www.water-alternatives.org Volume 16 | Issue 3

Dakyaga, F.; Schramm, S.; Lupala, J.M. and Magembe-Mushi, D.L. 2023.
Geographies of infrastructure: Everyday governance of urban
water supply beyond the utility network in Dar es Salaam.
Water Alternatives 16(3): 769-792

Geographies of Infrastructure: Everyday Governance of Urban Water Supply Beyond the Utility Network in Dar es Salaam

Francis Dakyaga

Ardhi, University Dar es Salaam, TU-Dortmund, Germany, and SD University of Business and Integrated Development Studies, Ghana, Dar es Salaam, Tanzania; francis.dakyaga@tu-dortmund.de

Sophie Schramm

International Planning Studies (IPS), TU-Dortmund, Germany, Dortmund, Germany; sophie.schramm@tu-dortmund.de

John. M. Lupala

Department of Urban and Regional Planning, Ardhi University, Dar es Salaam, Dar es Salaam, Tanzania; johnlupala@yahoo.com

Dawah Lulu Magembe-Mushi

Department of Urban and Regional Planning, Ardhi University, Dar es Salaam, Dar es Salaam, Tanzania; dimushi2000@yahoo.com

ABSTRACT: Due to uneven networked water coverage in the Global South, varied water infrastructures operate beyond utility networks to serve denizens in Global South cities. This study proposes a framework of governance modalities, actors, and interactions to analyse the governance of heterogeneous non-network water infrastructures in Dar es Salaam. This framework builds on existing literature on urban water infrastructure, everyday practices, and governance. The paper demonstrates the coexistence of private water networks, self-supply systems, and communal and hydro-mobile infrastructure that enable water collection beyond utilities. Multiple governance modalities, including co-production, self-governance, market-oriented governance, co-governance, and networked governance, control these infrastructures. Hybrid governance arrangements produce interdependent infrastructures that challenge utility's efforts by supplying water to suburbs beyond the utility's pipes. However, diverse actors and powers, conflicting responsibilities, and (in)formal regulatory mechanisms are still embodied in these modalities. This can result in (un)even water distribution among urbanites and across urban spaces.

KEYWORDS: (In)formality, heterogeneous infrastructure, governance, Dar es Salaam, Global South

INTRODUCTION

Similar to many cities in the Global South, Dar es Salaam, Tanzania, experiences unequal access to water supply. As a result, varied water infrastructures exist alongside the city's utility network to meet the needs of urban residents (Bender, 2021; Dakyaga et al., 2022). The utilisation and development of these water infrastructures by inhabitants have been significantly influenced by spatial segregation and the unequal allocation of networked water in both the colonial and post-colonial periods (Rugemalila and Gibbs, 2015; Wamuchiru, 2017; Smiley, 2020). The process of collecting water from the diverse infrastructures in Dar es Salaam involves a complex set of procedures that entail negotiation and bargaining for water from non-network water producers and distributors (Sweya et al., 2021; Hoffman,

2022). These everyday practices and procedural arrangements adopted by urban residents in coping with the water supply situation represent both 'need-driven' and 'policy-driven' approaches (Allen et al., 2017; Hofmann, 2018; Dakyaga et al., 2020). As observed elsewhere, these arrangements are invisible spaces where hydro-social relations are developed to mediate the collection of water (Sultana, 2013; Keough and Saidou, 2021).

Similarly, studies have demonstrated the varied ways in which urban residents secure water beyond utility networks in cities of the Global South (Cornea et al., 2016; Schramm and Ibrahim, 2019; Kundu and Chatterjee, 2020; 2021). The act of collecting water from diverse non-networked water infrastructures such as bore wells, kiosks, and private taps is a unique urban phenomenon (Lawhon et al., 2018; Truelove, 2019; Smiley, 2020). Scholars suggest that water supply in Global South cities is shifting from the 'network' to the 'archipelagos' of need-driven practices (Bakker, 2003; Allen et al., 2006). Scholars advocating for non-networked water infrastructures emphasise the importance of alternative infrastructures in achieving water coverage (Furlong and Kooy, 2017; Kooy, 2014; Truelove, 2020). Water supply beyond utility networks enables urbanites to collect water regardless of their access to networks (Allen et al., 2017; Chávez et al., 2020; Martínez-Santos et al., 2020). It is argued that multiple water supply systems can cater to different water preferences and choices of socio-economic groups present in Global South cities (Bichai et al., 2015; Dakyaga et al., 2018a; Słyś and Stec, 2020). Studies verifying this claim reveal how about 369 million (79%) of urban residents in Africa secure water from boreholes, water kiosks, carts/tankers, standpipes, or dug wells (Allen et al., 2017; Grönwall and Danert, 2020).

However, studies examining the connection between human health and water supply have cautioned against the use of non-networked water infrastructures (Sultana, 2013; WHO, 2014; Mudege and Zulu, 2014; Martínez-Santo et al., 2020). Studies (e.g.; Alba et al., 2019; Truelove, 2019; Kundu and Chatterjee, 2021) exploring the governance systems and everyday practices associated with urban water tankers and tube wells highlight how these distribution systems can complement utilities' water supply efforts. At the same time, they also suggest that an understanding of the governance arrangements surrounding the production and distribution of water is crucial for safeguarding the health of end users and that developing a framework to comprehensively analyse governance arrangements in heterogeneous infrastructural landscapes is still a challenging task in urban water studies. Such frameworks are important as urban water research on diverse infrastructures in Global South cities is developing (Lawhon, 2018; Smiley, 2020). This paper proposes a framework of governance modalities, actor interactions, and heterogeneous infrastructure landscapes, drawing on literature about urban water infrastructure and observations about everyday practices and governance systems surrounding heterogeneous infrastructures in Dar es Salaam. In so doing, the paper proposes a framework to concurrently explore, analyse, and categorise the existing governance modalities, actors, and interactions related to water infrastructure beyond utility networks. This kind of framework is critical for deepening and expanding conceptions of the water distribution systems beyond formal utilities in Global South cities.

This paper makes two contributions to urban infrastructure governance discourses. Firstly, it uses urban water infrastructure literature and observations about everyday practices and governance systems to propose a framework for analysing heterogeneous infrastructures. Secondly, it applies this framework to an empirical case, detailing: (i) water infrastructures, (ii) actors and modes of interactions, (iii) powers and regulatory mechanisms, and (iv) governance modalities of the varied non-networked water infrastructures beyond a utility network. The paper is structured as follows: Section 2 reviews urban water governance in the Global South; Section 3 proposes an analytical framework on governance in heterogeneous infrastructures beyond utilities; Section 4 describes the study setting and data collection; Section 5 presents the findings on governance modalities facilitating water supply to urbanites; and Section 6 concludes with a demonstration of the hybrid governance arrangements and their impact on water supply beyond utilities.

GOVERNANCE OF URBAN WATER SUPPLY BEYOND UTILITY NETWORKS IN GLOBAL SOUTH CITIES

In urban (water) studies, research on water infrastructure heterogeneity has grown, often referencing the waterscapes of Global South cities (Lawhon et al., 2018; Truelove 2019; Smiley, 2020; Alba and Bruns, 2021). These studies show how cities in the Global South are typically the geographies where heterogeneous infrastructures pervade (Lawhon et al., 2018; Alba et al., 2019). Lawhon et al. (2018) introduce the Heterogenous Infrastructure Configuration (HIC), drawing on sanitation and waste infrastructural experiences from Kampala, Uganda, to demonstrate the varied constellations/ assemblages of actors, technologies, and practices that co-exist in cities of the Global South. Truelove (2019) introduces the "gray zone" as a heuristic perspective that furthers debate on HICs, broadening scholarly understanding about the ways in which urbanites source water from varied configurated infrastructures beyond the utility network.

Moreover, considering the evolving debates on infrastructure heterogeneity, a systematic categorisation of the varied infrastructures, actors, and interactions surrounding heterogeneous infrastructures could provide an analytical ordering and a holistic comprehension of those infrastructures' governance arrangements. This paper contributes to these debates by drawing on urban water infrastructure literature and observations of everyday practices and governance systems in Dar es Salaam to holistically explore and analyse the governance arrangements of heterogeneous infrastructures beyond utility networks. In this study, infrastructures beyond utility networks entail the varied small-scale, (in)formal, off-grid water systems such as protected/tube wells, drilled mechanised boreholes, tanker trucks, rainwater harvesting systems, boreholes fitted with hand-pumps, and community-based water systems that supply water to urbanites (McDonald et al., 2011; Chakava et al., 2014; Truelove, 2019). Through these infrastructures, water is either produced outside the utility or collected from the utility network (Truelove, 2019). Water scholars stress the importance of studying the governance arrangements of heterogeneous water infrastructures for understanding water production, distribution, and consumption, as well as effects on human health (Alba et al., 2019; Sultana, 2014). Governance entails "those that determine *who gets what water* outside the utility *when* and *how,* and *who* has the right to be served with water" (Grönwall, 2016; Lim et al., 2022; Dakyaga et al., 2020). In urban water studies, governance occurs beyond the state domain and is studied through the ordinary practices of the actors involved in urban water supply (Cornea et al., 2017). Everyday governance refers to ordinary relationships between state and non-state actors and the processes that govern water beyond the utility network. However, the lens of "everyday practices and governance" is limited in analysing multiple infrastructures and their governance modalities. This paper proposes a new framework to analyse governance arrangements of heterogeneous water infrastructures beyond utility networks, contributing to the discourse on urban water infrastructure heterogeneity and governance. This is important for expanding our understanding of the actors and interactions involved in water production and distribution outside of utility networks in cities of the Global South.

Hoque (2021) demonstrates that although alternative water infrastructures complement utilities' efforts, formal regulations and mechanisms like monitoring and coordination of non-state actors are vital for improved water delivery and adherence. In the absence of formal regulations, non-state actors establish and regulate water infrastructure outside of formal processes (Chakava et al., 2014; Grönwall and Danert, 2020; Dakyaga et al., 2022). Even where formal regulatory measures exist, enforcement of regulations becomes necessary when non-state infrastructures produce unintended effects or threaten human health (Sultana 2013; Cain and Baptista, 2020). Regulatory mechanisms and their enforcement vary across cities in the Global South. Truelove's study in Delhi (2019), demonstrates how groundwater regulatory officials act as watchdogs to promote compliance through monitoring and coordinating tube wells in non-networked areas. Truelove (2019) reveals how operators use their financial power to bribe a police task force and prevent their illegal tube wells from being labelled as unauthorised water sources. This shows how actors can influence existing formal procedures through power and interactions, even

when such procedures are present. The urban water poor usually must rely on an unimproved water supply outside of a utility's service (Beard and Mitlin, 2021; Dakyaga et al., 2018b).

The multiplicity of infrastructures beyond a utility is made possible by people and material artefacts. Bodies act as infrastructures providing information, networking, and maintaining collaboration (Simone, 2015; Peloso and Morinville, 2014; Truelove and Ruszczyk, 2022). Water supply beyond the utility serves as a medium in which diverse relationships are built (Keough and Saidou, 2021). Scholars consider canals, pumps, treatment plants, and various technologies – such as plastics, pipes, and barrels – as crucial for storing, filtering, and transporting water to end users beyond utility networks (Meehan, 2014; Wutich et al., 2018; Meehan et al., 2020; Adeniran, 2022; Kasper and Schramm, 2022). Studies highlight the impact of environmental conditions, power relations, and socio-material factors on water production and distribution beyond utility networks (Sultana, 2013; Schramm and Ibrahim, 2019). These interactions differentiate water supply through the inclusion and exclusion of neighbourhoods and households within cities (Truelove, 2019; Dakyaga et al., 2022).

Furthermore, the involvement of community volunteers and organisations, NGOs, individuals, state political actors, and private individuals has been shown in providing water beyond utility networks (Moretto et al., 2018; Alba et al., 2019). Plumbers/technicians, engineers/water experts, government employees, public health workers, environmental resource managers, social entrepreneurs, and policymakers are (non)professional agents that offer socio-technical knowledge, as well as financial and material support, to enable water supply beyond utilities (Cleaver et al., 2005; Sultana, 2013; Moglia et al., 2011). Linking these actors with the water infrastructure they create and distribute is useful for understanding the complexities of water supply in the Global South. Examining water governance in Buguruni (a suburb of Dar es Salaam), Bourque (2010), and Smiley (2020) reveal how uneven relations manifest among water supply actors. Residents tend to cooperate more with local water providers than with utility and government authorities. Although the utility holds 'reinforcive' powers, urbanites lack trust in the utility due to unequal distribution of network water. Social hierarchies, resource capacities, and local leadership empower control over non-utility water systems. These determine in/exclusion of non-powerful residents from the utility's water connectivity (Truelove, 2019). Scholars have researched diverse aspects of governance in relation to water production and distribution beyond utility networks (Wamuchiru, 2017; Truelove, 2020; Alba et al., 2019; Dakyaga et al., 2020). However, holistic analysis of governance arrangements for heterogeneous infrastructures, including modalities, actors, and interactions, remains challenging. This is essential to broadening conceptions of governance modalities that mediate water flow beyond utility networks. The following section presents a framework to analyse the multiple infrastructures, actors, and interactions in the production and distribution of water beyond utility networks.

ANALYTICAL FRAMEWORK: GOVERNANCE MODALITIES AND ACTORS' INTERACTIONS IN HETEROGENEOUS INFRASTRUCTURE BEYOND THE UTILITY

The paper draws on urban water infrastructure literature, observations of everyday practices, and analysis of governance systems to propose a framework of governance modalities and actors' interactions within heterogeneous infrastructure landscapes. Since the 2000s, studies have evolved on everyday practices and governance as an approach for theorizing urban water infrastructure provision (Cornea et al., 2017; Truelove, 2019). This lens has been used in various studies to demonstrate the ordinary ways in which people relate with, and regulate, land (Le Meur and Lund, 2001); how local leaders interact with waste and regulate their subjects (Øyvind, 2011; Zimmer, 2012); how people interact with, and regulate, the natural environment (Cornea et al., 2017); and largely how water infrastructure provision and operation works (Cornea, 2020; Truelove, 2020; Kundu and Chatterjee, 2021). Perspectives on everyday practices and governance offer the possibility for urban scholars to engage with diverse logics, rationalities, and artefacts through (in)direct interaction with the state's actors (Plio, 2019).

Although this lens has been instrumental for understanding the practices, powers, regulations, and actor interactions in infrastructure provision (Velzeboer et al., 2017; Zhen et al., 2019; MacAfee, 2023), it is inherently incapable of categorizing the varied infrastructures *vis-à-vis* their governance modalities. Moreover, it is useful for analysing the governance of diverse infrastructures and showcasing the interconnected socio-technical arrangements involved in producing and distributing water beyond a utility network.

Infrastructure categorisation entails the compartmentalisation of the multiple infrastructures that co-exist in supplying water beyond utilities. These infrastructures differ in sizes, legality, ownership, regulation, and technicalities. Infrastructures are classified in several ways: by size – either large-scale/centralised or small-scale/decentralised (Domènech, 2011; Sesan et al., 2021); by legality – as formal or informal (Maryati et al., 2018); by ownership and regulation – as individually or communally owned and regulated; and as rudimentary technologies and techniques as opposed to standardized and sophisticated technologies for water production and distribution (Maryati et al., 2018). They may be owned and regulated by states, private groups, or individuals for mutual and collective benefits (Adams et al., 2018; Maryati et al., 2018). For example, community-based and self-supply infrastructures are independently controlled, monitored, and regulated for household and community use (Stoler et al., 2019; Wutich et al., 2018). Gifting and sharing of water are practices embodied in these water infrastructures (Allen et al., 2006; Allen et al., 2016). Private networked infrastructures also produce and distribute groundwater to residents (un)served by a utility (Bakker, 2003). These infrastructures are (in)directly connected to a utility as they draw electricity for water distribution (Dakyaga et al., 2022). Additionally, "hydro-mobile infrastructures" work to facilitate the distribution of water to end users beyond a utility's pipes. These infrastructures are non-static but mobile. "People may act as infrastructures" by mediating information provision and networking to collect water (Simone, 2021; Andueza et al., 2021). In this context, hydro-mobile infrastructures refer to infrastructures whose water distributions are mediated by the socio-material and bodily work of people. These include pushcart owners, tanker truck drivers, and tricycles/bicycle riders that distribute water to end users (Wutich et al., 2016; Alba et al., 2019; Truelove and Ruszczyk, 2022). Residents may chase for water to be delivered (Peloso and Morinville, 2014). Central to such arrangements are the material technologies such as storage artefacts, plastics, and metallic containers through which water is stored for onward distribution and use (Kasper and Schramm, 2022).

Modes of governance define actors and their roles and interactions in producing and distributing water beyond a utility network. The modes of governance define the powers and regulatory mechanisms for a given infrastructure (See Table 1). These may include co-production, co-management, co-governance, self-governance, network governance, and market-oriented governance. C*o-production* is a mode of governance characterised by an (in)formal working relationship between a state water utility and non-state actors/residents. Recipients of the service equally perform key roles or make substantial contributions towards the provision of the service (Moretto et al., 2018). Non-state actors may encompass volunteers, community groups, NGOs, Community-based Organisations (CBOs), private individuals, and organisations. They may participate as (co)producers or negotiators in water provision and delivery. Heterogeneous infrastructure may be self-governed, where non-state actors interact to address water-related issues by setting goals, exchanging resources, and negotiating common purposes based on their differential capacities (Stoker, 2018). Self-governance also involves self-help and associations formed by individuals to provide and operate water supply systems, which may be exclusively owned by the actors involved, with non-members having no rights (Nederhand et al., 2019). Market-oriented governance involves local entrepreneurs actively participating in water production and distribution (O'Keefe et al., 2015). Infrastructures may be collaboratively governed by involving state and non-state actors in power sharing, formal institutional decision making, and consensus building based on trust and social capital (Yu et al., 2012; Ansell and Gash, 2008).

Actors and modes of interaction refer to the individuals, groups, organisations, and institutions that facilitate water production and distribution beyond a utility, including formal and informal, state and non-state actors, users, producers, distributors, plumbers, and technicians. Formal actors comprise defined organisations, governmental departments, and agencies such as officials of the state utility and water policymakers. Non-state actors include individuals and groups, as well as associations such as CBOs, Civil Society Organisations (CSOs), and development partners. Private sector actors with technical knowledge, innovation, and resource capacities also participate in providing and managing water systems (Dakyaga et al., 2020). Technicians/plumbers and (co)producers of water can act as formal or informal state or non-state actors, regulating the provision of water infrastructure (Truelove, 2020). Their interactions are mediated by factors such as resource capacity, rules, and interdependency in the water supply chain (Pakizer and Lieberherr, 2018). Different types of infrastructure may involve various forms of collaboration, such as civic cooperation, alliance-building, coalition, collaboration, participation, and networking, to facilitate water supply beyond the utility (Ansell and Gash, 2008; Dakyaga et al., 2020). The interactions of actors may differ depending on the governance modalities of the infrastructures (Cornea et al., 2017). These interactions enable (non)state actors to structure processes and mechanisms for water service provision in their neighbourhoods (Pilo', 2019; Dakyaga et al., 2020). See Table 1.

Powers and regulatory mechanisms are the ways in which rules and regulations are established, both within and outside formal stipulations, and followed by actors involved in water supply beyond a utility network. They include existing interests, how they're pursued/challenged/undermined, and how powers are exercised (Alba et al., 2019; Truelove, 2020). Powers and regulatory mechanisms include (in)formal and market-based instruments – such as rules, regulations, legislation, and sanctions – that are legally binding and enforceable to ensure water quality and operational standards. The informal mechanisms consist of informal rules – such as social norms and values, local laws, and sanctions – that define authority and shape actor's relations (Pilo, 2017). Regulatory mechanisms direct actors, define ownership and decision-making, and establish protocols for water provision. Policy mechanisms enforce regulations and legislation, rewarding conformity and punishing non-conformity (Pakizer and Lieberherr, 2018). Institutional processes and procedures, such as licensing, registration, permitting, and enforcement, may encourage compliance with water extraction regulations. Regulations are central to practices but vary across infrastructures. They are caveats to power, including *innovative power* – the ability to mobilise resources for water supply (Velzeboer et al., 2017); '*Reinforcive' power* – top-down power exercised to enact and enforce rules towards water supply; and *transformative power* – the power to influence the production and distribution of water (Ayodele-Olajire, 2022). Operators may be accountable to political or non-political administrative units or directly to water users. However, Pakizer and Lieberherr (2018) note that water operators tend to be accountable to their consumers, rather than political-administrative actors. State actors ensure that water quality standards are met in commercial and domestic water provision by assessing, standardizing, monitoring, and evaluating water quality.

STUDY SETTING AND METHODS

Dar es Salaam, one of the largest and fastest-growing cities in Africa, is rapidly urbanising amidst less coordinated expansion and coverage of network water (Bender, 2021). The utility network has not kept pace with the city's expansion over the years (Sweya et al., 2021). Despite its multiple water sources, including boreholes and three different rivers (the Lower Ruvu, Upper Ruvu, and Mtoni), the city is still unable to meet its demand for water. About 80% of the city's residents, especially those in the fringes (Sakijege, 2019; Hofmann, 2020), lack adequate access to piped water connections from the utility (Bender, 2021). Most residents rely on heterogeneous infrastructures that supply water beyond the utility (Smiley, 2020). Rugemalila and Gibbs (2015) consider the uneven ways in which water is supplied within the city an issue of governance. This study builds on existing literature on urban water infrastructure, everyday practices, and governance to propose a framework for analysing the governance arrangements that mediate water flow from varied water infrastructures beyond the utility.

Table 1. Categorisation of water governance models, actors, and modes of interactions within heterogeneous infrastructures.

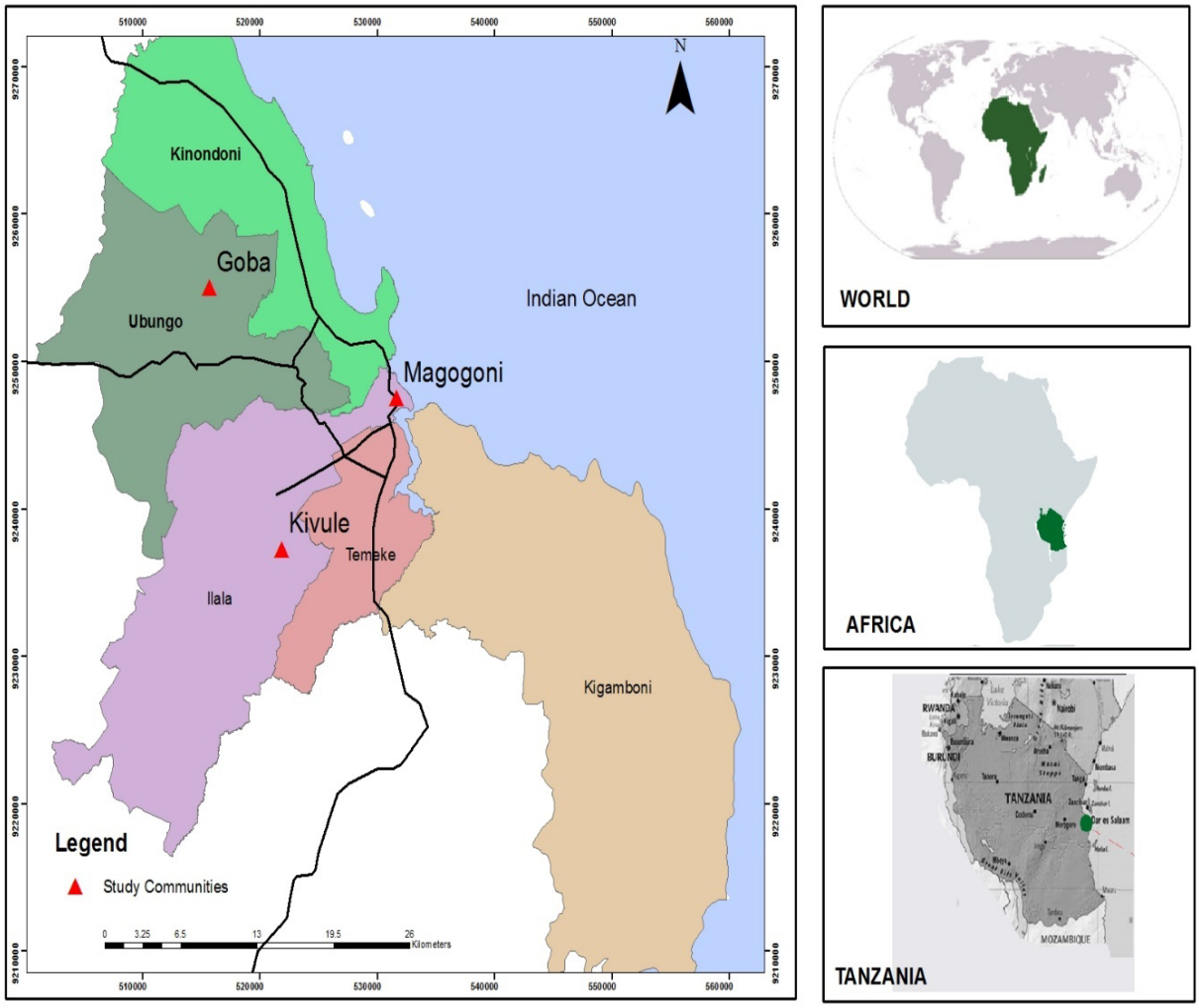
Models	Major actors involved		Roles and Modes of interactions	References
	State	Non-state		
Co-production	Agency /utility officials, etc.	Civil society NGOs Clients/service users Self-supply residents	(In)formal partnership, Coalition (In)formal collaborative (In)formal participations May involve defined responsibilities	Loeffler and Bovaird, 2016; Sorrentino et al., 2018; Turnhout et al., 2020; Otsuki, 2016; Rosati et al., 2020; Chatterjee and Kundu, 2020
Co-management	Utility/state water agencies	Small-scale individual/private provider/groups NGOs and residents.	Mostly formal partnerships, Utility formal assistance Defined responsibilities	Pomeroy, 1996; Alipour and Arefipour, 2020
Co-governance	Utility/state agencies	Water user's associations/committee Local/community leaders NGOs	Formal collaborative decision making Formal partnership and participation Cooperation/interdependence Defined responsibilities/arrangements	Ansell and Gash, 2008; Ansell et al., 2020
Self-governance	With(out) state actors	Residents, community-based self-help groups, Individuals/private/ water entrepreneurs etc.	Informal participation Informal collaboration Indirect interactions with the state Alliance/coalition	Rauws et al., 2020; Dakyaga et al., 2020
Network governance	State utility/agencies	Private individuals /NGOs/water experts/ civil society with specialised knowledge/utility kiosks	Consulting Contract service Defined arrangements/responsibilities	Graversgaard et al., 2018; Batory and Svensson, 2019
Market-oriented Governance	With(out) state utility as regulator	(in)formal local entrepreneurs, users, associations/groups	Responsibility over infrastructure and service provision, contract service Collection of user fees, marketing	Dakyaga et al., 2022; O'Keefe et al., 2015; Sakijege, 2019; Bakker, 2010

The study commenced in July 2021 with the review of policy documents, reports, and articles concerning water supply beyond the utility network. The goal was to understand the regulatory mechanisms and policies governing water supply beyond the utility and build a framework to analyse the governance arrangements of various infrastructures. The review offered a preliminary understanding of (non)state actors engaged in the water supply. A qualitative case study method was used to explore the various typologies of infrastructure that supply water beyond the utility and their governance modalities. Snowballing and Maximum Variation Purposive (MVP) sampling techniques, also known as heterogeneous sampling techniques, were used to select diverse participants for face-to-face interviews. Whilst the snowballing technique enabled the selection of participants engaged in similar water supply arrangements, like tanker drivers, the MVP enabled the identification of participants across diverse organisations within the city, such as experts and technicians. Thirty-six participants were interviewed, comprising utility officials, policymakers, residents engaged in water supply, plumbers/technicians, experts, advisors to the utility, and households as consumers. Expert interviews were conducted with water resources managers and scientists, the advisor to the utility and the off-grid director of the utility, and planning and monitoring officials. These participants were purposefully selected due to their in-depth knowledge and experiences with the water supply in the city. Participants were asked about the various ways in which water was sourced and distributed by residents beyond the utility. Questions were also asked about the existing (in)formal rules and regulations guiding residents engaged in the water supply; the power relations and modes of interaction between the utility and non-state actors; the governance approach(es) mediating urban water supply beyond the utility; and how utility officials generally regard non-state water providers in the waterscape.

Using a semi-structured interview guide, data were collected on the non-networked infrastructure across the city. These infrastructures were found to dominate in the peripheral areas where water network connectivity was lacking. As a result, three peripheral settlements, namely Kivule, Magogoni, and Goba, were selected and data collected. Goba Ward is in Ubungo Municipality, with about 54,630 people and uneven utility connections. Kivule Ward is in Temeke Municipality, with about 72,032 people and no utility connection. Magogoni is a sub-ward of Kigamboni, with about 36,701 people and no utility network. Semi-structured interviews were conducted in these settlements with three Ward *Mtaa*, leaders who monitor spatial and infrastructure development. They were asked about water supply, production, and distribution, as well as the types of water infrastructure and the rules governing water supply. Data were also collected on governance arrangements and the actors' roles in mediating such water supply. This also involved providing an elaborate description of different governance modalities, such as self-governance and co-production. Participants were asked to select the governance model(s) that best described how water is produced and distributed beyond the utility. Data were also collected on the mode of interaction between water providers, local government authorities, and the utility. In addition, six face-to-face household case studies were conducted, coupled with observations of materials used for water storage and collection processes. This involved developing a good rapport with selected households and asking different household members the arrangements through which water was collected.

Key Informant Interviews (KIIs), alongside observations and photography, were conducted with 23 purposely selected non-state water providers located in the three selected settlements. These included six water kiosk owners and resellers, three protected well caretakers, eight bore well owners, and four private water network providers. KIIs were also conducted with plumbers and pump technicians to ascertain the innovative ways in which urbanites facilitate water supply beyond the utility network. See Figure 1.

Figure 1. Map of Dar es Salaam showing study areas.



Interviews were conducted with borehole owners and caretakers at the households and community levels. Water pumping, storage, and distribution, and related technological artefacts were observed. Transect walks were conducted within the catchment areas of privately owned mechanised bore wells that provided in-house water connections to residents. Data were collected on water sourcing, distribution, regulations, interactions among actors, and governance modalities. In addition, four (un)registered water tanker drivers and pushcart operators were purposefully sampled and interviewed based on their experiences with water distribution in the city. Tanker truck drivers registered with the utility were interviewed at the various utility kiosks where they were stationed to collect water for onward distribution. Data were collected on governance practices, existing regulatory actors, and regulations. Interviews with tanker drivers were validated by conducting an FGD with private tanker truck drivers registered with the utility. Interviews were conducted in Swahili and English. Consent was sought, and the discussion recorded. Thematic analysis was conducted – transcribed data were edited and grouped, and codes were generated using MAXQDA. Themes were defined and substantiated using field evidence. Through thematic analysis, the paper presents water infrastructure, actors, and governance models beyond the utility, described in words and tables.

GOVERNANCE MODALITIES, ACTORS, AND MODES OF INTERACTIONS WITHIN HETEROGENEOUS INFRASTRUCTURES BEYOND THE UTILITY

Categorisation of water supply infrastructures beyond the utility network

The field interviews revealed four varied and interrelated sets of water supply infrastructure types in Dar es Salaam. These included community-owned water infrastructures (CWI), hydro-mobile infrastructures, independent household self-supply, and privately networked water, which operated collectively as interconnected infrastructures (Massey and Gunter, 2020). Despite their interrelatedness, water uses, water sources, infrastructure ownership, and water production and distribution define these infrastructures from one another. CWI comprised boreholes fitted with hand pumps and mechanised boreholes. These infrastructures were financed by religious bodies, development agencies, and NGOs. Ownership and regulatory powers were exercised by either the residents, the utility, or the local government authorities, as observed by previous studies (Allen et al., 2017). CWIs were people-centred, and their operations were shaped more by mutuality and/or the mechanics of common understanding among water users. Interviews showed that boreholes were popular due to the depletion of other water sources like rivers and shallow wells, which were commonly used in the outskirts of Dar es Salaam in the 1990s and 2000s. This was influenced by residential expansion/development (Andreasen and Møller-Jensen, 2016). Before modern hydrological technologies, bore wells were constructed through communal self-digging or by hiring artisans. With modern drilling equipment and private drilling companies, boreholes became the typical water system for urbanites unserved by the utility.

Independent self-supply infrastructures are provided for individual and household-specific water supply needs. These comprised households with rainwater harvesting facilities and mechanised boreholes. Experts opined that the high cost of storage facilities limited large-scale collection of rainwater through rainwater harvesting among residents in Dar es Salaam. Individual households in Dar es Salaam engage in need-driven practices via petty collection and storage of rainwater. This was mediated by the use of ordinary technologies such as buckets, plastic storage tanks/cans, and barrels (Meehan et al., 2020). However, the high salinity of the water in many parts of the city limited the usage of water from bore wells, especially for drinking. Except in Kivule, where the utility network does not exist, bore wells were the typical water infrastructure. This type of infrastructure enabled a sufficient supply of water to satisfy end users in terms of meeting their everyday water needs (cf. Uitermark and Tieleman, 2021 and Figure 2). As a 64-year-old owner of a self-supply water infrastructure explained:

> I have a borehole where I get water for everything (…), so anytime I hear announcement that DAWASA [the utility] is shutting down for repairs or doing maintenance at the Upper Ruvu pumping station, which is the main source of water supply for the city, and that for three days or more, the city will be dried (…) I am just tired of hearing this kind of information always, because, it does not matter, whether they do maintenance or not (…) it does not affect me. I am so sure of reliable water supply within the 365 days per year from my boreholes, but the rest of the residents in Dar es Salaam are subjected to this kind of calls or attention from the utility, like please tomorrow, we will have no water for the city [KII, 23 March 2022].

The findings suggest that water supplied beyond the utility in turn provides a fine-grained remedy, as it enabled residents to adapt to the utility's absence and failures. Although network water is the ideal for many residents (Smiley, 2020), long-term socio-natural interactions (between residents and boreholes) can contribute to the lack of interest in formal utility connections. A resident confirmed this:

> I am saving a lot of water from the borehole. I don't think DAWASA [the utility] water could have been enough for me. I could not have afforded their water supply with all the functions I have in the plot because the remaining acre or hectare of my house is committed for gardening/horticulture, very intensive (…) No! I don't need a utility connection. Whatever diameter size the pipe will be for me it doesn't mean anything. I don't need them. I am very self-reliant. On the contrary, I could help them – I could supplement their water like I am doing free for my neighbours [KII, 23/03/2022].

Figure 2. Privately mechanised borehole networked water system.

This reinforces Keough and Saidou's (2021) observations that off-grid water infrastructures not only structure supply but also serve as the medium through which hydro-social relations are built. In this context, neighbourhood-based social relations were developed and deepened through the act of supplying free water to neighbours living beyond the utility network. This partly reinforces Uitermark and Tieleman's (2021) observations that owners of mechanised boreholes rejected or disconnected themselves from the utility network. But for some residents, relying on heterogeneous infrastructures represents a safeguard measure (Lawhon et al., 2018).

As a private network water provider said, "Even when I get connectivity to the utility network, when it reaches me, I will still like to operate my own supply. If I disconnect my bore well and the utility's network gets a problem, what will I do?" (KII, 17th March, 2022). However, disparities were found across the city in terms of perceived sufficiency of groundwater use. Groundwater satisfied household water needs in Kivule, but such was not the case in Goba and Magogoni. In the latter, ordinary innovations (Martínez-Santos et al., Danert, 2020), such as boiling groundwater, helped reduce salinity and enabled residents to attain multiple uses. However, boiling water for drinking was not limited to groundwater, but also water sourced from the utility for doubt of quality.

In addition, private networked infrastructure provided hydraulic connections to neighbours, serving about 1-300 households. The practice of drilling was interceded by varied material technologies, such as plastic storage tanks (Kasper and Schramm, 2022), pipelines, and elevated towers, for the storage of water (See Figure 5). Groundwater was collected from artisanal dug wells for domestic use using rubber gallons tied with ropes as a routine practice (Figure 4). In rare cases, submerged water pumps were used as material artefacts to facilitate the circulation of water into elevated storage tanks about 14-15 meters in height for onward distribution by gravity. This routine practice ensured the continual collection and use of water from bore wells by residents. The higher the elevation, the higher the possibility of delivering water to connected households. Water from communal/shared water infrastructure was circulated through the ordinary practice of collection and transportation by residents. Through selective pumping and distribution of water, private networked water providers enabled regular flow of water to houses

Figure 3. Hydro-mobile reseller of utility water.

Figure 4. Protected bore well.

Figure 5. Standalone kiosk reseller of utility water.

located in highly elevated areas. Although operating beyond the water utility, these infrastructures are often connected to utility infrastructure and other systems. Some water providers constructed 32,000-litre storage dams as backup storage infrastructures in case of electricity failure.

Hydro-mobile infrastructures such as tanker trucks (un)registered with the utility, tricycles, bicycles, or pushcarts were found as the fourth infrastructural category. They provided residents with virtually connected water service (See Figure 3 and 4). Bodies and material artefacts enabled the transportation of water for household use based on request and purchase (Peloso and Morinville, 2014; Simone, 2021; 2014; Truelove and Ruszczyk, 2022). Road networks and mobile phones facilitated interactions as mediatory infrastructures. Storage tanks and water pump machines powered by petrol enabled the collection and discharge of water. Agents of hydro-mobile infrastructure responded to the challenge of uneven topographic spaces by delivering water across highly elevated areas beyond the pressure or reach of the pipes. Overall, although these water infrastructures co-existed as varied systems within the city, they were largely interconnected in terms of the sources and the technologies used for water distribution.

Modes of governance of water supply beyond the utility network

The interviews showed that hybrid governance modalities mediated water supplied beyond the utility network in Dar es Salaam. Mechanised boreholes, tankers, and pushcarts co-produced, co-governed, and self-governed water distribution. Co-production and self-governance arrangements were the dominant models that facilitated water production or extraction and distribution. Community-shared or owned water infrastructures, private networked water infrastructures, and self-supply households were informally co-produced and self-regulated. Non-state water actors such as community-shared or owned water providers, and non-utility water resellers and distributors informally engaged, extracted, and distributed groundwater to other residents. These actors configured material technologies, such as pipelines and tanker trucks, to collect and distribute water. As observed by previous studies (e.g.; Pakizer and Lieberherr, 2018; Truelove, 2020; Dakyaga, 2022), these acts challenged the mono-centric ways in which water was supplied by the utility (residents supplied water based on their self-will and abilities). As explained by a private networked water provider:

> When you are starting the drilling process, you don't ask for permission, you look for the people/companies in water drilling and you wake up in the morning and start drilling. You just tell the private companies with the expertise that you want to drill water, they come to you and you show them the locations, then you negotiate the price/cost, then they start the drilling processes. When you get the water drilled then you now start to follow the procedures, that is if you want to supply to people (KII, Goba, 07/03/2022).

Deep wells ranging from 50 to 70 meters in depth and boreholes ranging from 136 to 150 meters were discovered to have been constructed as a result of this arrangement. These informal ways in which non-utility infrastructures were produced defied the ability of the utility to govern their operations. As observed by previous studies (Sultana, 2013), monitoring became necessary only upon speculation of outbreaks of water-borne diseases such as cholera. In such occasions, monitoring and regulations were limited to commercial water producers and distributors, to the neglect of self-supply households. The owners of gated homes restricted self-supply water infrastructure to maintain their privacy and indirectly assert their ownership power (Dakyaga et al., 2022).

The interviews also uncovered how the mediating roles of collaborative governance modalities influenced the supply of water outside of the utility (Ansell and Gash, 2008). The utility partnered with private tankers to distribute water to unserved areas, including elevated locations like Goba and Mbezi, beyond the reach of its pipes. 'Utility water kiosk gatekeepers' coordinated the supply of water, enabling registered tankers and pushcarts to collect water from the utility kiosks for onward distribution. See Table 3.

Table 3. Typology of water infrastructures beyond the utility network and their governance modalities.

Water infrastructures	Mediating actors	Governance modalities											
		Production/extraction						Distribution/Circulation of water					
		Self-governance	Co-governance	Co-management	Co-production	Market-oriented gov.	Network governance	Self-governance	Co-governance	Co-management	Co-production	Market-oriented gov.	Network governance
Community-owned/shared infrastructure	Mosque water vendors	•			•			•			•		
	Community-based water vendors	•	•	•				•	•		•		
	Protected wells	•			•	•		•			•		
	Shared water networked actors	•			•	•		•			•	•	
Hydro-mobile infrastructures	Tanker drivers (non-registered)	•			•	•		•			•	•	
	Pushcart/tricycle operators							•			•	•	
	Utility kiosk's water vendors								•		•		•
	Tanker drivers (registered utility)								•		•	•	•
Private networked infrastructures	Bore wells connected to residents	•			•	•		•			•	•	
	Private taps	•			•	•		•			•	•	•
Self-supply water infrastructure	Households with bore wells for private use	•			•			•			•		

The gatekeepers of the utility's water kiosks oversaw, managed, organised, and assisted registered tankers in collecting water. Tanker drivers showed coupons as proof of payment to the utility and collected water for onward distribution. Tanker operators partnered with the utility based on their self-interest in co-distributing the utility's water (Doberstein et al., 2020). The utility's' water kiosk gatekeepers acted as mediators with interface interactions by maintaining relations between the tanker trucks water distributors and the utility at the designated utility kiosks. Private water providers, unregistered tankers, tricycles, and motorbikes operated outside of official regulations to produce and distribute water with the aim of providing a social service to residents. These actors drilled boreholes informally, in purview of self-supply and social agency, but in turn operated as commercial entities. Through partnerships between NGOs such as WaterAid, local government authorities, and the utility, boreholes were co-produced and co-managed for water distribution, especially in peri-urban areas (Sorrentino et al., 2018; Turnhout et al., 2020). In Goba, interviews revealed that beneficiaries' capacities were built on aspects of maintenance and repairs of water infrastructure provided by NGOs. Residents exercised responsibilities in aspects of repairs and maintenance of non-networked water infrastructure for continual use of the water. Technicians/pump engineers interacted with NGOs and residents as well as private networked water providers, to provide technical and technological support such as repairs and maintenance. These interactions were mediated by networked governance modality and developed through the acts of consulting and contractual service provision (Graversgaard et al., 2018; Batory and Svensson, 2019). These offered a fine-grained arrangement through which bore wells and tankers with pumps were made functional and distributed water beyond the utility.

The actors and modes of interactions towards water supply beyond the utility network

In peri-urban areas of Dar es Salaam, water was delivered largely by non-state actors. This was made possible through a complex web of interactions between, and within, actor groups. These interactions occurred between co-producers and distributors, amongst co-distributors, between co-financiers and engineers/technicians, and between consumers and (in)direct regulatory agencies. Co-producers and distributors comprised privately networked water providers and independent self-supply households that extracted groundwater mainly for domestic use. These actors voluntarily produced and distributed water via civic cooperation. As explained by a plumber; "We work with the hydrologist and the drilling companies sometimes. We go around mapping the water drilling point through the use of technological devices. I have worked for more than 200 customers on the issue of water connection…" (KII, Plumber). These relations existed between technicians, pump engineers, plumbers' hydrologists, and residents interested in drilling boreholes for their own household use and commercialisation. Technicians, plumbers, pump engineers, and hydrologists with the technical know-how invented tailor-made/customer-centred water distribution innovations. To address irregular water flow in peri-urban areas at higher elevations, they linked valves, pipes, wires, storage tanks, and submerged water pumps to increase pressure. Through socio-technical interactions (Keough and Saidou, 2021), plumbers and engineers configured material artefacts by providing single pipeline connectivity from the elevated storage towers to clients' homes (See Table 4).

Secondly, Pump technicians provided customers in higher-elevated areas with a dedicated pump machine, which distributed water utilising an 'Off' and 'On' switch control system. The interview revealed that NGOs financed the drilling of mechanised water systems through the relations of civic cooperation, partnership, collaboration, and voluntary participation (Turnhout et al., 2020; Otsuki, 2016). In Kivule and Goba, earlier settlers financed the drilling of bore well water systems through which newcomers collected water in peri-urban areas (Grönwall, 2016). This was enabled through the gifting and sharing of water, as observed by previous studies (e.g.; Wutich et al., 2018; Keough and Saidou, 2021). The findings also suggest that water infrastructures are not only artefacts that deliver water but also mediums through which varied socio-cultural relationships emerge and are deepened. In both cases, the mechanisation of water infrastructure enabled the delivery of running water to neighbours. Water system providers

Table 4. Categories of actors and modes of interactions toward supply in heterogeneous infrastructural landscapes.

Categories	Actors' specification	Modes of interaction														
		Among non-state actors							With state actors (Utility, WoW)							
		Civic cooperation	Partnership	Alliance/coalition	Networking	Vol. participation	Collaboration	Contractual	Interdependence	Civic cooperation	Partnership	Alliance/coalition	Networking	Vol. participation	Collaboration	Contractual	Interdependence
Co-producers and distributors	Mosque water vendors	●				●				●				●			
	Self-supply households	●				●				●				●			
	Community-based water vendors	●				●				●				●			●
	Private taps	●				●				●				●			
	Private water kiosk operators	●				●			●	●				●			
	Private networked water actors	●				●				●				●			
Co-distributors	Tanker drivers (non-registered)		●			●	●		●	●				●			
	Resellers of utility water	●	●			●	●			●	●			●		●	●
	Private kiosks – groundwater	●				●				●				●			
	Pushcart/tricycle operators	●				●			●	●				●			
	Utility kiosk operators	●				●			●	●	●			●	●	●	●
	Tanker drivers (registered utility)		●			●	●	●	●		●			●	●		●
Co-financiers & technicians	NGOs/Dev.t Agencies		●						●	●	●		●	●	●		●
	Plumbers	●			●			●			●		●				
	Drilling companies	●		●				●				●				●	
	Water pump mechanics	●		●				●	●	●							
(In)direct regulatory actors	The utility, the Basin Water Board	●					●		●								
	Ministries of water and health						●		●								●
	Municipal water engineers	●			●				●	●			●				●
	Local leaders (*Mtaa)*	●							●	●			●		●	●	●
Consumers	Households	●							●	●			●		●	●	●
	Businesses								●	●							●

without automatic switch pump technology hired workers to manually coordinate water pumping into storage tanks for distribution. The provision of these water infrastructures occurred through civic cooperation between the utility, local government authorities, and NGOs.

Technicians and pump engineers acted as mediators between the utility and non-state water actors, extending water systems and providing technical support. Plumbers assisted in drilling wells, connecting PVC pipes, installing water pumps, and monitoring household water systems. Sole distributors of water included (un)registered private water tanker drivers, so-called 'water boosers', pushcart operators, and tricycles/bicycle/motorbike operators. Some tanker truck drivers were found to engage in formal partnerships with the utility (DAWASA). These actors collected and delivered water from the utility. Except for the utility tankers, most water distributors configured and distributed water via self-regulated leadership, without formal unions or registration. As one tanker driver said, "Everywhere there is a leader, without the leader, you know we are all mature; the leader manages our affairs, but he is not here now" [FGD tanker drivers, 02/03/2021]. Local norms structured interactions among non-state actors, especially tanker drivers engaged in water distribution. Unregistered tanker trucks collected water from private bore wells/holes for onward distribution.

However, the relationships between the utility and non-state water providers were typically defined by cordial interdependence and (in)formal collaboration. As the utility advisor said:

> I think there is a positive interaction, there is a supportive environment for non-state actors, and the utility is not fighting them. To me, I don't see DAWASA [utility] fighting them, because the utility knows that if non-state actors are not there, they are in problems [KII, 03/2022].

DAWASA (the utility), the Ministry of Water, and local government authorities (LGAs) exercised legal mandates as water providers and regulators. Some drilling companies allied with and collaborated with the Ministry of Water to facilitate the drilling of bore wells, often via contractual agreements. They indirectly monitored the extraction of groundwater by testing and analysing samples of drilled groundwater to certify its quality for domestic use. These actors (in)directly structured the production and distribution of water outside the utility. As Grönwall (2016) observed, non-state actors were the "governors" who engaged in routine monitoring of the production and distribution of water through which the "governees" collected water. A private networked provider said, "I usually walk around the pipelines to check leakages. The first sign of detecting leakages is the source, and the subsequent indicators are the patches of leakages" (KII, private networked provider, 07/03/2022). This demonstrates the hydro-socio-technological interactions that mediate water distribution (Keough and Saidou, 2021). The next section demonstrates the various powers and mechanisms that mediate water supply.

Powers and the regulatory mechanisms governing water supply beyond the utility network

In Dar es Salaam, multiple actors (in)directly regulated the drilling of mechanised boreholes, water kiosks, water tanker drivers, and pushcarts. These comprised the Ministry of Health (MoH), the Ministry of Water (MoW), the Energy and Water Utility Regulatory Authority (EWURA), DAWASA, Mtaa, the Basin Water Board (BWB), and waterworks units at the municipal councils. The MoH and MoW played leading roles in the provision of policy guidelines to EWURA. The interviews showed that EWURA held direct 'reinforcive' power to (dis)empower utilities in terms of licensing and tariffing. EWURA has the mandate to review and monitor the performance of utilities towards safe water and electricity service delivery. In reality, in the aspect of water, EWURA regulated formal service providers, particularly DAWASA. DAWASA has the legal mandate to regulate mechanised boreholes, tanker truck operators, and other non-state actors in its service areas. It exercises the power to monitor and ensure compliance of non-state actors with regulatory mechanisms such as the registration, permitting, and licenses for water supply. One utility official said:

> There are procedures, you see. You need to have, first of all, a drilling permit from the Basin Water Board, for any borehole, that is the procedure. Of course, the control is a challenge because of so many people. Sometimes some might not follow, but the procedure is there… (Utility official, 02/03/2021).

Overall, the utility exercised the power to mobilise material, financial, and human resources and to determine the inclusion and exclusion of non-state actors engaged in water distribution. Despite these regulatory mechanisms, water supplied by non-network water providers was less monitored and coordinated by the utility/DAWASA. In the case of Magogoni (Kigamboni), inspections and confirmation by the Mtaa paved the way for residents to engage in groundwater extraction for self-supply.

Although the utility has the power to cease, own, and/or manage the operational assets of non-state actors upon network extension in areas served by non-state actors, the utility has been vulnerable. This is due to its inability to attain even coverage of networked extension. Even in peri-urban areas with utility networks, such as Goba, the utility's policy of 50 meters distance extension from transmission pipes restricted its efforts to attain wider coverage. In light of its incapacity, the utility recognised non-state water suppliers as informal collaborators, temporal alternatives, and enablers. Consequently, non-state actors engaged, interacted with, configured, and structured water supply to their advantage in the purview of filling service gaps. This further suggests that the utility is not only vulnerable to changing ecological conditions (Rugemalila and Gibbs, 2015), but also to its institutional inabilities. The utility lacked the ability to identify and monitor the activities of non-state actors and enforce regulations for compliance (Grönwall, 2016). As an expert explained:

> Compliance requires enforcement; compliance does not come automatically (…), and if you talk of enforcement, you are now referring to the capacity of DAWASA. The capacity of DAWASA is very limited, if it exists at all, because it has not been able to meet even the service requirement in terms of network extension a capacity in terms of tools, instruments, and staff to ensure compliance.

Despite limited enforcement, non-network water suppliers were allowed to register during the utility's monitoring; See Figure 6.

Figure 6. Registered tankers stationed waiting for calls from clients (left)) or collecting water before delivery (right).

Monitoring was conducted sporadically during outbreaks of waterborne disease (Sultana, 2013; Cain and Baptista, 2020). Licensing and monitoring selectively targeted privately networked water providers who extracted groundwater and extended connections to neighbourhoods. Beyond conformity to legal regulations, ownership of permits and licenses for water supply represented a kind of power to non-state water actors, especially tanker water distributors. Firstly, it signified the power of legality and inclusion

through which registered tankers collected water from the utility and served residents bypassed by the utility. Secondly, regulatory power and partnerships enabled the utility to differentiate, regulate, and collect fees from registered private tankers. Through formal registration, tanker drivers were able to organise a protest and resisted the utility's decision to close water kiosks in the past. Tankers with formal partnerships and collaborative arrangements were restricted from using registered vehicles for the collection of wastewater, stones, and sand.

Despite the formal partnership, quality water distribution was sometimes compromised. Some registered tankers collected groundwater instead of utility water kiosk water. This happened during water scarcity when demand for water was high due to the inconsistent flow from the utility. Beyond the utility-defined rules and regulations, informal norms mediated the collection of water by tankers at the various utility kiosks. Tanker truck drivers queued at the water kiosks to collect water only when they got requests from clients to deliver water. Whilst regulatory mechanisms represented mediating powers, their enforcement was hampered by fragmented regulatory actors with overlapping, conflicting roles and responsibilities. Whereas the BWB held the power to provide permits for the drilling of bore wells, registered actors interviewed obtained permits from the Ministry of Water. This contradicted the formal instituted arrangement, challenged the enforcement of regulations, and served as an impetus through which water was supplied beyond the utility. It suggests that the roles of state agencies, such as the MoW, produced, empowered, and facilitated the proliferation of non-state actors that engaged in water supply beyond the utility network. This showed how state regulatory structures created loopholes for non-state actors to exercise agency. State agencies were indirectly connected to the evolution of non-utility service providers. The MoW enabled non-state actors by verifying and certifying the quality of groundwater extracted by private mechanised household water providers. Private water drilling companies allied to the MoW facilitated the drilling, collection, testing, and analysis of groundwater samples for self-supply.

CONCLUSION AND IMPLICATIONS FOR IMPROVING URBAN WATER SUPPLY BEYOND THE UTILITY

Previous studies typified cities in the Global South as peculiar geographies where infrastructural heterogeneity prevails (Jaglin, 2014; Lawhon et al., 2018). Categorising these infrastructures, actors, and their interactions can enhance understandings of heterogeneous infrastructures. However, it is still challenging to develop a complete framework for studying the governance of these infrastructures. Inspired by Heterogeneous Infrastructure Configuration (HIC) debates, this study builds on literature on urban water infrastructure, everyday practices, and governance to propose a comprehensive framework of governance modalities, actors' interactions, and regulatory mechanisms surrounding heterogeneous infrastructures. By situating the framework in Dar es Salaam's diverse infrastructure landscape, this study adds to discussions on urban water infrastructure governance. The study shows that multiple categories of non-networked infrastructure co-exist, supplying water to residents in Dar es Salaam. These comprised privately networked water, self-supply water infrastructure, communal/shared water infrastructure, and hydro-mobile infrastructure. Water pump machines, vehicles, generators, pipes, and equipment were material technologies that enabled the storage and distribution of water. The interconnected and interdependent nature of these infrastructures fostered the configuration and delivery of water to meet place-specific conditions. Water production and distribution were mediated by diverse governance modalities, including informal and formal co-production, self-governance, co-governance, market-oriented governance, and networked governance. (In)formal co-production and self-governance arrangements were dominant governance modes facilitating water supply beyond the utility network in Dar es Salaam. These worked to challenge and expose the vulnerability of the hierarchical water supply approach of the utility as they supplied water to most areas beyond the pressures of the utility pipes.

Except for formal tanker truck drivers registered with the utility, regulatory agencies did not regulate informal actors like pushcart/tricycle/motorbike/bicycle water vendors and distributors, protected wells,

private tankers, water kiosks, private water taps, mosque/church water vendors, self-supply households, and resellers of utility water due to their informal ways of producing and distributing water to urbanites. The utility's inability to achieve coverage of networked water and regulate non-state actors challenged its power to in/exclude actors in the waterscape. If formally monitored and regulated, non-utility water actors could be valuable assets for improving urban water supply, given the vulnerability of the utility.

In conclusion, the study contributes to urban water infrastructure configuration, infrastructure heterogeneity, everyday practices, and governance debates by revealing that multiple governance modalities, such as co-production, self-governance, market-oriented governance, co-governance, and networked governance, shape how water is produced and distributed beyond the utility network in cities of the Global South. Moreover, (in)formal co-production and self-governance arrangements represent the dominant modes facilitating the production and distribution of water. Diverse actors, powers, conflicting responsibilities, and (in)formal regulatory mechanisms are embodied in these modalities. The multiplicity of governance modalities shapes the modes of interactions and powers of the various actors through which they (re)produce varied arrangements for water distribution across infrastructural categories. These arrangements and the infrastructure serve as the medium through which hydro-social and technological relations are built and deepened. They are equally influenced by (in)informal norms/mechanisms, and power relations. These have consequences for (un)even water distribution among urbanites and across urban spaces. The study recommends that future research pay attention to how residents navigate and manage trade-offs within heterogeneous infrastructures to collect water.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the German Academic Exchange Service (DAAD) for this research. The lead author received financial support from DAAD for his PhD research.

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