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The politics of tied aid: Technology transfer and the maintenance and repair of water infrastructure

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ABSTRACT

In many African countries, international donor funding schemes contribute significantly to financing water infrastructures, especially for constructing new networks and water plants and upgrading existing ones. However, little is known about how these financial arrangements shape infrastructure maintenance and repair. This article explores the politics of tied water aid to show how international donors' technology transfer schemes and their associated funding conditionalities shape water infrastructure maintenance and repair. Empirically, this study builds on a qualitative study of the cities of Accra (Ghana) and Dar es Salaam (Tanzania), where the maintenance and repair of water infrastructures have been a persistent challenge. The article shows that the compulsory adoption of foreign technologies embedded in donors' funding schemes limits local capacity to properly maintain and repair water infrastructure. As maintenance and repair increasingly depend on imported expert knowledge, spare parts, and engineering services, donors' funding schemes undermine effective maintenance and repair in both cities. We argue that to make transferred water technologies work sustainably in recipient countries, funding schemes need to anticipate maintenance and repair by incorporating local capacity building and knowledge transfer to reduce import dependence.

1. Introduction

International donors play a crucial role in urban water supply in Africa, and Ghana and Tanzania provide helpful examples to illustrate their importance. In these countries, donor funding schemes significantly contribute to financing urban water supply. For example, external loans and donor grants contributed over 80 % of the funding needed to execute Tanzania's National Water Sector Development Program (WSDP-II) between 2015 and 2020 (URT, 2020). Similarly, they contributed about 90 % of Ghana's water sector budgets between 2013 and 2014 (Monney and Antwi-Agyei, 2018: 134). These funds were primarily invested in upgrading existing systems' capacity and developing transmission networks in Dar es Salaam (URT, 2020), while in Ghana, they have also financed the extension of distribution networks (Mansour and Esseku, 2017; Effah Ameyaw and Chan, 2013) and the construction of a seawater desalination plant (Jambadu et al., 2022). These investments have undoubtedly improved these countries' urban water infrastructures and the residents' access to critical water resources.

Although the impact of donors and their funding schemes on infrastructure development has gained considerable attention in development studies (Mattlin and Nojonen, 2015; El Khanji, 2022; Quadir, 2013), we still know little about how such financial arrangements shape infrastructure maintenance and repair and their underpinning political logics and effects in African cities. Understanding this relationship is crucial because research on urban infrastructures in Africa and other parts of the Global South has identified inadequate maintenance and repair as a critical challenge facing externally funded infrastructure projects (Alves, 2022; Harvey and Reeds, 2004; El Khanji, 2022; Holcombe et al., 2018).

Recently, urban scholars have critically examined urban water infrastructure maintenance and repair in African cities and have emphasized the incremental and improvisational practices through which users, engineers, and plumbers tinker with, contest, and shape water networks (Alda-Vidal et al., 2018; Jambadu et al., 2022; Wahby, 2021). They have also highlighted how these actors' practices (re)shape

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power relations between the state and non-state actors (Barnes, 2017; Wahby, 2021; Alves, 2022; Jambadu et al., 2023). However, to date, no study has examined how donor funding coupled with technology transfer schemes affects infrastructure maintenance and repair and their underpinning political effects in recipient countries in Africa.

This article uses qualitative research to analyze how donors' tied water aid schemes affect infrastructure maintenance and repair in Accra and Dar es Salaam. The objective is to provide a detailed account of how donor-tied water aid schemes affect the maintenance and repair of infrastructure in both cities. These cities were selected because of their dependence on donors' funding schemes in reforming their water sectors. Thus, they represent meaningful empirical examples to illustrate how these funding programs affect water infrastructure maintenance and repair in Africa. We systematically address two critical questions: (1) How does technology transfer embedded in donors' funding schemes affect water infrastructure maintenance and repair in Accra and Dar es Salaam? (2) What political implications and power relations do donor-funded technologies enact in water supply, and how do they affect water supply in recipient countries? Although donor funding schemes improve water supply, we argue that the contractual obligation to use highly complex and costly technologies and buy spare parts from donor countries makes maintaining and repairing water infrastructure strongly dependent on imports. While this reliance provides a market opportunity for donor countries to export their technologies and engineering services, it negatively affects the local capacity of recipient water companies to maintain and repair water infrastructure.

To explore this dynamic, we draw on the politics of tied aid and the politics of technology transfer to show how donors' tied water aid schemes affect maintenance and repair in Accra and Dar es Salaam through the interplay of their institutional conditionalities, technology, and knowledge transfer. We argue that technology transfer provides a helpful conceptual lens for grasping the complex power relations within infrastructures (Lu and Qiu, 2022; Casadella and Liu, 2019; Chen and Landry, 2018) and we illustrate how specific political ideas become embedded in technological artifacts (Pilo', 2021). We further argue that technology transfer is not solely about implanting new technical artifacts; for transferred technologies to work sustainably in recipient countries it is necessary to build the local knowledge and skills needed to maintain and repair transferred technologies. However, Science and Technology Studies (STS) research has shown that technology transfer is a highly complex and political process; even though technologies travel, they need to be adapted to connect with the contexts of their new settings (Behrends et al., 2014), whereas some knowledge does not travel but needs to be developed locally (Monstadt and Schramm, 2017).

This paper makes two specific contributions: First, it expands our understanding of water infrastructure maintenance and repair in the Global South beyond local actors (see e.g., Jambadu et al., 2022; Wahby, 2021; Barnes, 2017) by explaining the crucial role of donors' funding schemes in the performance of these operations. Analyzing donors' roles helps illustrate the multi-dimensionality and multi-scalarity of maintenance and repair operations. Second, we introduce a new conceptual framework (Fig. 1) to understand better the complex relations between donors' technology transfer and the political economics of water infrastructure maintenance and repair. This helps to reveal the ambivalent effects of donors' technology transfer schemes and how technological systems shape power relations and the (re)distribution of financial aid resources.

The remainder of the paper is structured as follows: Section two reviews the debates on development aid, technology transfer, and their relations to maintenance and repair. Section three describes the research methodology. Section four first provides an overview of donor funding schemes in Ghana and Tanzania's water sectors. Based on case studies on Accra and Dar es Salaam, we further explore the politics of tied water aid and how it affects maintenance and repair practices by assessing their institutional conditionalities and technology and knowledge transfer schemes. Section five concludes by calling for stakeholders to anticipate maintenance and repair in donor funding schemes and urban water policies in order to reduce the effect of import dependence and enhance infrastructure sustainability in Africa.

2. Literature review

This section first introduces the debates on development aid and technology transfers and then discusses technology transfer in terms of its politics and its effect on maintenance and repair.

2.1. Development aid and technology transfer

Development aid generally refers to financial or technical assistance given to low-income countries to improve the living conditions of people (Apodaca, 2017). It entails bilateral and multilateral assistance schemes (Kim and Kim, 2016; Douch et al., 2022). The traditional donor countries include many European countries, the USA, Canada, Japan, and Australia, while China and India are often described as emerging donor countries (Mattlin and Nojonen, 2015; Chung et al., 2016; Chen and Landry, 2018). Donor aid can be tied or untied. It is called tied aid if the recipient country is required to fulfill specific conditionalities, but it is untied aid if no conditionalities are attached (Koeberle, 2005). Conditionalities refer to the actions and requirements the recipient country must satisfy to be eligible for donor aid, or the set of principles and rules that guide the application of aid funds (Douch et al., 2022; Koeberle, 2005). Aid conditionalities vary substantially across different donor countries. For example, the USA and China often tie bilateral aid to the procurement of goods and services from companies and contractors in their home countries (Morgenstern and Brown, 2022; Mattlin and Nojonen, 2015; Monson, 2009), while other countries often stipulate anti-corruption policies, adherence to democratic or 'good governance' principles, free trade and liberalization policies, and private sector participation (Koeberle, 2005; World Bank, 2007; Douch, et al., 2022). Depending on how policymakers in donor countries formulate these conditionalities, some scholars have argued that donors' conditionalities are a set of strategic tools to pursue and protect donor countries' foreign policy objectives in recipient countries (Apodaca, 2017; Douch et al., 2022; Dalgaard and Hansen, 2001).

Although the Paris Declaration on aid effectiveness of 2005 resulted in the share of untied aid from traditional donor countries increasing from 78 % in 2005 to 84 % in 2009 (Chung et al., 2016), recent studies show that in 2018 alone, the USA spent about 40 % of its bilateral aid on procuring goods and services from USA-based companies and contractors (Morgenstern and Brown, 2022). In the case of China, an explicit conditionality is for recipient countries to recognize China's political sovereignty over Taiwan (Mattlin and Nojonen, 2015; Oakes, 2021), but in addition, the Export–Import Bank of China (China Exim Bank) usually requires recipient countries to engage Chinese contractors and workers and to buy technologies made in China (Mattlin and Nojonen, 2015; Oakes, 2021; Tan-Mullins et al., 2010; Yang, 2022). According to some studies, these tied aid procurement practices can increase the cost of aid for recipient countries by 10–40 %, as they deny them the opportunity to explore other sources that could offer the same services or products more cheaply (Chung et al., 2016; Kim and Kim, 2016; Morgenstern and Brown, 2022).

Aside from direct monetary assistance, donor aid frequently transfers technologies from a donor to a recipient country, and the recipient countries tend to be in the Global South (Lu and Qiu, 2022; Li, 2016). Technology transfer is often seen as the precondition for rapid development, societal transformation, and modernity in the Global South (Lu and Qiu, 2022; Pandey et al., 2022; Watson, 2014). However, STS studies have shown that technology transfer is far more complex because it is not simply about 'implanting' new technologies in settings. Instead, it involves 'de-territorializing' technologies from their current settings and 're-territorializing' them in new contexts with distinct ontological and epistemological backgrounds, practices, knowledge, and

institutional arrangements (Monstadt and Schramm, 2017; Behrends et al., 2014). This process of de/re-territorializing is highly political and place-based and thus has implications for the maintenance and repair practices in recipient contexts.

2.2. The politics of technology transfer and maintenance and repair

Technology transfer is an important aspect of international development aid and is vital for economic development and industrial transformation in the Global South (Casadella and Liu, 2019; Giorcelli and Li, 2021). For instance, it has been argued that donor technology transfer enables less resourceful countries to access advanced technologies that they otherwise may not be able to afford, and that access to new technologies and innovations can fast-track economic development and industrial transformation and create new jobs in recipient countries (Giorcelli and Li, 2021; Li, 2016; Lu and Qiu, 2022).

Despite these merits, technology transfer is a highly complex political process, as it is driven and shaped by diverse interests and power relations (Pilo', 2021; Casadella and Liu, 2019; Watson, 2014; Li, 2016). Some scholars argue that current technology transfer practices bring about uneven power relations and create opportunistic relations between powerful donor countries and less resourceful recipient nations in the Global South (Casadella and Liu, 2019; Li, 2016). In the African context, postcolonial scholars contend that technology transfer reinforces colonial relationships by enabling imperial nations to maintain their presence in former African colonies and exert political influence over these countries' development (Li, 2016; Watson, 2014; Monson, 2009). Other scholars argue that donors' technology transfer conditionalities implicitly tie recipient countries' economic development to imported technologies, imported labor, and imported spare parts, which benefits the economies of donors' home countries (El Khanji, 2022; Pandey, de Coninck, & Sagar, 2022; Quadir, 2013). This import dependence ends up suppressing local industrial growth in recipient countries because local firms cannot compete with imported goods, but it contributes to donor countries' industrial growth.

Beyond these explicit political considerations, STS studies have shown that technology transfer is far more complex than generally assumed and that even without these political rationalities attached to aid, it is still a highly political process because of the simplistic and diffusionist logics underlying aid and technology transfer. As many STS studies have shown (Monstadt and Schramm, 2017; Behrends et al., 2014; Lu and Qiu, 2014; Pandey et al., 2022), technologies are not simply 'implanted' into new settings but instead need to be adapted to connect with preexisting materialities, knowledge, and institutional arrangements (Lu and Qiu, 2022; Monstadt and Schramm, 2017; Behrends et al., 2014). Therefore, technology transfer is not a 'copy and paste' process but requires 'place-based' adaptation, which is highly political and shaped by local contexts and circumstances. For the new technologies to work in their new settings, they require specific "techniques of how to deal with a standardized model in place-based contexts" (Behrends et al., 2014:2). These techniques consist of embodied knowledge that does not travel with the technological artifacts but needs to be reinvented in recipient contexts through improvised and experimental practices (Monstadt and Schramm, 2017:5). Another complex dimension of knowledge transfer relates to intellectual property rights that shape access to specific knowledge and also knowledge circulation and use (Lu and Qiu, 2022). The specific knowledge required to ensure specific technologies function is not universal, as it is usually owned by individual firms and manufacturers who control its distribution and use in society (Lu and Qiu, 2022). Hence, powerful manufacturers can use this monopoly power to their advantage but at the expense of maintenance and repair in recipient countries. In sum, knowledge cannot simply be transferred from one setting to another but needs to be developed from their situated contexts.

The complex political dimensions of technology and knowledge transfers affect maintenance, repair, and their role in shaping infrastructures in the Global South. Over the last decade, STS literature has increasingly focused on the maintenance and repair of urban infrastructure processes in the Global South (Graham and Thrift, 2007; Anand, 2017; Barnes, 2017; Baptista, 2019; Wahby, 2021; Ramakrishnan et al., 2021). In these publications, scholars have almost exclusively focused on the everyday practices of local actors (such as engineers, plumbers, and water users) and how they shape and, in turn, are shaped by urban infrastructure-making processes in cities. At the same time, Jambadu et al. (2022), Graham and Thrift (2007), and De Coss-Corzo (2020) have pointed to the crucial importance of maintenance and repair in shaping the operation of urban infrastructures, with De Coss-Corzo (2020) and Baptista (2019) also highlighting how maintenance and repair build and shape local knowledge and innovation through learning by doing, improvisation, and ad-hoc tinkering practices. All these authors have also shown how actors routinely mobilize these local adaptive practices to adapt and shape foreign technologies to work in certain ways that are often beyond how their original designers anticipated. De Coss-Corzo (2020) has argued, however, that such adaptive practices often do not follow any standardized guiding rule but can be considered to be "patchworks" that depend on what works and what does not work in each repair case. This means every repair work is unique and relies upon the repair workers' embodied expertise and experience (Björkman, 2018; Graham & Thrift, 2007; Ramakrishnan, O'Reilly, & Budds, 2021). While some scholars see these local adaptive and improvised practices as manifesting local agency (Graham and Thrift, 2007; De Coss-Corzo, 2020; Baptista, 2019), we frame them as the results of failures to align and situate foreign technologies to connect with local contexts and capacities. Despite the rich scholarly debates on urban infrastructure maintenance and repair and donors' technology transfer in the Global South, it is still poorly understood how donors' funding schemes conditioned on technology transfer affect maintenance and repair in recipient countries.

In this study, we draw on the literature on politics of tied aid and politics of technology transfers to explain how donor-tied water aid schemes affect maintenance and repair practices in Accra and Dar es Salaam, using the lenses of institutional conditionalities, transferred technologies, and local knowledge-building. We argue that the politics of tied water aid influence these three variables, which, in turn, influence maintenance and repair practices in Accra and Dar es Salaam (Fig. 1).

We define institutional conditionalities as the rules and policy requirements defining the procurement rules and how water aid funds

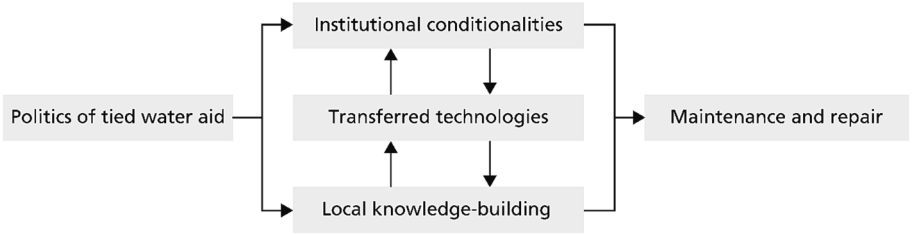

Fig. 1. Tied water aid and its effects on maintenance and repair.

should be used. These variables affect maintenance and repair because they influence the technology choices and their underlying technical and regulatory standards relating to the quality of infrastructure. Transferred technologies here refer to specific material artifacts being transferred to recipient countries through water aid. They include water plants, equipment, pipelines, and their associated spare parts. This aspect of technology transfer is vital in shaping maintenance and repair because they define the system's complexities, cost, technical properties, the knowledge required, and ease of accessing necessary spare parts. The "local knowledge-building" dimension pertains to the knowledge required to maintain and repair specific technologies: such knowledge is often imported and added to the local knowledge base and may also be adapted and enriched with existing local knowledge in order for the maintenance and repair to be effective. We argue that in both cities, the politics of tied water aid shape maintenance and repair through the interaction between these three dimensions.

3. Research methodology

This article is based on qualitative research conducted in Accra and Dare es Salaam on the effect of donors' funding schemes on water infrastructure maintenance and repair. Using the analytical lenses of institutional conditionalities, transferred technology, and local knowledge-building in the two cities, we applied an illustrative case study approach (see Epler, 2019) to explain how politics of tied water aid affect the cities' infrastructure maintenance and repair. The illustrative case study is especially useful because it allows us to explain in detail "what is happening and why it is happening" in the two cities (Hayes et al., 2015:8).

Recently, Cawood et al. (2022) used this approach to explain how water access, maintenance, and repair are organized across different cities in the Global South. Our illustrative case study allows us to mobilize concrete examples from both cases to vividly describe the role of donors and how their tied water aid schemes affect maintenance and repair in two different African cities with distinct political, socioeconomic, and institutional arrangements in water supply. To this end, we aim not to systematically compare the two cities but to provide an in-depth account of the effects of donors' tied water aid on maintenance and repair, using concrete examples from the two cities. However, we also highlight a few differences, similarities, and patterns that emerge from our analysis of the institutional conditionalities, transferred technologies, and knowledge transfer across the two cities. A detailed analysis of donors' role in water supply is especially relevant because African countries rely heavily on donor aid (Monney and Antwi-Agyei, 2018; Pigeon, 2012), and the two cases provide a broader insight into the impacts of donor aid on maintenance and repair in Africa. It also enables us to understand how differentiated donor conditionalities, transferred technologies, and knowledge transfer might shape maintenance and repair practices differently in African countries.

3.1. Rationale for the selection of the case studies

The case cities of Accra and Dar es Salaam were selected because they share many development challenges, yet each of them represents a unique context. Despite their difference in population size (the population of Dar es Salaam is more than double that of Accra), their political structures and institutional arrangements in water supply are similar, which can attract similar donor countries. Secondly, both cities have undergone World Bank structural reforms in their urban water sectors, which has paved the way for introducing neoliberal ideals in their respective water sectors (Pigeon, 2012; Effah Ameyaw and Chan, 2013; Kjellén, 2006). Third, while both cities still depend strongly on donor funding schemes for financing water infrastructure (Monney and Antwi-Agyei, 2018; URT, 2020), water challenges persist as residents rely on private providers for water supply (Bartels et al., 2018; Dakyaga et al., 2022; Jambadu et al., 2022). All these characteristics make both cities suitable to study in order to learn about the effects of tied water aid on maintenance and repair and their implications for water supply in Africa.

3.2. Data collection and analysis

The empirical data for this study was gathered between 2018 and 2021. We paid two fieldwork visits to each city and used three methods to gather data from various respondents and sources. First, we analyzed official water policy documents, reports, laws, and water supply regulations, and examined various academic literature relating to Accra and Dar es Salaam in order to obtain a broad understanding of the policy and institutional contexts of water supply and donor funding schemes across the two cities. Second, we conducted semi-structured interviews focusing on how donor funding schemes operate in the water sectors of the two countries. Two different interview guides were used, depending on the interviewees. When interviewing government officials, international donors/development partners, NGOs, and local research institutions, we explored issues related to urban water supply, infrastructure financing, key actors and their responsibilities, specific donor funding schemes, institutional conditionalities, and the technologies donors fund in the two cities. When interviewing GWCL (Ghana Water Company Limited) and DAWASA (Dar es Salaam Water and Sewerage Authority) officials (administrators and managers), we focused on the maintenance and repair of water infrastructure, exploring the specific maintenance and repair challenges, their financing, and local experts' knowledge and capacity. In total, 46 interviews were conducted across the two cities. Analysis of these interviews clarified our understanding of broader policy issues relating to water supply, infrastructure maintenance and repair, and their relations with donors' funding schemes in the two cities.

The third method entailed making observations in the field and holding informal conversations with various utility engineers, technicians, and repairers across the two cities. We visited field locations to observe repair workers operating maintenance and repair in real-life contexts (Yin, 2009). We visited various water plants and observed how GWCL and DAWASA official engineers and technicians maintained and repaired equipment and water networks in both cities. These observations yielded critical empirical data on the everyday practices of maintenance and repair, the challenges involved, and the innovative practices repair workers use to solve repair and maintenance needs in water networks.

The first author conducted 41 of the field interviews in person; the remaining five were conducted online due to COVID-19 restrictions. Ethical approval for the study was obtained from our University's ethics board, and we also implemented all the University's standard protocols and guidelines for responsible conduct of research.[1]

The empirical data was analyzed through thematic analysis strategies, which included coding the data according to four major themes: the donors' funding schemes, their institutional conditionalities, transferred technologies, and transferred knowledge. We have used examples from both cases to illustrate how these dimensions affect maintenance and repair in the two cities.

4. Results

Below, we first present an overview of the urban water sectors of Ghana and Tanzania, before going on to demonstrate how the politics of tied water aid in the two cities affect maintenance and repair through

[1] Before commencing this study, we obtained formal approval from both water companies and also obtained informed consent from all research participants before they were interviewed. Personal data on the research participants was also anonymized in the interviews and analyses to ensure confidentiality.

conditionalities, transferred technologies, and transferred knowledge.

4.1. Donor funding schemes in Ghana and Tanzania's water sectors

Accra is the largest city in Ghana and the country's national capital and has a population of approximately 2.5 million (Ghana Statistical Services[GSS], 2021). It is the headquarters of all the country's political administrations and governance institutions and hosts the country's most crucial trade infrastructure, such as Tema harbor. Similarly, Dar es Salaam is Tanzania's largest and most important city. Its estimated population was 5.4 million in 2020, and it is the fastest-growing city in East Africa (Dakyaga et al., 2022). Although Dar es Salaam is not the capital city, it has remained the commercial hub and headquarters of Tanzania's most important political institutions and commercial infrastructure (United Republic of Tanzania [URT], 2021).

In both cities, the stakeholders critical for urban water supply are the central governments (including the water ministry[2]), various state regulatory agencies and municipalities, civil society organizations, water providers, users, and various international donors. These actors play specific roles and responsibilities stipulated in the water legislation and national water policies. For example, the central government in both countries is ultimately responsible for urban water provision and infrastructure financing (Monney and Antwi-Agyei, 2018; Effah Ameyaw and Chan, 2013; URT, 2020), while the Ministry of Water is responsible for developing water policies, regulations, and legal frameworks for the water sectors (URT, 2019; Fuest et al., 2005), and the urban water supply companies are responsible for infrastructure maintenance and repair (Kjellén, 2006; Bartels et al., 2018).

The water sectors of both countries are governed through slightly different institutional arrangements. In Ghana, the Statutory Corporations (Conversion to Companies) Act 461 (1993) established the GWCL as a state-owned limited liability company and redefined its mandate as the sole urban water supply provider in Ghana (GWCL, 2017). Act 522 (1996) established the Water Resources Commission to regulate water resource use in Ghana (Fuest et al., 2005), while Act 538 (1997) established the Public Utilities Regulation Commission (PURC) to regulate urban water tariffs and service quality (Fuest et al., 2005; Jambadu et al., 2023). Ghana's national water aspirations are articulated in the national water policy developed in 2007 and which recognized basic water access as a fundamental human right for every citizen (Ministry of Water Resources, Works, and Housing [MWRWH], 2007).

An integrated legal and regulatory framework governs Tanzania's water sector. The Water Resources Management Act (No. 11) of 2009 regulates water resource use and gives residents the right to drill private boreholes for domestic purposes (URT, 2009; Dakyaga et al., 2022). The Water Supply and Sanitation Act (WSSA 5) (2019) established the DAWASA and mandated it to supply water and sanitation services in Dar es Salaam (URT, 2019). The act also reaffirms the regulatory authority and responsibilities of the Energy and Water Utilities Regulatory Authority (EWURA) concerning tariffs and the issuance of operating permits to various regional water authorities (URT, 2019). Tanzania's first national water policy was developed in 2002 (URT, 2002). The WSSA regards basic access to safe drinking water as a fundamental human right (URT, 2019: 12).

Although they do not have explicit responsibilities in water supply in either country, international donors play a critical role in financing water infrastructure. For instance, in Ghana, donors contributed about GHS 174 million (about USD 14 million) out of the GHS 260 million (about USD 130 million) budget for the Ministry of Water and Sanitation Resources in 2019 alone (Ministry of Sanitation and Water Resources [MSWR], 2020). This figure translates to approximately 67 % of the ministry's budget. Similarly, about 57 % of Tanzania's water sector budget in 2019 came from donors, who also funded up to 84 % of the entire budget for WSDP-II (URT, 2020:103). Key donors for water supply in Ghana include the World Bank, China, the USA, and Canada (Ghana Ministry of Finance, 2020), while in Dar es Salaam they include India, the World Bank, and the African Development Bank (URT, 2020:104). Table 1 presents some major water projects funded by donors in Accra and Dar es Salaam.

Table 1
Selected infrastructure projects funded by donors in Accra and Dar es Salaam.

City	*Description of project*	*Amount (USD)/m*	*Donors /Funders*
Accra	Construction of a new seawater desalination plant at Teshie-Nungua	126	World Bank/ Standard Charted Bank of South Africa
	Extension of distribution and sewer networks in Greater Accra Metropolitan Area	150	World Bank
	Upgrading of Kpong Water plant	273	China Exim Bank
	Upgrading of Weija Water plant	22	World Bank/IMF/ Dutch government
Dar es Salaam	Upgrading of Upper Ruvu plant	178	India Exim Bank
	Upgrading of Lower Ruvu water plant	46	Millennium Challenge Corporation
	Construction of a new 56.7 km long transmission network from Lower Ruvu River to Dar es Salaam township	59	Government loan from World Bank
	Water resource management, operational efficiency, and sanitation infrastructure	230	World Bank

Source: authors, based on policy documents and literature.

Table 1 shows that donors' loans and grants mainly supported the construction of large-scale water infrastructure such as new water plants, the upgrading of existing systems, and desalination systems and transmission networks. These large-scale infrastructure projects have undoubtedly improved water supply in both cities, although they presented different challenges in water maintenance and repair.

4.2. Unpacking the politics of tied water aid and its effect on maintenance and repair

Below we examine the politics of tied water aid through the lenses of institutional conditionalities, transferred technologies, and local knowledge-building to reveal how these politics affect maintenance and repair in the two cities.

4.2.1. Institutional conditionalities

Conditionalities are an essential dimension of tied water aid in both cities. Our research revealed that donors funding conditionalities vary slightly across the two cities. A typical conditionality in Accra and Dar es Salaam relates to hiring foreign contractors for donor-funded infrastructure projects. In Accra, this concerns the upgrading of the Kpong water plant, while in Dar es Salaam it applies to rehabilitating the Upper Ruvu water plant. However, China's Exim Bank funded the Kpong project in Accra (PUWU, 2019), while India's Exim Bank funded the Upper Ruvu plant in Dar es Salaam (Interviews 1, 2, 3, & 4, 2018/2021). Yet both projects were tied to foreign contractors from the donor countries.

The USD 273 million Kpong water project was awarded to China Gezhouba Group Corporation (CGGC) (Interviews 3, 4, & 5, 2018), while the USD 178 million Upper Ruvu plant was given to India's construction giant, WABAG group (Kiganda, 2016). Both were turn-key projects, meaning the same contractors handled the design, construction, and equipment installation (Interviews 2, 5, 6, & 7, 2018/2019). The foreign contractors also used foreign technologies and engineers to

[2] The Ministry of Sanitation and Water Resources in Accra and the Ministry of Water and Irrigation in Dar es Salaam.

design and build both water systems, while the GWCL and DAWASA engineers conducted monitoring and periodic checks to ensure compliance with agreed quality and technical standards (Interviews 2, 7, 8, 9 & 10, 2018/2019).

These findings show that local experts were not directly involved in the construction and installation of equipment because turn-key projects give the contractors full responsibility to design, construct, and install technical equipment in line with agreed international standards specified by donors. This bound the contractors to use foreign technologies and experts to ensure the quality and standards that they had agreed with donors. Using quality materials and complying with quality standards in infrastructure constructions can enhance the systems' durability, prolong their lifespan, and reduce technical breakdowns (Ramakrishnan et al., 2021), which brings the benefits of lower short-term maintenance and repair costs. However, it also limits local agency, especially regarding how local actors can influence technical standards and technologies that were agreed in contractual agreements with donors, even if these are unsuitable for the local context (Pandey et al., 2019). Moreover, implementing foreign standards in local contexts can be seen as an attempt to impose certain technical principles as 'universal standards' across different contexts without considering that they need to be adapted to fit each locale's 'place-based' circumstances and preexisting knowledge, institutions, and materialities (Behrends et al., 2014; Monstadt and Schramm, 2017). The end result will be that donors' home standards and knowledge become the universally accepted standards and are placed above all others in conducting maintenance and repair everywhere.

The second conditionality relates to open and fair completive bidding for donors' infrastructure projects. This conditionality applies to upgrading the Lower Ruvu water plant in Dar es Salaam. The USA funded the USD 46 million water project through its Millennium Challenge Corporation (MCC) (MCC, 2021; URT, 2011). The critical procurement conditionality required the government of Tanzania to implement free and fair bidding for the project, and to engage only competent and qualified contractors (URT, 2011). Degremont and Spencon Services Limited (a French construction company based in Kenya) subsequently won the contract and handled the system's design, construction, and installations (ibid).

While competitive bidding has significant merits in terms of competence, quality, and cost-effectiveness (Interviews 11, 12, 13, 14, 15, 2018/2021), it can also restrict local firms' participation in constructing large-scale infrastructure because they usually have insufficient financial and technical capacity to be able to compete with foreign contractors for such projects and hence, even if the tender process is open, local firms are implicitly left out of the construction projects (Interview 11, 2021). This presupposes that competitive bidding creates an opportunity to enlist foreign firms in local infrastructure projects, in both cities laying the basis for the water system's dependence on imports. In this sense, technology transfer conditionalities implicitly tie water system development in the two cities to imported technologies, imported labor, and imported spare parts (Mattlin and Nojonen, 2015), a situation that increases the cost of maintenance and repair and the long-term sustainability of infrastructure.

The two examples discussed above illustrate different conditionalities informed by different political considerations. The cases of the Kpong and Upper Ruvu water plants demonstrate donor state economic protection policies and the need to promote their domestic industries (Morgenstern and Brown, 2022). That is why China's eight principles for providing loans to other countries prioritize China's public enterprises and contractors in implementing all external infrastructure projects financed by China's public funds (Li, 2016). However, the case of the Lower Ruvu water plant in Dar es Salaam illustrates the need to ensure cost-efficiency, fairness, and transparency in the application of donor funds, all of which are also consistent with the USA's foreign policies relating to the promotion of anti-corruption, transparency, and democratic principles in the application of public funds (Morgenstern and Brown, 2022). However, both conditionalities limit local agency in the construction process and produce highly complex and costly systems, as discussed in the following sections.

4.2.2. *Transferred technology*

Our interviews and analysis of official reports revealed that donors funded slightly different water infrastructures in Accra and Dar es Salaam. For example, in Accra, China Exim Bank funded the Kpong water plant upgrading project, while the World Bank also funded a novel but controversial seawater desalination technology (see Table 1). The USD 126 million reverse osmosis desalination plant was developed by Befessa Aqua of Spain in 2015 and is funded through a private–public partnership (PPP) arrangement (Interviews 14 &16, 2020). The PPP entails a 25-year lease agreement in which Befessa is permitted to design, build, and operate the plant and transfer it to the state-owned utility (GWCL) after the contract expires (PURC, 2018). The desalination plant enables seawater to be converted into drinking water for residents of Accra. The plant can produce about 60,000 m^3/day (Interview 5, 2020). Under the contract agreement, the private operator must sell treated water to the GWCL, which, in turn, sells it to its customers (PURC, 2018).

The contractual agreement means that although the GWCL does not manage the desalination plant, its operation affects GWCL's financial capacity to conduct major structural maintenance and repair of their water infrastructure. For instance, the Public Utilities Workers Union (PUWU) contested the desalination plant in 2019, arguing that a desalination plant was "technically and financially flawed" and that there were cheaper alternative technologies that should have been adopted (PUWU, 2019:1). Many GWCL officials also argued that a desalination plant is expensive to operate and puts a financial burden on the company, making it difficult to finance critical infrastructure maintenance and repair (Interviews 5, 17 & 18, 2018/2020). The consequence is that GWCL cannot raise funds to maintain and repair its water systems due to its debt obligations to private operators (PUWU, 2019). These opinions show that the desalination plant can be considered to be inappropriate technology because it is sophisticated and expensive.

In Dar es Salaam, donors mainly funded the upgrading of technical systems and expansion of existing plant capacity in the Lower and Upper Ruvu water plants and developed additional transmission mains to convey water from the two plants to Dar es Salaam city (URT, 2020; Kiganda, 2016; URT, 2011). Both plants comprise conventional water treatment systems using standard filtration, chlorination, and clarification technologies (Interviews 19 & 21, 2019). The latter two interviews revealed that the rehabilitation projects involve installing additional water pumping mains, disinfection and filtration equipment, and clean water tankers to store the water for onward distribution. This means old pumps and equipment have been replaced with new and modern systems, and other new technologies and equipment have been added to the existing systems. After the upgrading, the Upper Ruvu system's capacity increased to about 200,0000 m^3/day (EWURA, 2018), while according to the interviewees, the Lower Ruvu system went up to 270,000 m^3/day. Several kilometers of new transmission mains were also installed.

The water supply systems in both cities are large-scale, complex, and costly to maintain and repair. As indicated earlier, this complexity results from using foreign contractors, who usually use foreign technologies and equipment to construct water systems to comply with donor countries' quality and regulatory standards. These standard compliance requirements technically bind water systems to imported spare parts, expertise, and engineering services after the contractors leave. As many development scholars have shown (Mattlin and Nojonen, 2015; Kim and Kim, 2016; Yang, 2022), importing these spare parts and experts services will benefit the donor countries' domestic economies in terms of providing a market for their industrial products and technology services.

However, strong reliance on imports affects maintenance and repair in the two cities in two main ways. The first is the high cost of imported spare parts and materials, which makes them unaffordable for utility

companies (Interviews 7, 10, 19 & 20, 2018/2019). For example, a GWCL official in Accra indicated that "*one of our major problems is the cedis depreciating so fast against dollars. When we budget for materials and spare parts in the beginning of the year, the cost will increase by more than half in the middle of the year due to depreciation. This always pushes our budgets off-track. We often have to cut down the quantities and buy what we can*" (Interview 5, 2020). In practice, these constraints mean doing without critical equipment and spare parts needed for maintenance whenever possible, and otherwise only using the bare minimum. In some situations, maintenance and repair needs (e.g., network maintenance) must be suppressed in order to be able to import critical spare parts, or else the equipment is abandoned because there are insufficient funds to import the correct spare parts (Interview 3, 2018). For example, Fig. 2 shows a dysfunctional booster pump that has been abandoned at one of GWCL's water stations in Accra. The site engineer revealed that the equipment had developed a technical fault a few years previously, but the company was unable to import the correct spare parts. The pump was thus left to deteriorate further to the point that at which repairing it would cost more than buying a new one (Interview 21, 2018).

Source: author 1.

Second, importing spare parts causes delays in maintaining and repairing water systems. An official of DAWASA in Dar es Salaam revealed, "*We import most of the plant/equipment from South Africa or India, which causes many delays. Sometimes we don't have the experts and must bring down experts from the manufacturers, which takes much time*" (Interview 7, 2019). Getting equipment or spare parts to Ghana from distant places like China can take an especially long time—up to three months (Interview 21, 2020). And meanwhile, the malfunction may worsen, pushing up the repair cost considerably (Jambadu et al., 2022) or even leading to it being abandoned, as in the case of the pump shown in Fig. 2. The DAWASA company has decided to foster local solutions by producing certain basic spare parts locally to reduce dependence on and the challenges associated with imports. A company official disclosed that they usually engage local artisans (blacksmiths) to improvise or reinvent some of the essential spare parts and equipment it frequently uses, thereby enabling them to reduce the costs and delays associated with importing spare parts (Interview 7, 2019). These local adaptive practices show how utilities cope with the challenges of foreign technologies by adapting and appropriating them to connect with their local contexts and circumstances (Monstadt and Schramm, 2017).

Fig. 2. An abandoned booster pump in Accra.

Other scholars (Mattlin and Nojonen, 2015; Chung et al., 2016; Pandey et al., 2022) have also shown that technology transfer and the associated import dependence benefits donors' domestic economies in terms of exports and employment creation but can come at the expense of maintenance and repair and long-term sustainability of technologies in recipient countries.

4.2.3. Local knowledge-building

Making technologies work in local contexts depends on the recipient organization's capacity to reinvent and adapt existing knowledge to connect with the new expertise it needs to use to maintain and repair the foreign systems (Monstadt and Schramm, 2017).

Our research findings show that local experts in GWCL and DAWASA have limited knowledge of the new technologies and systems transferred by donors, and therefore their ability to maintain and repair complex water technologies is restricted. For instance, although engineers and technicians of both companies in Accra and Dar es Salaam could handle most of the everyday maintenance and repair problems at the various water plants and networks, they struggled to deal with more complex issues, such as troubleshooting malfunctions of certain electro-mechanical equipment at the water plants (Interviews 7, 8, 9 & 21, 2018/2019).

A system technician stationed at the Kpong water plant in Accra revealed, "*we can handle most of the common problems if the correct spare parts are available. But when there are complex issues we cannot handle, we report to the headquarters for higher expertise. Even for them [the headquarters], there are some issues they cannot also handle. In that case, they have to hire a specialist from abroad*" (Interview 23, 2018). Similarly, a technician at the Upper Ruvu water plants in Dar es Salaam reported that "*sometimes when new equipment is imported, we do not have the expertise immediately to operate, repair, or maintain them. So we have to do our research to learn about them. The company does not have money to sponsor training abroad*" (Interview 24, 2019). These statements show the limits to the knowledge of utility engineers and technicians and reveal the multi-scalar nature of maintenance and repair knowledge in technical systems.

In the case of more complex technological systems such as the desalination plant, no GWCL engineer has the necessary maintenance and repair expertise, even though the plant is to be operated by the company after the lease contract expires (Interviews 5 and 17, 2018). These interviews revealed that GWCL officials were also unsure if there were plans or arrangements to build up their knowledge and skills so they could operate, maintain, and repair the systems after the foreign contractors leave.

The opinions noted above indicate that building local knowledge and capacity for maintenance and repair have been poorly anticipated or adequately addressed in the donor-funded technology transfer schemes for the two cities. This accounts for the persistent knowledge gap in both companies and their limited capacity to handle the complex maintenance and repair of imported technologies. It seems probable that donors often consider such capacity building and training of local experts to be a core task of the utility companies that are responsible for maintenance and repair (Alves, 2022). This misconception can also be interpreted as the negative consequence of tying water aid to foreign contractors and complex technologies, and the resulting ripple effects that further consolidate import dependence in both cities' water systems (Mattlin and Nojonen, 2015).

These findings highlight an important political dimension of knowledge. The knowledge and skill set required to maintain and repair specific infrastructure is not ubiquitous (Houston, 2019; Jackson, 2011) but instead is limited and controlled by a handful of foreign manufacturing firms who also control their production, use, and

distribution through intellectual property rights (Lu and Qiu, 2022). Therefore, building local knowledge and capacity for maintenance and repair in recipient countries will reduce dependence on foreign experts and engineering services and destabilize these firms' power and monopoly over using and distributing such knowledge. Thus, transferring technologies without building local knowledge protects the monopoly power, but at the expense of maintenance, repair, and sustainability.

Local experts in both cities thus compensated for the above knowledge shortcomings by frequently improvising, learning, and tinkering with various infrastructure artifacts to find local and place-based solutions to maintenance and repair needs. For example, the interviews revealed that without formal capacity building and training opportunities, many technicians in both cities conduct personal research online by watching free videos and reading manuals and other resources to learn about new technologies and techniques so they can experiment on maintaining and repairing new equipment and that some technicians use personal knowledge and experiences to tinker with various material artifacts to solve diverse maintenance and repair problems, even if such solutions are temporary (Interviews 7, 9, 19, 20, 23, & 24, 2018/2019).

These tinkering and improvisation practices often do not follow prescribed technical standards or guides but are instead based mainly on individual experience and knowledge (De Coss-Corzo, 2020). Therefore, they can also pose additional risks to the system's functionality. For instance, although we observed that some experiments at maintenance and repair succeeded, interviewees reported that many have failed, further damaging the faulty equipment (Interviews 7 & 21, 2018/2019). However, as many STS studies in the Global South have shown (Graham and Thrift, 2007; Jackson, 2019; Baptista, 2019; De Coss-Corzo, 2020), the everyday acts of tinkering and improvising also stimulated an environment of ongoing learning and innovation among local engineers and technicians. These acts not only enable local experts to appropriate foreign technologies to work under conditions of resource poverty but can also be interpreted as acts of resistance that challenge foreign technologies, the universalization of repair knowledge, and standardization.

5. Conclusion

This article has investigated the politics of donor funding schemes in water supply and how they shape infrastructure maintenance and repair in Accra and Dar es Salaam—two fast-growing cities in sub-Saharan Africa. To illustrate how tied water aid practices affect maintenance and repair practices in both cities, we relied on the politics of tied aid and technology transfer and the analytical lenses of donors' institutional conditionalities, transferred technologies, and local knowledge-building. We have unpacked the complexities of the politics of tied water aid through these analytical dimensions to show how donors' funding schemes have had ambivalent effects on maintenance and repair in both cities but can positively impact donor home countries' economies in promoting exports and employment. Although donors funded slightly different technologies in the two cities and imposed different conditionalities, their effects on maintenance and repair were generally similar: i.e., delays and costly spare parts that are difficult or impossible to obtain and expensive to import. Moreover, these imposed technologies challenge local experts' knowledge and skills.

In general, donor conditionalities have imposed complex and costly technologies without considering the need to build local knowledge or to provide appropriate foreign technologies to connect with the local contexts and their situated materialities, knowledge, and institutional arrangements (Behrends et al., 2014). This misalignment has resulted in tension because local experts lacked the knowledge required to handle the maintenance and repair of complex systems. Both utility companies also struggled to afford imported spare parts, facilitate local knowledge-building, or hire foreign experts to handle complicated maintenance and repair problems. Thus, although donor-funded technologies have improved water supply in both cities, their long-term sustainability is problematic because donors poorly anticipated the maintenance and repair possibilities in recipient countries. Overall, the case study has illustrated the crucial importance of donors in maintenance and repair and the need to address their role more systematically in the study of maintenance and repair in Africa and, more broadly, in the Global South.

Our case study contributes critically to infrastructure maintenance and repair literature and the politics of tied aid and technology transfer in the Global South in several ways. First, by investigating the role of donors in water infrastructure maintenance and repair, the paper has illustrated the multi-scalarity and multi-dimensionality of infrastructure maintenance and repair. We have shown how different aspects of technologies (i.e., actors, artifacts, knowledge, institutions, and political rationalities) interact at different scales in shaping maintenance and repair practices. This insight also shows that even though maintenance and repair involve practices of local actors such as utilities, engineers, plumbers, and users (Wahby, 2021; Alda-Vidal et al., 2018; Jambadu et al., 2022), they are simultaneously shaped and driven by the political rationalities, decisions, and agencies of international donors. Second, we have demonstrated that the impact of development aid goes beyond the time of the infrastructures' construction and installation (past decisions) and their operations (present-day) and extends far into the long-term maintenance and repair (future). This has practical implications and relevance for shaping policy formulation and international donor funding programs in Africa. We argue that there is a need for donors and national governments to anticipate the maintenance and repair of infrastructure more systematically by incorporating knowledge transfer and local capacity-building programs in donor-funded infrastructure projects in order to reduce import dependence and enhance long-term sustainability.

CRediT authorship contribution statement

Lazarus Jambadu Collected the data, conceptualised and drafted the article. **Jochen Monstadt** Provided supervision and comments to improve it. **Francesca Pilo'** Conceptualisation, supervision and comments

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Table A1
Field interviews cited in text.

Code	Function of respondents	Place and date
1	Government official, Ministry of Sanitation and Water Resources	Accra, December 17, 2018
2	DAWASA director of water supply	Dar es Salaam, February 26, 2019
3	Deputy MD, GWCL, headquarters	Accra, December 14, 2018
4	Chief engineer, GWCL-projects,	Accra, December 20, 2018
5	Engineer, GWCL-ATM	Accra, March 20, 2020
6	DAWASA Regional manager,	Dar es Salaam, February 18, 2019
7	Technician, Lower Ruvu plant	Dar es Salaam, March 1, 2019
8	Technician, Upper Ruvu plant	Dar es Salaam, March 4, 2019
9	Technician, Weija water plant	Accra, March 26, 2018
10	Regional Chief Engineer, GWCL-ATM	Accra, April 29, 2020
11	Researcher, Tanzania Water Institute	Dar es Salaam, August 23, 2021
12	WASH specialist, UNICEF Tanzania	Dar es Salaam, February 19, 2019
13	Technical officer, WaterAid Ghana	Accra, December 14, 2018
14	Consultant, World Bank	Accra, December 18, 2018
15	GIZ official, Dar es Salaam	Dar es Salaam, July 5, 2021
16	WASH specialist, UNICEF Ghana	Accra, December 14, 2018
17	Chief manager, GWCL, Accra east	Accra, December 20, 2018
18	Distribution manager, Accra east region	Accra, March 26, 2018
19	DAWASA Manager, Kinondoni region	Dar es Salaam, February 22, 2019
20	Manager, Weija water plant	Accra, March 26, 2018
21	Technician, Dodowa booster plant	Accra, December 12, 2018
22	Technician Kpong water plant,	Accra, December 17, 2018
23	Manager, Upper Ruvu plant	Dar es Salaam, February 21, 2019

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