Engineering modernity: water, electricity and the infrastructure landscapes of Bangalore, India

Abstract

The concept of 'nexus' has gained popularity in urban studies to examine the interconnections between the management of resources and the provision of urban services. This paper proposes a conceptualization of the urban nexus as the contingent product of the operation of physical, ecological, and social processes around urban technologies in a specific location. The paper focuses on the configuration of the nexus within particular trajectories of urban development, and the wider consequences of these trajectories for urban life.

The strategy of the paper is to examine the water-energy nexus within a particular infrastructure landscape, that is, as it emerges from the historical co-evolution of social practices and the built environment. Such co-evolution can be described as an urban trajectory that reveals the consolidation of different aspects of the nexus at varying levels from the household to the extra-urban connections that shape the city. This perspective is applied to analyse processes of infrastructure development in the city of Bangalore, India, since the completion of the first works to establish a water network and the electrification of the city at the beginning of the twentieth century. The analysis reveals a historically built and context-dependent nexus that reflects the interconnectedness of the mechanisms of infrastructure governance and urban inequality.

Keywords: energy-water nexus, Bengaluru, service provision, inequality, urban trajectories

1. Introduction

Heroic tales of modern engineers pervade accounts of the making of Bangalore. Sir M. Visvesvaraya (Sir MV) (1861-1962) is celebrated in India as a model engineer, with his own dedicated Engineer Day on the 15 of September. In 1910, as Chief Engineer of the Princely State of Mysore, Sir MV presented a project for the construction of a large dam in the Cauvery River, the biggest public project ever conceived in the state. Upon seeing the dam blocked by financial considerations, Sir MV felt frustrated and contemplated retirement from state service:

> "*Noticing my altered attitude, His Highness the Maharaja sent for me while he was camping in Bangalore and enquired why I was not interesting myself in new works and developments as I used to do before. I told His Highness the truth, which I was disappointed with the facilities given me to carry on the new works and progressive developments. (…) His Highness reply was: 'Don't be hasty, I will do what you want.'*" (Visvesvaraya, 1951: p. 48)

The construction of the Krishna Raja Sagara (KRS) Dam began in 1911, forever shaping Bangalore's infrastructure futures. Sir MV would go on to occupy the office of Diwan of Mysore in 1912 and become an architect of the developmental state in Mysore (Gowda, 2010). Constructing the KRS dam took 20 years, the efforts of over 10,000 workers, and the displacement of thousands of people. Originally built to provide a reliable electricity supply to the Kolar Gold Fields in the north of the state, the dam became a vital infrastructure for Bangalore—a means to balance the industrialisation of the city with the development of irrigation works in rural areas and, eventually, a source of drinking water. The dam became a node marking the interdependence of the mechanisms of electricity and water provision. An engineering vision connecting water and electricity became central to state-building projects that emerged from princeling Mysore.

The embeddedness of electricity and water networks in the production of urban Bangalore reveals the social and political constitution of the nexus alongside a state modernisation project. The urban nexus emerges from a dynamic and contextually embedded process that follows contingent urban trajectories (Lam et al., 2016). The concept of nexus is invoked to explain the interconnections and trade-offs between different natural resource systems (Cairns and Krzywoszynska, 2016). However, historical perspectives on the co-evolution of urban infrastructure systems are still largely missing (cf. Foran, 2015).

The aim of this paper is to show how the historical constitution of the urban nexus relates to the simultaneous production of hegemonic visions of urban futures and urban inequality. We develop a co-evolutionary perspective on the nexus, built on the concept of urban infrastructure landscapes to link wider political changes to infrastructure practices.

We apply this perspective to the case of Bangalore (also known as Bengaluru), a city facing pressing resource availability problems. The landscapes of water and electricity in Bangalore have been shaped by the colonial history of Bangalore, industrial growth in the post-independence period, and insertion of the economy of the city into global flows of technology and capital after the growth of the IT and offshoring industries. Urban sprawl has accompanied the city's growth and has put further pressure on water resources. Blackouts are frequent. There are gross inequalities in the levels and quality of access to water and electricity. Inequalities emerge within a historical urban trajectory in which Bangalore has been a site of innovation in both water management and electricity provision.

The paper concludes with a reflection on the value of landscape perspectives in understanding the water-energy nexus within a socio-ecological context of urban development that links wider political projects with resource-use practices in urban life.

2. Co-evolutionary perspectives on the urban nexus

Within the literature on civil engineering, 'nexus' refers to the interlinkages and trade-offs in the provision of resources, offering an 'interconnected perspective' of subsystems previously organised into separate sectors such as water, energy, and food (Smajgl et al., 2016). 'Nexus' captures long-standing concerns about the integrated management of environmental resources (Yumkella and Yillia, 2015). Situating the nexus in the urban context allows critical analysis away from the notions of infrastructure integration alone, focusing instead on the synchronous operation of different systems in a given location within a given historical trajectory.

Adopting urban infrastructure landscapes as a conceptual lens enables analysing the interactions between the interconnected systems of service provision and use as they manifest in different aspects of everyday life. Urban infrastructure landscapes are visible spatial patterns that result from the social and institutional practices that embed resource systems in everyday life. Gandy (2014; 2011) argues that urban infrastructure landscapes are a material record of public memory. The 'landscape' component evokes the methodological possibilities of accessing social relations through analysis of the visual manifestation of urban infrastructure patterns, integrated with contingent practices of resource use. For example, looking at the different spatial patterns of sanitation in Hanoi, Monstadt and Schramm (2015) explain how urban infrastructure landscapes reveal "hybridities, borderlands and in-between conditions." They draw on a tradition of post-colonial technoscience (Anderson, 2002: p. 643) which engages with "the materiality and specificity of neo-colonial encounters." These materialities can be read within an urban infrastructure landscape. Urban infrastructure landscapes emerge from a multiplicity of interactions and everyday practices which sometimes turn into unpredictable styles of politics. They direct attention to the ambivalence of technology and the endless possibility of reimaging the city to open up spaces of hope (cf. Coutard and Guy, 2007). The nexus in urban infrastructure landscapes is the contingent product of the operation of physical, ecological, and social processes in a specific location around urban technologies.

Urban infrastructure landscapes complement the ideas of urban infrastructure regimes. Regimes relate to the ordering of life alongside systems of provision (cf. Monstadt, 2009), while infrastructure landscapes link political developments to the experience of the urban fabric and how it supports multiple non-strategic daily tasks. Changes in landscapes emerge as multi-dimensional processes whereby multiple agents shift the urban fabric until it becomes unrecognisable, in contrast to understandings of urban transitions as processes of reconfiguration of different components of the infrastructure regime (Monstadt, 2009).

The sequence of states that, over time, leads to the current state of urban infrastructure landscapes can be thought of as an urban trajectory (Castán Broto, 2017). In an urban setting, coevolution accounts for the particular configuration of the built environment which enables resource transformation. Co-evolution presupposes mutual influence between social practices, technology and the built environment, and the ecosystems that sustain them (Brand, 2005). Trajectories relate to broader social and political contexts, or 'pathways', that refer to a wide diversity of imagined urban futures that shape the direction of travel and close off alternative destinations (Rydin et al., 2013; Hodson et al., 2015). The politics of possibility in urban infrastructure landscapes relate to an understanding of the conditions that emerge from historical trajectories alongside the range of routes opened in future pathways.

Methodologically, urban infrastructure landscapes call for a situated and historical interpretation of nexuses and their manifestation in urban infrastructure landscapes. Such landscapes require a lens of observation that starts from the dynamics of urban life while recognising how such dynamics are conditioned by the broad socio-political context in which urban dwellers operate. Hardoy et al. (2013) have developed a perspective on urban environments that recognises the experiences of urban dwellers in the everyday provision of services. They propose starting with how life unfolds in the household and in relation to broader processes within the neighbourhood, the city, and the linkages beyond narrowly considered administrative boundaries. These three levels are not nested, location-based scales. They refer to different types of processes which produce a particular water-energy nexus: use practices of water and energy, the movement and distribution of resources across the city, and the extraction, mobilisation and conversion of resources. Each level concerns institutional, social and political dimensions of the nexus which can be visible in spatial patterns in urban infrastructure landscapes.

3. Bangalore as a case study of the water-energy nexus

From 'garden city' to 'Silicon Valley of India,' the city of Bangalore grew in the 20th century at the expense of democracy and citizenship (Nair, 2005). Bangalore has witnessed pioneering attempts at transforming the urban infrastructure landscape: it was probably the first city to have electric street lights in South Asia in 1905, and it boasts a millennial history of water management that relied on the community management of multipurpose lakes, locally called tanks (Nagendra, 2016).

The city has always been a critical commercial and industrial centre of the state of Karnataka (Princely State of Mysore until 1950). It grew from 180,336 inhabitants in 1891 (Rice, 1897) to over 8 million inhabitants in 2011. Urban growth has resulted in a three-fold administrative structure including the core city, administered by the Bruhat Bengaluru Mahanagara Palike (BBMP); the metropolitan area planned by the Bangalore Development Authority (BMA); and the larger metropolitan and rural area under the Bangalore Metropolitan Region Development Authority (BMRDA) (see Figure 1).

Urban development in Bangalore is interlinked with a political history of conflict and contestation over identity, land, and resources (Nair 2005). Industrialisation efforts emerged at the turn of the twentieth century, associated with a developmental state (Gowda, 2010), and have shaped life practices and resource politics in the city. We documented urban infrastructure regimes using governmental reports (Reports on the Administration of Mysore, Karnataka and Bangalore), historical accounts and nine semi-structured interviews with infrastructure managers conducted between 2014 and 2015 and during a workshop with 10 NGO representatives in February 2014. In addition, to document the constitution of urban infrastructure landscapes, we used documentary sources that track dwelling practices in the city, such as travel guides, business reports, and reports on housing. To document the impact of these dwelling practices on the landscape, we compiled observations in three walking transects across the city and two field trips to the Shivanasamudra plant and the Hesaragattha dam.

The analysis focuses on combining an analysis of the reconfiguration of urban infrastructure regimes and their multiple manifestations according to Hardoy et al.'s (2013) analysis of urban environments from the perspective of urban dwellers. To understand the different regimes, the analysis has been organised into three periods that represent major changes in the urban infrastructure regimes. This periodisation resonates with the logics of urban development (Nair, 2013) and the stages in the electrification of India (Kale, 2014). The first period relates to the pre-independence era, when Bangalore was part of the Princely State of Mysore ruled by the Wodeyar dynasty. This dynasty's cordial relationship with the British was based on a shared authority agreement, in which the Maharaja of Mysore retained control of the old city and the British ruled the Bangalore Cantonment of the British Raj next to it. The second period dates from 1947 to 1991, which corresponds to the post-independence period during which modernist attempts shaped the processes of industrialisation and commerce in Bangalore. The third period, starting in 1991, relates to the insertion of Bangalore in the global economy under a paradigm of liberalisation. This phase corresponds with the introduction of ideas of 'New Public Management' (NPM) in the governance of urban areas in India. NPM supporters introduced principles of neo-classical economics and rational choice theory into the Karnataka state's public management procedures, alongside calls for increasing efficiency in public administration. This period may be coming to a close now, as land and resource pressures over the extended metropolitan area challenge liberalisation paradigms.

4. Urban trajectories of the water-energy nexus in Bangalore

4.1. The water-electricity nexus as a modernisation drive: 1883-1949

In the late 19th century, town planning and infrastructure services were managed by the Bangalore City Municipality and the Bangalore Civil and Military Station Municipality.

Administrations experimented with a network of tanks and employed workers to light kerosene lamps in theatres, clubs, and public buildings frequented by the colonial establishment and the city's elite. Several events accelerated the adoption of networked systems in Bangalore. In 1894, Chamarajendra Water Works was built, including the first water pipeline to the city. In 1898, an outbreak of bubonic plague forced the rapid expansion of the city as people moved away from the old city quarters, prompting a rush to service new extensions such as Basavangudi and Malleshwaram. In 1905, taking advantage of the transmission line which supplied electricity from the Shivanasamudra Hydropower station, the state lighted the first electric lights in the city.

Histories of infrastructure development in Bangalore include heroic, visionary administrators, such as the Diwan of Mysore, the chief public administrator of the State, who held responsibility for both drinking water and electricity provision. Among the thirteen Diwans appointed in Mysore over this period, three had a direct imprint in the spatial configuration of the city. K. Seshadri Iyer, Diwan from 1883 until 1901, experimented with initiatives to bring about modern infrastructures in Bangalore. M. Visvesvaraya (Sir MV), Diwan from 1912 until 1918, brought an engineering-based vision to the city that was instrumental in the development of extensions and networked infrastructure. Mirza Ismail, Diwan from 1926 until 1941, promoted infrastructure as support for industrial development.

New models of infrastructure focused on connecting water, electricity, economies, and households. Sir MV himself described the profound cultural change that followed the rise of ideas of 'municipal convenience' at the heart of city planning in Bangalore—towns that had never seen piped water supplies were now 'clamouring for it' (Visvesvaraya, 1917). These models reflected the priorities of Mysore elites and the British and disregarded traditional models of service provision and habitation.

Changing dwelling practices

Changes in the labour structure of the city determined both the city's aspiration and its spatial configuration. Before the transition to networked systems, high-income households would rely on labour for water and energy provision. Take, for example, the advice on good housekeeping for British visitors:

> "*In Bangalore wood is chiefly used for fuel though coal and charcoal are consumed by those who have stoves (…). Wood is always procurable at the Market, but the cheapest way is to buy a whole load as it is brought into town of a morning. Servants can easily do this, but of course they never do, as their little pickings would be cut off and the after-labour of chopping fall on them. (…) Most houses have wells, but properly speaking, very few depend entirely on them for wholly supplying the daily wants of a family. Those who are able to afford the expense keep a small cask and bullock and make use of the Public Wells, many of which are scattered about the station. Others employ one of the termed*

Kavady men, who for Rs. 2 to 5 supply Families with sufficient water for drinking or culinary purposes" (Anonymous, 1873: pp 29-31).

The 'better classes of people' would benefit from people employed in supplying water and firewood, and contractors maintained a street lighting system of kerosene lamps fixed on stone or cast iron at 'convenient points' (Rau, 1968).

The introduction of a networked system at the turn of the century reduced the needs for labour in high-income and colonial households. However, the majority of the population, living in indigenous huts, still depended on their own work to access water tanks and local fuel resources. For most people, this meant the immediate deterioration of their everyday life. Four decades later, in their detailed study of the housing conditions of the working class, Srinivasan and Moorty (1935: p. i) explained that the houses of 22% of families living in huts and 53% of families living in tenements did not provide 'the conditions for decent living', namely, 'light, space, ventilation, privacy, sanitation, and water supply.' The majority of the population remained excluded from networked services, while networking practices led to the deterioration of tanks and the fragmentation of markets that the poorest sections of the population depended on (see also: Nagendra, 2016).

Dynamics of urban development

According to Nair (2013), the government of the 'indigenous city' relied on complex arrangements that achieved partial orderings and differentiated population groups. High-income settlements developed in areas with different marks of desirability. For example, the extension called High Ground was built in an elevated area with beautiful natural resources and fewer concerns for 'salubriousness.' Healthy and beautiful as they were, these elevated areas lacked water and, in some houses, 'no amount of digging' could be done to reach it. The working population living in 'native huts' was concentrated in neighbourhoods such as Shoolay and Blackpully that boasted cheap markets but were thought of as 'insalubrious' or in distant areas such as Ulsoor that depended on water tanks (as detailed in Anonymous, 1873; Paul, 1929; Hicken, 1930).

Pumping technologies made it possible to reimagine the supply of water to the city. Bangalore stands on a ridge that divides three watersheds at approximately 920 m above the mean sea level. The terrain is undulating in several parts and has elevations as low as 885 m in the southwestern part of the city. Given the city's natural division into watersheds, tanks were constructed upon the drainage basis (Subramanian, 1985; Lakshman Rau, 1986). In the late 19th century, tanks were the main sources of drinking water in the City and the Cantonment, but there were frequent complaints and health scares.

The Chamarajendra Water Works were built to supply the native population of Bangalore with water from the Hesaraghatta dam. The pipeline to the Low-Level Reservoir was strategically positioned to supply the High Ground and the British Cantonment residences. The pipeline reinforced the spatial differentiation of areas of privilege in the centre of the city. Commercial advertising and tourist guides advertised the luxuries of both piped water and electricity in guest houses (Anonymous, 1873; Paul, 1929).

After the outbreak of bubonic plague in 1898, new extensions proliferated. The city's administration faced the twin challenges of extending water connections while simultaneously establishing regulatory mechanisms to maintain the system of provision. This created tensions over who should pay for the water and how, transforming a physical problem into an institutional one: "[o]n the receipt of numerous petitions form rate-payers objecting to the payment of water-tax owing to the distance of the stand posts from their houses a committee was appointed to consider the question. (…) In accordance with the recommendations of this committee a map was prepared showing by means of a red line the area within which the tax should be levied. It was provided, however, that on the extension of the water-supply system the definition of taxable area might be revised. (…) As funds become available the following extensions will be taken up: Benson Town, Langford Town, Lavelle's Property, Anasamy Moodeliar Road, Ulsoor Bazaar" (p. 13). The report concluded that, at least from the administrative point of view, the water-supply system was still 'at an experimental stage.'

These experiments led to a transformation of the water regime. Connections increased exponentially from 1359 in 1915 to 10327 in 1938. Inequalities in service provision persisted. Considering that in the early 1930s, there were 17,481 dwellings in Bangalore City (Srinivasan and Moorty, 1935) in addition to those in the Civic and Military Station, a considerable part of the population still depended on traditional wells and tanks until well into the 20th century.

Extra-urban forces

Bangalore was, since the late 19th century, a strategic location for British and American entrepreneurs, and British and American engineers held positions of power within the Mysore administration. The Mysore administration elite promoted the image of a "progressive state" open for businesses, technology, and international influence (e.g., Nunn, 1926). The development of the electricity network exemplifies the internationalisation which shaped both urban development and the use of resources in Bangalore.

In 1894, British entrepreneurs approached the Wodeyar administration with a proposal for hydropower generation in the River Cauvery, in Shivanasamudra. The proposal was turned down, and the Diwan K. Seshadri Iyer took on the task to examine the project. An order of 29 June 1899 sent ACJ Lotbiniere, then Deputy Chief Engineer, to study hydropower plants in Europe, where he also obtained quotations from the General Electric Company of the USA, the Westinghouse Company, Brown Boveri, Arlicon and the General Electric Company of Britain. Meanwhile, the Diwan negotiated with the Madras Presidency the rights for using water from the river Cauvery for power generation, a negotiation of privileges which is still at the centre of water disputes between the Karnataka and the downstream state of Tamil Nadu.

The objective of the Shivanasamudra project was to replenish the government's treasury: the Diwan negotiated a power purchase agreement with the British company M/s John Taylor and

Sons to use electricity in the operation of the Kolar Gold Fields (KGF) in the north of Karnataka State (Sharma, 2003). The hydropower plant of Shivanasamudra started supplying the KGFs on the 30th of June 1902. In 1903, the newly created Government of Mysore Electric Department (GoMED) took charge of the generation, transmission, and distribution of power from the plant. As the Maharaja approved plans to increase power generation, a perception of having a 'surplus' of electricity led to calls for the electrification of Bangalore. A receiving station ('M' station) was completed in Bangalore on 5 August 1905.

Electricity took longer to reach households. In 1910, only 7% of the revenue from the Shivanasamudra project was from the electrification of Bangalore, with 93% being from the KGFs. In the same year, there were 2367 street lights and 395 interior lighting installations. New receiving stations were built in Bangalore in 1919-20. One was in the Ananda Rao Circle, in the centre-east of the city, to supply the prosperous cotton mills and the new urban extensions that hosted the labour force. The second was in the centre-west of the city, near today's MG road, for the provision of the British Cantonment areas.

Between 1908 and 1938, the hydropower plant in Shivanasamudra gained capacity. Engineers such as Sir MV took over the administration, with an emphasis on facilitating the growth of the networked system in the city and the state. New hydropower plants were established in the River Shimsha (1938) and the River Sharavathi (1939).

Pumps played a crucial role in modernisation of the water supply. While oil pumps were common in small installations, electricity made more ambitious water projects possible. The use of a pump in the pumping station in Soladevanahalli in 1918 to deliver water from the Hesaraghatta Dam to the centre of the city facilitated the development of the water infrastructure. Following the success of the Chamarajendra Water Works, the Tippagondanahalli Water Works were completed in 1932, increasing the supply of water from the Arkavati River to the city through the Jewell Filters water treatment plant at Malleshwaram.

The availability of electricity and water fostered water-intensive industries such as cotton mills. In 1938, according to the State Administration records, the average consumption of water in Bangalore City and the Civil and Military Station was 3.50 and 2.03 million gallons, respectively, with an additional 3.6 million gallons supplied only to industries. Sir Mirza Ismail used access to electricity and water as one of the incentives for promoting local industries. The establishment of industries such as Hindustan Aircraft (HAL) in 1940 led to new patterns of spatial development. Sites such as HAL, located on the east of the Civil and Military Station, extended the boundaries of the city beyond the extensions adjacent to the city and marked a new stage in the urban development of Bangalore.

4.2. The water-electricity nexus in large infrastructure works: 1947 to 1991

Towards the end of the colonial period, service disruptions became increasingly common. In 1944, for example, production in the Shivanasamudra was interrupted by a fire caused by lightning that almost damaged the station beyond repair. Construction was constantly interrupted by the lack of materials. Administration reports reveal the gap between the level of provision that was considered normal and the realities of service on the ground.

An emphasis on the renationalisation of resources influenced state and city management. In 1944, the State of Mysore published regulations to support private licenses for electricity distribution. However, in 1948, the Electricity (supply) Act sought to reorient the sector with a focus on public control of electricity and renationalisation of electricity resources. The act proposed the creation of a Central Electricity Authority and the State Electricity Boards (SEBs), which should act as regional agencies for electrification. In Mysore (soon to be Karnataka), the administration opposed the formation of an SEB because electricity, managed by the State's Electricity Department, provided a direct source of revenue (Kale, 2014). It took four years (1953 until 1957) to establish the Mysore State Electricity Board (MSEB). In 1958, the MSEB faced integration problems derived from existing private licenses and the tariffs agreed upon with local industries, which led to litigation and constant redefinition of the role of MSEB in the context of previous legislation and the spatial configuration of infrastructures.

Changing dwelling practices

Networked systems established a physical divide between households with and without access. A United Nations report on the population of Mysore provides data on the conditions of habitation in the city (UN, 1961). The report illustrates the differences between the population in the city, who tended to live in houses made of brick, stone or cement, and those in rural areas, where mud huts with thatched or tiled roofs were more common. In their sample, over 40% of people living in Bangalore had electricity, compared to most rural areas, where less than 5% of the population had connections.

The UN study reveals the spatial differences within the city, providing detailed data about the types of houses and lighting for the survey sampled in Bangalore City. The overall data are stratified to consider different sectors of the population dependent on different socio-economic conditions. The data distinguished between more privileged areas (inhabited mostly by Muslims, Christians and highly educated Hindus) and areas where a higher percent of the population is classified as scheduled caste or has lower levels of literacy. In the latter, mud huts remained common. Only 17% of people living in 'scheduled caste areas' had access to electricity, in comparison with the over 40% average in the city (and over 66% in highly educated, Hindu areas). Finally, there were underlying suggestions that these patterns of inequality are not zoned, but interspersed and that selective processes of provision occur within putatively similar areas, thus decoupling access to services from the geographical distance to the networks.

Dynamics of urban development

Bangalore reached 1 million inhabitants between 1955 and 1960. In 1949, the Corporation of the City of Bangalore was constituted to amalgamate the City and the Civil and Military Station. The City Improvement Trust Board (CITB), established in 1945, became a critical institution in land redevelopment. While the initial mandate of the CITB was to develop a master plan for urban development, fostering industrial development and investment soon became its priority (Singh, 1964). Administrators sought to entice entrepreneurs with measures such as the provision of power and water at cheap rates (Baldwin, 1959). Electrification was not only an incentive for businesses but also an industry in itself, supporting the companies created in the pre-independence period such as the government porcelain factory, the government electric factory (GEF) and Mysore Lamp Works.

The first administration report after independence, from 1956, specified that "the existing water supply system designed for less than half of the present population was found to be utterly inadequate to meet the requirements." Pumping raised another problem for city managers as the demand for electricity increased. Maintaining a reliable supply of water became a key challenge, and tractors and carts were used to provide an additional supply of water when required.

Communities maintained old water tanks and traditional systems of water provision in peri-urban villages. However, as the extent of the metropolitan area incorporated peri-urban villages, tanks progressively disappeared. Tanks also vanished around old city areas and extensions. Some became residential layouts, such as Miller's tank, the Koramangala tank, the Subhashnagara tank, the Kurubarahalli tank, the Kodihalli tank, the Srinivagilu tank, or the Marenahalli tank. Others became sports facilities, such as the Sampangi tank, the Shoolay tank, and the Akkithimmanhalli tank, or gave space to new infrastructures, such as the Dharmanbudhi tank in Gandhinagara, where today, we can find the Kempe Gowda Bus Station (for a compilation see: Thippaiah, 2009). The disappearance of the tanks augmented the precariousness of the water supply in many communities (Mundoli et al., 2015; Nagendra, 2016).

Extra-urban forces

Transmission lines were put in place first to supply power at Bhadravathi, an industrial town near Shivamogga, and then extended to Bangalore. On 22 April 1950, power from MGHEP and from Shivanasamudra was synchronised at a Receiving Station near Rajajinagar in Bangalore. The Karnataka Power Corporation Limited (KPCL), a state-owned enterprise in charge of energy generation, was established in 1970. The state continued building dams for power generation until the 1980s, particularly in the Western Ghats of Karnataka. During the mid-1970s, environmental movements gained momentum and stopped a hydroelectric project in the River Bedthi. The state then focused on thermal energy. The Raichur Thermal Power Station (RTPS), completed in 1985 in North Karnataka, symbolised the shift from hydropower to thermal energy. The KPCL built another thermal power plant near Bellary. Both facilities are still the main sources of power for Bangalore.

By the mid-1950s, increasing demand for water led to the formation of a committee that eventually conceived the Cauvery Water Supply project, whose construction started in 1965.

Water from the Cauvery River was first drawn through Shiva Anikut (a barrage) and pumped to a treatment pumping station at Thorekadanahalli. The water was then taken to a new high-level reservoir in Bangalore which depended on two pumping stations in Harohalli and Tataguni. A new institution, the Bangalore Water Supply and Sewerage Board (BWSSB), was established in 1964 to manage an increasingly complex water supply system.

The first stage of the Cauvery scheme started supplying water to Bangalore on the 25th of Jan 1974. Given that water from the Cauvery reaches the city from the southwest, areas in the northeast tend to be chronically underserved. The increase in water withdrawals from the Cauvery came at significant energy costs for the city of Bangalore. The dependence on electricity has increased—in 2015, the BWSSB reported that over 32% of their expenditures were power charges (BWSSB, 2016). The transfer also increased tensions around ongoing resource conflicts between the states of Karnataka and Tamil Nadu. The verdict of the Cauvery Water Disputes Tribunal was announced in 2007. According to Mehta et al. (2013), the capacity that current Cauvery Projects will add (planned and completed) is just below the cap established by the verdict (1400 million litres per day), which is insufficient for the city's needs. The conflict is not over—in September 2016, a directive from the Supreme Court for the release of water to Tamil Nadu provoked a sudden outbreak of violence in Bangalore (BBC, 2016).

As Nair (2013) explains, the visions of a unified city and industrialisation aspirations were never quite achieved but left a strong imprint on the infrastructures and systems of provision, such as water and electricity. The result was a stark contrast between practices of 'normal urban living' and the fragmented realities of access to water and electricity provision in Bangalore.

4.3. Privatisation and the water-electricity nexus: 1992 to 2012

The growth of an internationally oriented ICT and offshoring industry has influenced infrastructure efforts through the formation of corridors and large transport infrastructures (Nair, 2015), although colonial and postcolonial legacies remain visible in the infrastructure landscape.

Changes in dwelling practices

Intermittency and self-provision are characteristics of the infrastructure landscape of Bangalore. The diesel generator has become a standard to deal with blackouts. Middle-income families and residents in old tenements seek alternatives to secure energy. According to a KERC representative in the energy sector, over 10-11% of electricity generation in Bangalore is from non-conventional energy sources (Interview 9, July 2015). There is evidence of household-led initiatives alongside more visible government-led programmes (e.g., half a million households have solar water heaters supported by BESCOM's rebate to support installation).

Private wells have proliferated in both isolated high-income compounds and low-income communities without access to a reliable water supply. Approximately 600,000 of BWSSB consumers have invested in an overhead tank and an underground sump (water storage). Rainwater harvesting is heralded as an alternative that could reduce the dependence of

Bangalore's households on piped water. In 2010, the BWSSB made rainwater harvesting mandatory for all buildings of 2400 square feet and above and for new buildings of over 1200 square feet, but the initiative has had mixed success.

Households bear the immediate consequences of the proliferation of private alternatives for service provision. Private strategies exacerbate current problems of service provision for the whole city. For example, Karnataka has the second highest number of cases of electricity theft among states in India (Kumar, 2009). By performing transects, we witnessed people connecting to the network in public in very crowded areas without any opposition or complaint. Blackouts follow electricity thefts. Policing is largely ineffective, so BESCOM representatives hope that smart meters will serve to control theft.

The extraction of groundwater, legally or not, encroaches in the overall water table and has long-term consequences for the whole city. The use of increasingly powerful pumps to reach lower depths reflects the increasing dependence on energy resources to provide water. A discussion during the NGO workshop in February 2014 showed that latent energy conflicts are linked to tariff structures and overemphasis on irrigation in rural areas and pumping water in urban areas. The trend towards private strategies of service provision shapes the varying forms and qualities of water and electricity supplies across the city.

Dynamics of urban development

Nair (2015: 55) highlights that the rise of the residential enclave provides "an assurance of all that state planning had failed to provide—reliable water supply, electricity, and other scarce commodities, as also withdrawal from the uncertainties and intolerable strains of social life in Indian cities." In peri urban areas, 'revenue layouts' proliferate as residents negotiate semi-legal or illegal arrangements for tenure and service provision (Ranganathan, 2014; Ranganathan et al., 2009). Informal settlements emerge interspersed with well-serviced areas. Pockets of extreme poverty are visible all over the city.

Past industrial centres disappeared in favour of an ever-expanding city. The Rajajinagar Industrial Estate that once boasted mills and small industries gradually paved the way for marriage halls during the late 1990s and 2000s. Small and medium textile-based industries survived and dot most of the landscape in western Bengaluru between Tumakuru Road, Magadi Road and Mysuru Road. Bangalore thrives on the development of hubs for the IT and offshoring industry, such as the Electronic City. Following the demands of these industries, communication and mobility infrastructures have become a priority for urban development.

Since the late 1990s, the first outer ring road has pushed the city's boundaries. Apartment complexes have mushroomed, and planning violations have become a common mechanism of vernacular governance (Sundaresan, 2017). This has happened at the expense of the city's resources, with extended appropriation of groundwater resources, the proliferation of diesel generators, and the proliferation of private solutions and decentralised technologies to meet self-sufficiency aspirations within apartment complexes (Bulkeley and Castán Broto, 2014).

The current infrastructure regime reflects multiple pressures shaping infrastructure landscapes. In 1999, the Government of Karnataka passed a bill that established the Electricity Regulatory Commission (KERC) to provide policy and regulatory oversight for other organisations in charge of electricity provision. Transmission and distribution responsibilities were allocated between a separate entity for transmission, called Karnataka Power Transmission Corporation Limited (KPTCL), and electricity supply companies for different regions in the state.

KPTCL buys power from the state-run KPCL, the central grid and other independent power producers, which, in turn, are bought by the state-run electricity supply companies (ESCOMs, BESCOM for the Bangalore region). Power purchase agreements with independent power producers have helped diversify the supply sources and introduce renewables. No single entity is responsible for energy planning in Bangalore, except for the 'perspective plans' that BESCOM prepares to plan the electricity supply.

A similar situation characterises the institutional structure of water governance. The BWSSB is now an autonomous organisation with jurisdiction over the water supply and sewage distribution. The Cauvery River Project and the BWSSB were established simultaneously, following similar visions of securing the means of supply. However, different systems of provision correspond to gross spatial differences in the distribution of piped water in the city in what is described as a mismatch between the location of needs and the structure of the network (Mehta et al., 2013). The BWSSB maintains approximately 6000 bore wells for public use, and estimations suggest that there could be as many as 50,000 residential bore wells (Sawkar, 2011), but much of their operational discourse remains tied to large water transfers.

Scholars have argued that 'parastatals' such as BESCOM and BWSSB reproduce inequality in access to water and energy services through attachment to privatisation logics (e.g., Dasgupta, 2012). The discourse of privatisation, however, is not fully integrated in the operation of services. For example, BESCOM finds limitations in the current arrangements for power purchase, and their preference is 't*o buy from Government of India',* that is, from companies such as NTPC[1] (Interview 1, June 2015).

Simultaneously, both organisations remain tied to foundational myths about engineering-led supply systems.

Historical legacies emerge in the day-to-day management of services. For example, a KERC interviewee explained that "*for power distribution, the right of way to install the transmission lines and towers are invoked through the Indian Telegraph Act of 1885, something that the British made*" (Interview 8, July 2015).

[1] Formerly known as National Thermal Power Corporation Limited, NTPC is 'the largest utility in India'.

Multiple water supply regimes coexist, with the municipal supply coexisting with a series of other arrangements, from community organisations to private suppliers and individuals drilling boreholes.

In describing the governance of water in Bangalore, Ranganathan (2014: p 102) argued that "mafias nonetheless wield a type of everyday public authority that can be conjugated with the idiom of the state." Similarly, a networked electricity supply coexists with private forms of provision which are highly individualised, from diesel generators to solar lights, in an energy landscape characterised by intermittency and fragmentation. Changing the system requires engaging with the multiple coexisting systems of governance, for example, understanding the operation and reproduction of private forms of service provision.

5. Water-energy trajectories in Bangalore

In Bangalore, neither water nor energy can be understood without reference to each other. Table 1 shows the correlation between the operation of dominant forces (municipal-based engineering, state-based centralisation, globalised liberalisation) and the transformation of the water-electricity nexus (from the adoption of networked technologies in the first period to the construction of large infrastructures and dependence on growth in the second period, and then to the shift towards private-based strategies of water and electricity securitisation in the third period).

[Insert Table 1 here]

The progressive integration of water and electricity infrastructures made possible meeting the growing demand for networked water and electricity. Hydropower technology made electrification possible. The electrification of Bangalore did not respond only to the extractive aspirations of the colonial system, as materialised in the KGFs, but also to the promotion and, later, wider adoption of a certain model of modernity among citizens. The availability of electricity fostered new imaginations of water and supported the extension of the city. Electrification was central to the development of the piped system, especially after construction of the electric water pump in Soldenavanhalli, which determined the direction of water flows and the distribution of water across the city. This led to changes in lifestyle and forms of habitation, as well as the transformation of urban citizens' relationships with water and energy resources.

After independence, insufficiency fears stimulated the development of large-scale electricity generation and large-scale water withdrawals and transfers. Insufficiency remains a pivotal discourse for urban management in Bangalore. The prioritisation of a model of centralised piped water networks, dependent on electricity for pumping, led to the rapid disappearance and degradation of water tanks. Social differences in terms of network coverage, affordability, and needs led to differentiation between households integrated into the networked system and those that relied on private solutions for both water and energy provision.

In the third period, new interconnections between water and energy have developed out of recognition of the need for an integrated solution for the city's resource challenges. The increasing power costs for pumping water frame the water-energy nexus as a problem. Low-carbon technologies such as solar water heaters create new forms of nexus between water and electricity systems.

Through their coevolution, both water and electricity provision have been implicated in the production of inequality. The location of distribution infrastructures such as receiving stations and water reservoirs enabled the development of 'strategic' areas of privilege. This gap has deepened over the years, and it is visible in the infrastructure landscape. Central neighbourhoods that traditionally maintained an independent water supply have had their water access compromised because of the extractive possibilities opened by electricity and technology. Today's IT and offshoring industries are resource-intensive, not just because of their demands for energy to support data management and communications but also because of the new lifestyle demands of the cosmopolitan workforce of Bangalore. In contrast, dispossessed people pay disproportionate prices for water in private markets in comparison with the subsidised tariffs that the traditional middle class can access through the network (Ranganathan et al., 2009). Revealing the colonial and post-colonial histories that constitute the water-electricity nexus reveals opportunities for change associated with infrastructure dependencies. Such opportunities relate, for example, with the identification of spatial patterns of urban inequality and the analysis of discourses that reproduce it.

6. Conclusion

The conceptualisation of the nexus in this paper focuses on the structural drivers of resource interdependencies, rather than on thinking of these interdependencies themselves as objects of study. Sustainability trajectories and future pathways will always be embedded in urban and industrial histories, from mills to high-precision engineering to the offshoring industry and from villages to market neighbourhoods to the suburban extensions of Bangalore. This is the context in which urban citizens access services. In the context of pro-poor land planning in Bangalore, Benjamin (2004) has argued that citizens are not passive recipients of urban policy but are instead 'active agents in a conflict-ridden domain.' The question is in how models of urban development constraint urban life. Engineers and planners may play roles in making the nexus, but so do multiple other actors who co-produce infrastructure landscapes through everyday life practices.

Even accounts of everyday life tend to focus on the elite's needs and aspirations. Are there opportunities to develop subaltern views of the city and its infrastructure dependencies? How can we measure people's lives in their own terms, focusing on how they see them, rather than looking into how they respond to external impositions? These questions help move from tracing the histories of infrastructure regimes to understanding the imprint of such regimes on people's landscapes.

A landscape perspective provides new insight into the urban nexus. Today, we see infrastructure landscapes that reflect the coevolution of multiple services in complex processes, whereby inequality is produced. Such inequality can be read in the spatial patterns of urbanisation and infrastructure delivery and, hence, integrated into a multi-level conceptualisation of urban infrastructure landscapes and the processes that shape them. We also see systems 'separating', developing specific governance institutions adjusted to the conditions and technologies of provision. Integrated approaches need to engage with the political economy of urban development. The nexus between different forms of infrastructure becomes legible between the local consequences of environmental change and the structural drivers that shape them.

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