* 2010, Guy *et al.* 2001, Melosi & Hanley 2000, Monstadt 2009) and might include, for example, developing infrastructure that reduces carbon emissions, supports 'ecosystem services' and reduces the degradation of the natural environment.

Ecological modernisation echoes the positive, utopian position of modernism, suggesting that deliberate change, in this case towards more sustainable infrastructures, is not only feasible but also highly desirable, thinking that has been applied to the risks and opportunities presented by urbanisation and urban change (Floater *et al.* 2014, Rode *et al.* 2011, 2013, Suzuki *et al.* 2010). In terms of infrastructure development, ecological modernisation implies a central commitment to infrastructure systems that enable the building of a green economy. In the energy sector, for example, this cuts across renewable energy generation, smart distribution systems and energy storage. In transport, public and active transport infrastructures are most relevant, increasingly complemented by electrification and telecommunication infrastructure, impacting on the entire transport ecosystem. Ecological modernisation embraces interconnectedness, allowing for energy and resource efficiencies generated at new interfaces and nexuses between, for example, energy and transport, transport and urban form, buildings and energy, and water and transport (Belaieff *et al.* 2007, GIZ & ICLEI 2014).

Ecological modernisation also recognises that infrastructure services today are over-supplying and under-pricing resources such as water, energy and transport with damaging effects for the environment (Murthy 2013). Policy reforms are particularly attentive to the challenges around changing infrastructure pathways (Stern & Zenghelis 2018) and the financial losses that confront investors through sunk costs and the risk of obsolescence and stranded assets (Jakob & Hilaire 2015). Within this ideal, assumptions are made that political regimes and economies are able to 'internalize the care for the environment' and to reframe it as a 'management problem' (Hajer 1995).

The role of infrastructure in ecological modernisation is as a central policy tool that can be used proactively to support environmental transitions and a break with business-as-usual development, through integrated solutions, such as integrated transport authorities, feed-in tariffs, re-municipalisation of infrastructure utilities and citizens' energy and transport cooperatives (Becker *et al.* 2015, Hajer & Huitzing 2012, Rode 2018). Ecological modernisation undoubtedly informed the thinking of the engineers and many of the techno-policy researchers on the team, while the notion of leapfrogging business-as-usual approaches appealed to the proponents of infrastructural modernisation in Addis Ababa and especially echoed with national government policy.

The fourth and last infrastructural ideal we identify is *new self-sufficiency and post-networked infrastructure.* It builds on perspectives and insights from urban anthropology, geography and sociology, but links these to revived aspirations for local self-sufficiency and a post-networked urban infrastructure (Coutard & Rutherford 2015). As an infrastructural ideal, new self-sufficiency implies replacing the long-term objective of access to networked services with permanent rather than temporary forms of off-grid, small-scale and at times informal alternatives. New self-sufficiency suggests a rescaling of spheres of collective, citywide service provision, to individual and community-scale infrastructural actions. In practice, the new self-sufficiency and post-networked infrastructural ideal can imply a considerable degree of sharing of local service access points, such as for water, electricity and toilets (Banerjee *et al.* 2008); hyper-individualised off-grid solutions; and the establishment of local, micro-grids that are not connected to a wider system.

The ideal of new self-sufficiency has been taken up most enthusiastically by two groups. First, there are those who are deeply sceptical of centralised and particularly state-led systems and who opt for or promote the development of off-grid systems to enable access irrespective of the functioning of the citywide system. Second, there are critics of the networked city as an imposed ideal, totally out of touch with the realities of developing cities. Emanating from 'southern urban theory', which theorises urban change from the perspective of 'southern' cities, the new self-sufficiency offers an explicit critique as well as an extension of the concept of splintering urbanism, in that alongside a recognition of splintered urbanism the perception of a 'post-networked city' subverts the 'modern infrastructure ideal' (Coutard & Rutherford 2015, Pieterse & Hyman, 2014).

Where state-coordinated infrastructural provision is absent or wanting, it is argued that others move in to fill the vacuum. This is well captured in a recent discussion of 'southern urban practice', calling for a body of thought that 'gives us ways of moving and modes of practice' where notions of practice are not confined to professional practitioners alone, thereby excluding the potential insights from wide swathes of participants who bring their experience, common sense and situated expertise (Bhan 2019). As such, southern urban practice offers a modality whereby hybrid and heterogeneous infrastructure creates new pathways for access and city-making (Pieterse 2011). It is perhaps not surprising that most of the socio-political researchers and participants on the project had enormous sympathy for this approach and those long schooled in redistribution with growth development thinking saw it as compatible with the pursuit of universal access to services.

Historically, the most common forms of infrastructure services beyond grid connectivity have been water and sanitation solutions, such as community standpipes or local-level waste collection enterprises. For sanitation, solutions have conventionally

included the ventilated improved pit (VIP), compost, chemical, concrete slab and cover (SanPlat) pit toilets, as well as septic tanks, all of which have been endorsed as 'viable substitutes for networked services' (Banerjee *et al.* 2008: x). Increasingly widely used are high-tech, decentralised municipal wastewater treatment systems, such as Kotari's biological processing plant, deploying microbial membrane bioreactors (MBR) for sludge management. They are being promoted as a technology of choice in areas where the cost of extending trunk sewerage infrastructure is prohibitive. This was the technology explored in our sanitation case, a large condominium settlement on the outskirts of Addis Ababa. Smaller electrical networks have also become an innovative area of new self-sufficiency, enabled by the novel and decentralised micro-generation of electricity, operating independently from the main utility grid.

There are a number of virtues of post-networked infrastructure relating particularly to access and environmental gains. Some commentators even link self-sufficiency to political empowerment, as exemplified in the literature on the off-grid movement (Rosen 2008). However, there are also risks in relying on self-sufficiency, most obviously in instances where growth in demand exceeds what can be supplied locally without networked infrastructure. In such cases, providing for additional services can be prohibitively expensive if not impossible. For example, supplying water to areas not connected to the main water network and where local sources are insufficient can involve high transport costs, while the involvement of many intermediaries can drive up costs even further. In such circumstances, water prices can easily exceed those charged by utilities by a factor of ten to twenty (Murthy 2013). Clearly the policy of the Ethiopian national government was supportive of post-networked infrastructure, and the high-tech solutions on offer captured the imagination of some of the researchers and participants, fascinated by the potential possibilities.

In practice, these stylised infrastructural ideals are not pursued in isolation from one another and all acknowledge that infrastructure and services are powerful tools for shaping cities and city-making. Yet different ideals do shape how infrastructure is understood. While the ideals are somewhat crudely assigned and individual and institutional positions are often informed by more than one ideal, it is important to distinguish the various positions. This is because they can and do get conflated with disciplinary predispositions and, although there is fusion at times, it is not automatic and they have a different genesis.

The infrastructural turn in research

Just as the last couple of decades saw an escalation in advocacy for interdisciplinary research, so they witnessed something of an 'infrastructure turn' within the social sciences. This degree of interest has not always been the case. Anthropologists, for

example, eschewed research on infrastructure before modernity was recognised as a material experience affecting people. Susan Leigh Star called infrastructure 'frequently mundane to the point of boredom, involving things such as plugs, standards and bureaucratic forms' (Star 1999: 377). Yet now infrastructure is seen as contributing towards how our sense of self and our environment is hardwired (Jensen & Morita 2017, Marvin & Medd 2010) and as something upon which nations, cities and societies ground their aspirations and expectations (Dalakoglou 2010, Gandy 2014). Social science studies of infrastructure have shifted debates such that infrastructure can no longer be seen as a purely technical or neutral endeavour. While highways and pipelines might embody visions of progress, they can also create geographies of abjection and segregation (Anand 2012, Rodgers & O'Neill 2012).

Alongside traditional physical and technical questions coming from engineering or economists' concerns about financial feasibility, socio-political scholars began asking what infrastructure reveals about social and political life. They ask how the infrastructures providing air, water, sanitation, waste management, energy and transport impact on and are influenced by people (McFarlane & Rutherford 2008, von Schnitzler 2016). They explore the relationships between the pipes, roads, rails and power lines that facilitate the circulation of goods, services and people and the socio-spatial and socio-political life of cities (Anand *et al.* 2018, Harvey & Knox 2015). For example, in *Hydraulic City,* Nikhil Anand (2017) examines the ways in which cities and citizens are made through the everyday management of water infrastructure in Mumbai. Of particular interest to social scientists are the informal and often piratical activities of urban dwellers seeking to fill the gaps in provision left by failing or incomplete state-driven infrastructures, such as irregular connections to electricity and micro-enterprises selling water (De Boeck 2013, Simone & Pieterse 2017).

Against the background of this flurry of scholarly activity we categorise the research approaches of different disciplines involved in infrastructure research either as *techno-policy* (architecture, engineering, planning and economics/finance) or *socio-political* (anthropologists, geographers, political scientists and sociologists). Although somewhat crude and an over-simplification of reality, given the hybridity between and porousness across a number of disciplinary boundaries (notably planning and geography), this proved a useful heuristic device for guiding our reflections on the process and experience of our own research endeavour.

Techno-policy researchers focus primarily on infrastructure systems, their financing and management. Trained in quantitative analysis and technical skills, economists and engineers are driven to shape and implement policy in linear fashion, from problem identification to the development of pragmatic solutions (Straub 2011). Engineers are said to exhibit a number of stereotypical characteristics, such as a focus

on technical problem definition, a technocratic view of decision-making process and ingrained assumptions about management hierarchies. Economists working on infrastructure are generally concerned with how resources are prioritised and allocated and the financial implications of investment at various levels, scales and sequencing, or based on different kinds of infrastructure provision (Estache & Fay 2009). Finance, a subset of economics, is less concerned with what should be funded and why, preoccupied instead with how to structure budgetary flows to support delivery. For techno-policy researchers, the fascination of social scientists with intangible connections and flows is often perplexing.

Socio-political contributions that best capture the imagination of researchers we characterise as techno-policy in their approach are those that focus on the interplay between modes of economic development and their impact on social and political phenomena. These are generally structural accounts that situate metropolitan and local contexts within macro-level and global trends. More relational accounts that characterise urban contexts as complex, fluid and infused by power relations they generally find less accessible. Social scientists often use the lens of infrastructure to explore wider social and political phenomena, rather than what techno-policy researchers would regard as the real task at hand: namely the effective, efficient and sustainable delivery of infrastructure. Particularly influential across the socio-political and techno-policy divide has been the work of Steve Graham and Simon Marvin (2001) who have shown how urban infrastructure reproduces and restructures social and economic relations in the city. However, more abstract accounts are often critiqued for their infinite particularism and resistance to normativity (Pieterse 2011).

Does that mean social science research is only relevant in interdisciplinary contexts when it serves policy or practice in instrumental ways? There is no doubt it gains more traction in interdisciplinary contexts when it analyses and explains behaviours: for example, in relation to use and consumption of infrastructure systems. It is digested with greater difficulty by techno-policy researchers when it complexifies context or dwells on the construction of norms, beliefs and values. There tends to be a techno-policy impatience with the way in which the term infrastructure has come to be ascribed not only to hardware but also to 'poetics' (Larkin 2013) and various intangible forms such as social networks and other configurations facilitating related activity and interaction. Encapsulated in the notion of 'people as infrastructure' (Simone 2004) is the view that infrastructure is less a 'thing' and more a 'relation' or even something 'in between' (Simone, 2012). Metaphorical readings of infrastructure, for example, adapting Gilles Deleuze and Félix Guattari's (1987) notion of 'assemblage' to the study of infrastructure, signify that it is co-constituted by human and non-human agents and emphasises the reciprocal impact (McFarlane 2011, Nail 2017). For techno-policy researchers, the evolution of the term generated out of a diversity

of disciplinary engagement with infrastructure has at worst led to conceptual confusion and at best seen the prioritisation of semantics over pragmatics. Yet the humanities and social sciences have extended and transformed the concept of infrastructure in ways that suggest there is no turning back.

INFRASTRUCTURE INTERFACES AND INTERDISCIPLINARITY IN PRACTICE

Infrastructure interfaces and their boundaries tend to be neglected in urban research and praxis. Yet it is here where many critical questions for cities arise: who governs, who decides, who funds, who has access and who uses what and how? We combined analysis of the technical and material infrastructure interfaces within transport and sanitation systems, with institutional analysis of associated administrative, political and civic governance regimes. We also focused on the relationship between wider development goals and infrastructure roll-out on the one hand and, on the other, the challenges of balancing investment for long-term economic growth and wellbeing with the objective of simultaneously achieving social wellbeing in the here and now. We identified critical nodes of tension in infrastructure interfaces that were only made visible by combining both socio-political and techno-policy approaches.

Our multidisciplinary research team and the specialists we involved, included scholars and practitioners in development studies, economics, planning and transport studies, architecture and engineering, anthropology, sociology, geography, political science and public administration. They came to the task with their own expertise and predilections, as well as infrastructural ideals. Assessing how the different disciplines engaged, there was no doubt that some 'travel better than others' (Keith *et al.* 2019: 10–11). Nevertheless, there were sufficient among us who were able to straddle the techno-policy and socio-political divide and play a positive bridging role.

In terms of infrastructural ideas, there was a general acceptance that economic development was important, but alongside it there had to be wellbeing outcomes, whether for social justice or political legitimacy reasons. There was also recognition that post-networked infrastructure was inevitable in a city such as Addis Ababa. There was less agreement on a role for informal actors and how to broach irregular activities in infrastructure systems.

The first tension we encountered related to attitude: more precisely, optimism versus pessimism. The American economist, James Duesenberry, once remarked that 'economics' is the study of the choices that people make, while 'sociology' is the study of why people have no choices (cited in Boudon 1981: 6). In a sense, this characterised the techno-policy and socio-political approaches in our team in Addis Ababa with an

addendum: in the context of a modernising developmental state, some felt that people did not need to choose because the best already had been selected on their behalf. The techno-policy disciplines brought optimism to the table by highlighting the value of high-end technological change, while the socio-political voices emphasised the constraints people faced and what could go wrong when confronted with unfamiliar high-tech alternatives. The techno-policy interest was in the novel, innovative and technically ambitious. They admired the utopian vision for a capital city poised to become a monument to the African renaissance and appreciated the LTR and the MBR waste treatment plant as audacious.

On the socio-political side it was pointed out that the top-down imposition of technology solutions and the concomitant failure to consult or involve city-level professionals and citizens meant there were bound to be problems. However, it was not the social scientists alone who worried about the processes by which new infrastructures had been chosen and introduced. Officials and professionals at the city level pointed to problems of stranded assets, path dependencies, poor capacity to operate and maintain the new infrastructure, resulting in failures at the governance interfaces. Socio-political researchers were able to extend this analysis to the very local scale and introduce civic organisation and leadership into the chain of governance constituting infrastructure interfaces.

Another fault line between techno-policy and socio-political researchers related to context and complexity. In short, views differed as to how much information was actually needed. Levels of patience varied when it came to excavating detail. Was it enough to canvass passengers or should they be disaggregated by age, gender, route? Was it sufficient to engage the residents' association or should the women's group be consulted too? It is the case that engineers tend to reduce levels of complexity in order more confidently to propose and advance solutions. Infrastructure systems are usually developed as 'closed systems' with considerable separation from contextual factors and uncertainties over the longer term (Dimitriou *et al.* 2015). Economists, too, categorise and order information and ideas better to analyse them. The broader social sciences by contrast critically interrogate what to others appear either obvious or unremarkable phenomena.

Figures 4 and 5 offer a good representation of the techno-policy view of the world. Figure 4 represents our initial analysis of different spatial scales. Once the project was underway and cross-fertilisation of ideas and methodologies had begun, research extended to surveying different kinds of transport users as well as those tangentially affected by infrastructure changes, such as a range of transport providers, shopkeepers, street vendors, drivers as well as pedestrians.

In the sanitation case, the techno-policy and socio-political research and analysis happened simultaneously. Figures 6 and 7 illustrate a worm's eye view of the social

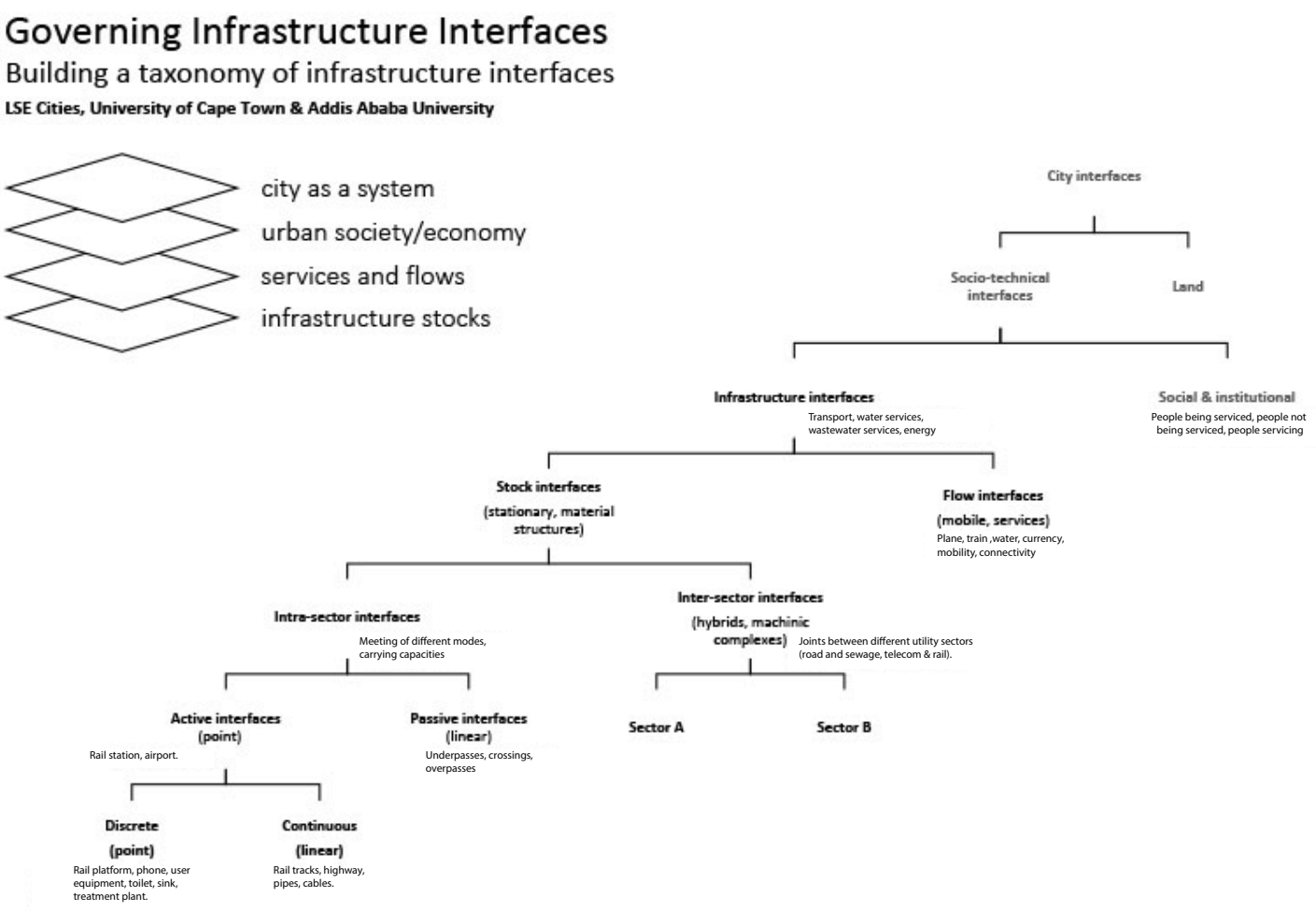

Figure 4. A multi-scalar view of infrastructure interfaces.

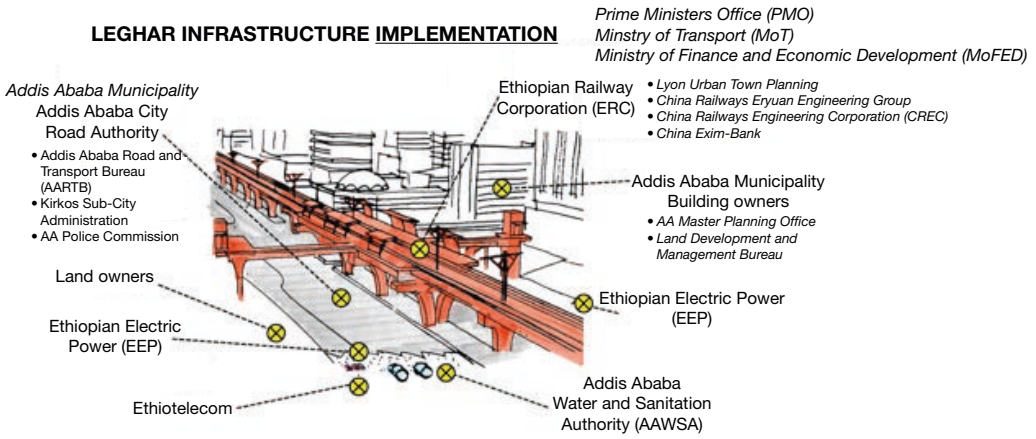

Figure 5. A techno-policy view of the Leghar LTR Interchange.

Figure 6. A socio-political take on sanitation governance: the interface of the manhole.

Figure 7. Chair of the Kotari Condominium Association.

scientists who worked on the sanitation case. As well as engaging with the city's broader sanitation system, the decentralised MBR treatment and city-level institutions like the Addis Ababa Water and Sewerage Authority (AAWSA), there was tight analysis at the community, condominium and household level. Through a fine-grained study of manholes around the site, the functionality of the system was assessed. It was found that the receiving drains between the apartments and the MBR plant frequently became blocked. The AAWSA manholes (see Figure 6) were not used to unblock the system as the authority could not or did not respond to the frequency of call out. Instead, unofficially constructed manholes were used to clear blockages, with the

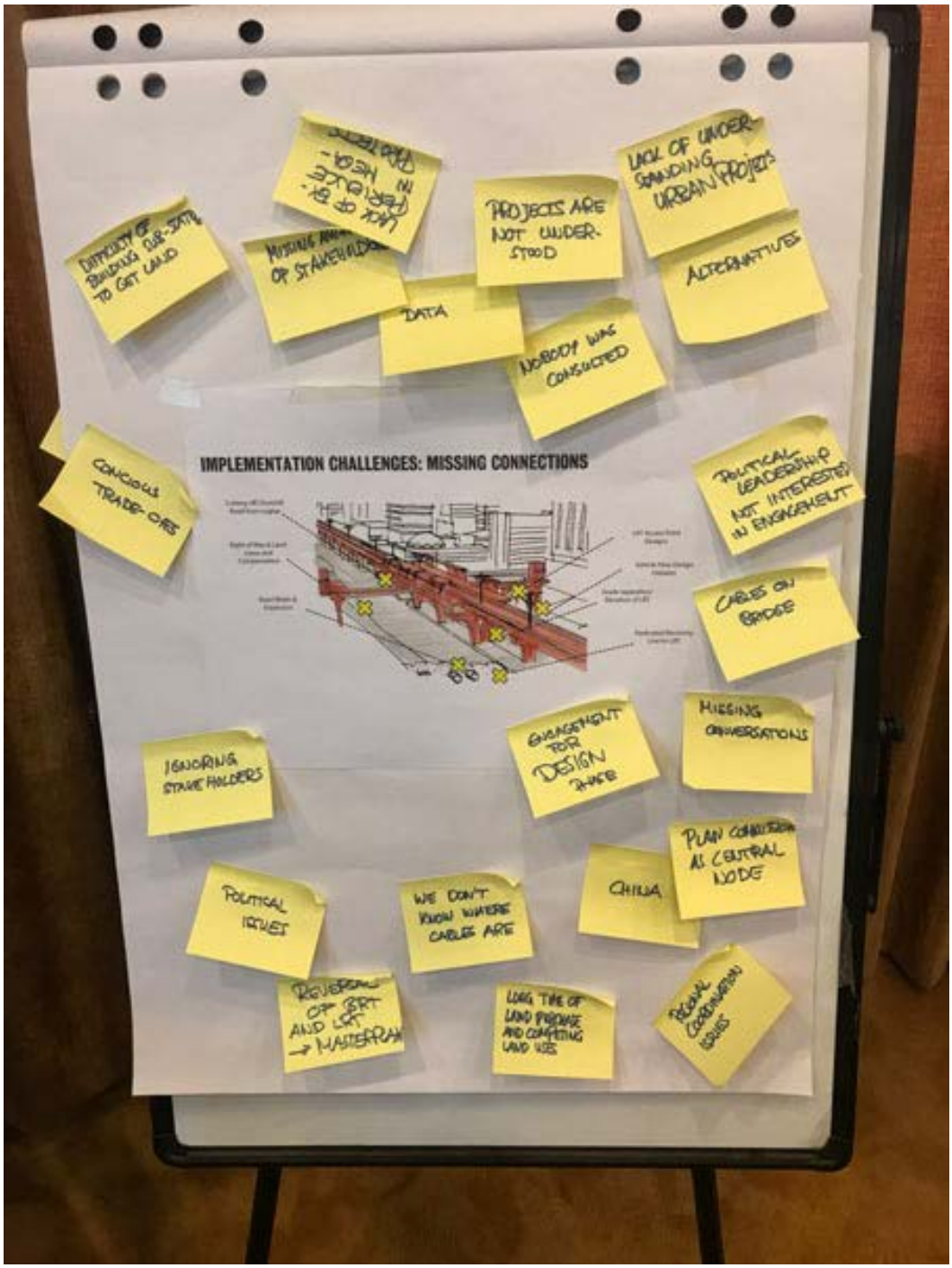

Figure 8. Problem identification in the transport workshop.

Figure 9. Observational and Conversational Walkabout in Haile Garment Area.

work being undertaken by casually contracted unemployed people in the area, who worked without technical supervision. These examples illustrate how value was found and shared through looking at the world through both ends of the telescope, both the celebration of the bold and ambitious and the embracing of messiness and apparent but quite well-organised chaos at the most micro of levels.

How did we overcome the different starting points of the researchers and practitioners involved? Our methods were fairly conventional. We held focus groups and workshops with government officials, professionals, representatives of civic groups and others involved in the governance of infrastructure interfaces. With them we

co-created an extended cartography of stakeholders involved in the transport and sanitation case studies, making visible and analysing their diverse interests and discovering when they coincided or collided (see Figure 8). We also conducted observational walkabouts involving people from different disciplines and backgrounds (see Figure 9). A learning process emerged out of what different people observed, who they spoke to and the questions they asked. Through the selection of people in the room or taking part in the walks, as well as the conversational nature of the various encounters, different vantage points were aired and understood.

It was not always easy making legible the different imperatives and rationalities that emerged across those operating at different urban scales. For instance, those responsible for importing and/or implementing technologies from elsewhere, such as the LTR system or the decentralised MBR sanitation system, were puzzled by the uneven benefits and unanticipated consequences of their good intentions, while others were equally bemused as to why the habits and practices of ordinary people had been ignored in the planning. In the end, though, we were able to develop something of a collective understanding of each other's entrenched vocabularies and, in the process, we developed a shared lexicon if not a common language.

There was general agreement that decisions about infrastructure investments are never only technical and that they stem from and extend into social and political domains as well. This was helped by the fact that most of the researchers and participants involved were of a pragmatic and issue-based persuasion and were intricately involved in at least some if not all of the governance interfaces we scrutinised. So, something of a knowledge community emerged and, although participants did not necessarily know each other or previously work together, they pursued professional interests in common. Moreover, many of the techno-policy researchers and professionals were people deeply concerned about social issues, either through their professional experience and training or their own personal histories. As such, there was openness to the surprises yielded by varying perspectives and a willingness to engage with nuance and granularity. In the course of working together there was a sharing of what Bhan (2019: 2) calls 'maps of different life-worlds of knowledge, including their hierarchies'.

The major obstacle in our interdisciplinary endeavour was one of size and scale. Techno-policy and socio-political researchers happily bridge when the scale is small and time-bound. In such situations they are able to feel the benefits of interdisciplinarity most acutely. Similarly, it has been found in relation to energy research that interdisciplinarity is best exemplified in research on energy consumption at the individual building scale but proves to be much harder at the urban scale (Pellegrino & Musy 2017). Similarly, when considering large-scale infrastructure, such as the Addis Ababa LTR or the city's overall sanitation strategy across longer time horizons, tensions tended to emerge.

When techno-policy world views clash up against critical social theory in infrastructure research, the result is an inevitable retreat into small and local solutions. The engineers asked whether Ethiopia's ambition for a modern post-networked citywide sanitation system was equivalent to the vision of those behind the great Victorian sanitation revolution in 19th-century Britain? The question followed: would the latter have occurred if social scientists had insisted on small-scale, short-term or incremental change? Would the London underground system have been built if the self-interested views of hackney carriage drivers had been allowed to prevail over those of the inventive and far-sighted Brunels? These questions gave the socio-political researchers serious pause for thought, in relation to wider benefits and longer time horizons.

CONCLUSIONS

Did we achieve interdisciplinarity? We incorporated and shared novel perspectives. We expanded the insights of the researchers involved and captured the imagination of participant partners through exposure to new sources and methodologies and indeed new objects of study. To this extent, we believe we undertook and successfully executed an interdisciplinary project together. When research priorities are driven by practical problems requiring viable solutions, a shared confidence in the application of knowledge to policy allows interdisciplinary knowledge communities to emerge, and this was our experience. We were driven by the logic of accountability and innovation, but in our interdisciplinarity did not pass the Barry and Born (2014) test on the logic of ontology. As a group we did not undergo any existential transformation and nor did we develop theory. If we did indeed create an epistemic community, it will probably prove ephemeral. Certainly, on the part of policy makers, it is not clear they will remain attentive to socio-political dynamics and the ways in which people make sense of infrastructure.

One reason is that hierarchies do tend to creep into the interdisciplinary endeavour. This is not necessarily the result of banal ranking or the exercise of power, although the ministries and departments with which socio-political researchers are associated usually carry less weight that those dealing with infrastructure and finance. In the research process, hierarchies emanate from the way in which in different disciplines facilitate relationships between academics and practising professionals. On graduating, engineers, economists, architects and planners can join a professional cadre of similarly trained and like-minded colleagues. If they remain academics they can easily create channels of access and influence across to fellow professionals in practice. The same is not true for anthropologists, geographers, sociologists and political scientists. They rarely find their equivalents in government departments or private companies and

certainly not *en bloc*. Social development and the more recently evolved sub-profession of 'governance' constitute something of an exception. Here academics are better able to transmit knowledge and influence professionals and practitioners, particularly in the context of international development and with associated agencies (Hulme & Toye 2006: 16).

Despite these limitations, our research illustrated effectively the diversity and value of interdisciplinary approaches. We demonstrated the need to be upfront about normative framing, whether infrastructural ideals or disciplinary habits of thinking, and we made visible the priorities given to different disciplinary registers. As a result of the process, alongside the non-negotiables of technological efficacy and financial feasibility, attitudes, behaviours and context were accepted as explanatory factors. We shifted thinking from infrastructure consumers being seen as largely responsible for failures through poor usage or uninformed choices, to a recognition that systems are sometimes ill-suited to users, who in turn are often ill-prepared to adapt.

To us the most interesting question was how interdisciplinarity might foster an iterative process of multi-scalar aggregation and disaggregation in order to reach a holistic understanding of infrastructure interfaces at different scales and over time. We made some progress on the issue of scale. Techno-policy researchers sought to value the insights derived from socio-political research for the here and now, while socio-political researchers began to recognise they were not necessarily well equipped to assess contemporary imperatives against long-term visions. We concluded that longitudinal research was necessary to capture temporal change and the impact of public policy on governance of infrastructure interfaces over time. Going beyond the parameters of the current research, this remains an imperative but a work in progress.

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