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Powershifts, organisational value, and water management: Digital transformation of Ghana's public water utility

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ABSTRACT

There are fundamental unresolved questions about the nature of the interplay between digital innovations and water management processes. However, there has been little research on how increasing digital transformation impacts water management and infrastructure in the Global South. This article draws on a socio-technical lens and primary field data to analyse the digital transformation of water management in Ghana's state water utility company. Digital water innovations were found to be recent and delivering relatively limited impacts yet, with value mainly accruing at the utility's operational rather than strategic level, and incremental, not transformative. Digitalisation and datafication also present avenues for power shifts, internal and external struggles, and changes in water management structures and responsibilities. The paper ends with a brief discussion of the implications for water service governance and research and suggestions for using data and information generated from digital water infrastructure to improve services.

1. Introduction

The past decade has witnessed significant progress in municipal and piped water supply infrastructure for potable water delivery. Despite these improvements, centralised water utilities and providers, especially in low- and middle-income countries, still face operational, management and governance challenges across social, technological, environmental, financial and administrative systems (Hope and Rouse, 2013; Water Policy Group, 2021). Digital technologies have increasingly been seen as one significant means to address these challenges and ensure effective and efficient service delivery (Sarni et al., 2019). Also, the ambitious Sustainable Development Goal of establishing universal (premises) household-level access to safe, reliable, and affordable drinking water by 2030 (SDG 6.1) has encouraged on-grid and piped water investment strategies towards the adoption of digital innovations to improve the sector (Sarni et al., 2019; Bluefield Research, 2022). Past studies have highlighted how the digitalisation of the water sector presents pathways to addressing water governance and management challenges, offering opportunities for an improvement in processes, services and functions ranging from daily operations to designing integrated smart infrastructure (Mukhtarov et al., 2018; Sarni et al., 2019). This recognition has resulted in many efforts to foster water-related digital innovations at different levels (organisational, sector, policy), thus changing the water innovation landscape (Wehn and Montalvo, 2018).

Despite the recognised importance of digital transformation in the (public) water utility sector worldwide, arguments about their impact and developmental implications in the global South have, to date, been based on little research and evidence (Amankwaa et al., 2021). There is a general lack of research focusing on the (urban) global South, despite this being the location for most of the world's population, with a particular lack of empirically-based research. Most research on the digitalisation of water utilities has focused on high-income country contexts and solutions, overlooking significant specificities and inherent complexities of water systems and type of service provisioning in such locales (Amankwaa et al., 2021, 2022; GSMA. 2022). It is also argued that most water innovations deployed in global South cities, particularly in Africa, have been piloted in a few places and have hardly been scaled up, making the study of impacts problematic (Mvulirwenande and Wehn, 2020). Others have also raised important questions regarding how digital or smart technologies transform, reproduce and reconfigure relations, power dynamics and knowledge within these systems (Hoolohan et al., 2021).

This article addresses gaps and contributes to these debates by analysing an empirical case study of the digital transformation of Ghana

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Water Company Limited (GWCL), Ghana's sole public urban water utility. This paper is guided by two main questions: (i) How are digital innovations implemented and deployed by GWCL, and (ii) how have those digital innovations impacted water service management and governance? We focus on Ghana for two reasons. Although all country contexts have their features, it exemplifies features of public water providers and provision in the global South. It follows a digital roadmap, implementing digital technologies in its operations from source to consumer (Amankwaa et al., 2020; GWCL, 2019). So, in a sense, Ghana is emblematic of the very core of the struggle and opportunities of public water utility digitalisation. Also, GWCL's experiences with digitalisation, while still relatively recent, have progressed enough for us to draw conclusions about their implementation and impacts.

The paper is interested in the digital transformation processes and their impacts, and not one particular technology. For this analysis, therefore, the paper brings scholarship from Science and Technology Studies (STS) and processes of socio-technical change to address implementation and impact issues at the intersection of digital technologies and urban water management. The paper's specific contributions are threefold. First, it contributes real-world empirical evidence to understanding the digital transformation of (water) utilities within a geographical setting that remains unexamined from an infrastructural and socio-technical perspective, even though the utility sector and the global South are gaining increasing attention for digital transformations. Second, it adds to and extends existing conceptualisation in STS and the notion of incrementalism by highlighting how the link between different configurations and technologies mediate the relationship of actors and the socio-materialities and outcomes of change which make and remake digital water innovations. This paper also adds to the organisational studies literature on how digital technologies affect or change organisational structure and systems, drawing on the inherent complexities, politics, and peculiarities of digital technology in the water sector. Third, the case of GWCL and Ghana expands our understanding of the dynamics of digital transitions within a public utility in a developing country context, for instance, expanding our understanding of how top-down (digital) governance practices shape the agency and everyday experiences of actors, especially residents or consumers.

The paper is structured as follows. Section 2 discusses the literature on digitalisation in urban water management before framing the conceptual base of digital and water governance within socio-technical system literature, particularly around socio-technical configurations, and explains how the combined socio-technical approach can contribute to studying digitalisation impacts on urban water management in developing countries. Section 3 provides the case study description and methods. In section 4, findings from the empirical study are presented. In the penultimate section, we discuss the significance of our findings and provide conclusions in section 6.

2. Conceptual background

2.1. Urban water management and governance in the digital age

The digital age and the associated processes of digitalisation and datafication[1] have reshaped the management and supply of infrastructure services in cities. Digital technologies are seen as integral to "smart city" visions worldwide and have spread to the global South through the aegis of local and global technology firms (Datta, 2015; Joss et al., 2019). Looking beyond the hype of these visions, organisational studies literature on digitalisation and organisational change has taken a less sanguine view, identifying both positive and negative outcomes (Verhoef et al., 2021). It has raised issues about the challenges of implementing digital systems, including achieving radical as opposed to incremental change and delivering new forms of value (Hanelt et al., 2021; Orlikowski, 1993). Such issues have, in turn, been explicitly seen within the literature on the application of digital systems in the water sector.

In the water sector, digital technologies are being implemented in privatised and public water companies (Sarni et al., 2019) and are noted to have profound potential implications for the organisational structure and governance of water utilities and water infrastructures. Critical scholars and practitioners have acknowledged how the digitalisation of infrastructural services and networks opens up possibilities for water and infrastructural improvement, and at the same time are a terrain of political expression and struggles over power and citizenship (Hoolohan et al., 2021; Ingildsen and Olsson, 2016). As Geels and Verhees (2011) argue, understanding a technological solution is not only based on its performative measure but also its social, political, economic, ecological, or spatial contexts.

Within the literature focused on these processes in the global South, three emerging perspectives on the digitalisation of urban water infrastructure governance and service management have been identified – one around implementation/adoption processes, one around value, and one around power (Amankwaa et al., 2021; Taylor and Richter, 2017). *Implementation-related* research focuses on technologies and constraints that either have to be overcome for digital systems to operate or prevent the full effective implementation of those systems. In the digital water literature, Amankwaa et al. (2021) identified two main implementation challenges affecting the different technologies' functionalities across the digital lifecycle. The first pertains to technical issues which are either internal to the digital system, such as problems with data or software quality, or more related to external infrastructure, such as limited penetration of internet connectivity or frequent power/telecommunication breakdowns (Hope et al., 2011). The second relates to human challenges that render service providers unable to fully implement or use the technologies, such as the lack of necessary skills (user capabilities, skills, and knowledge), incentives and motivations or more general resistance among user groups (Bediako et al., 2018; Ndaw, 2015). Whilst there has been much research focused on implementation/adoption processes, the other two perspectives (value and power) are incipient only in research on digital water and the global South (Amankwaa et al., 2021).

The *value* perspective deals with the improvements digital systems can make to organisational decisions. Following organisational studies, value is often discussed in terms of impacts (benefits) across the organisational decision levels: operational, tactical and strategic (e.g., Turban et al., 2018). In the case of water, the literature has analysed predominantly from technical and positive perspectives and has emphasised the benefits digitalisation brings to water governance; for instance, how the production of digital data from digital water innovations can create value for both operational and strategic decisions (Amankwaa et al., 2021; Taylor and Richter, 2017). Scholars have articulated how water utilities have progressively implemented sensors, meters, and supervisory control and data acquisition (SCADA) systems to ensure the supply and monitoring of potable water through urban space (Hoefsloot et al., 2022a), providing information on urban water infrastructure in near real-time regarding water quantity and quality for consumers and promoting a sense of insight and control. Moreover, they are typically promoted by an overwhelmingly positive vision of digital and data governance among utilities and their customers in helping address issues of empowerment for the most marginalised people and furthering the co-production of water services (Hoefsloot et al., 2022b; Taylor and Richter, 2017).

The *power*-related strand of literature has highlighted the broader outcomes and techno-politics associated with digital water innovations (Blomkvist et al., 2020; von Schnitzler, 2008) and how digital intersects with power and broader politics in water service governance (Hoolohan

[1] Digitalisation and datafication as used in this paper to represent processes associated with digital water innovations or transformations. Datafication specifically represents the use of data emerging from digitalisation processes or digital technologies.

et al., 2021). Some of these studies have explained how digitalisation and its associated processes (such as datafication) introduce new actors and power dynamics in terms of "who counts", who has epistemic control and the implications of new structures and positionality of relations (Taylor and Broeders, 2015; Heeks et al., 2021). For instance, despite their potential, Hoolohan et al. (2021) argue how digital water systems and datafication of water infrastructure are tools to make visible and monitor but also actively obscure processes. Hoefsloot et al. (2022b) argue in their study in Lima how implementing "smart" technologies and datafication of water infrastructure does not automatically lead to the incorporation of residents into the water network but produces new distinctions and obscurities in the relationship between the water provider and consumer and produces, more or less unintentionally, new categories of water consumers.

From this literature review, a few strengths of existing research on socio-technical transitions of central value to this paper can be readily identified, providing a foundation for examining the nexus between the domains of digital technologies and water utilities. With its *pervasive* impact on everyday water management and governance, digitalisation implies opportunities and challenges for water management and infrastructure, but the discussions on these impacts have remained in the shadows of research analyses. Due to the early-stage and limited nature of field evidence, empirical analyses on digital water management have been very limited, and socio-technicality has been alluded to, but direct engagement has been rare. Most of the pertinent issues relating to the socio-technicality of digital water transitions have received far less attention to date or are formulated as future research needs (Amankwaa et al., 2021, 2022; Hoefsloot et al., 2022b; Hoolohan et al., 2021). In focusing on the emerging processes of socio-technical futures for digital water, this study draws on and operationalises insights from STS literature around socio-technical configurations. This approach provides rich debates around the nature of infrastructure management evolution, the complex networks of people, actors, organisations, and technologies, and the governance processes and mechanisms of digital water infrastructure transition.

2.2. *Theorising the linkages between digitalisation and urban water governance*

Until recently, the literature on urban water and critical digital studies had remained distanced. With a few notable exceptions (e.g., Amankwaa et al., 2022, 2023; Hoefsloot et al., 2022b; Hoolohan et al., 2021), debates and conceptualisations on digitalising water management and governance tend to focus on adoption-based or technology-centric frames with little consideration of how digital technologies are embedded within broader water and infrastructural practices and governance (Amankwaa et al., 2021). As indicated in the previous section, there has been a call for new methods and broader conceptualisation to better understand the intersection of digital technologies, institutions and the complexity of water governance.

To attend to this lacuna in the literature and using insights from the emerging studies on digital water services in the global South as a foundation, this study draws on and operationalises insights of STS around socio-technical configurations. Seminal works on socio-technical theories have addressed the co-evolution of technology and organisation, highlighting micro- and macro-level impacts (Akrich, 1992). Broadly building on science and technology studies, the notion of socio-technical configurations views technologies not simply as designed and engineered material objects but as socio-technically embedded – with producers, infrastructures, users, consumers, regulators and other intermediaries all embroiled and configured (Amankwaa et al., 2022; Bijker, 1987; Coutard, 1999). Under such a conceptualisation, the implementation and management of digital technologies for large technical systems such as water infrastructures are co-constitutive, continually co-evolving and strongly varying in terms of processes, actors, institutions, and participation, resulting in differences in outcomes and configurations (McLoughlin et al., 2000). STS has relevance to describing the growth dynamics and system logics of large infrastructures, institutional arrangements, and how technical systems interact or co-evolve with their environment/everyday life to produce context-specific outcomes (Blomkvist and Nilsson, 2017; Hughes, 1987).

Drawing from technological and institutional concepts, socio-technical configuration asks whether and how actors in organisations can deal with the tasks assigned to them and with power relations, their (dis)alignments and reconfiguration outcomes (Geels, 2002; Heiberg et al., 2022; McLoughlin et al., 2000). In this paper, the socio-technical configuration is not only seen as a transition from one path to another "but as a contested and discursive process strongly framed by contexts of action and contingent events" (Moss 2014 pp. 1435) among actors, including water providers, enabling one to see how (in)decision to implement and use digital technologies affects water governance and management. It also involves understanding the visible and hidden complexities embedded within arrangements, connections and relations in which technological infrastructure is implicated (Walker and Cass, 2007; Rutherford, 2020). Taking urban water infrastructure and services as a socio-technical system and drawing on the emerging literature on digital urban water management and governance, this paper focuses on socio-technical configuration as an analytical lens.

3. Case description and methods

The provisioning of water in Ghana involves a combination of centralised and decentralised approaches, with noted challenges including high operational costs and low revenues, unrealistic pricing, weak physical and institutional infrastructure, billing and payment inefficiencies, and colonial legacies of segregation and politicisation (Amankwaa and Ampratwum, 2020; Bohman, 2012). These challenges are particularly associated with the public sector, as water service provisioning is the responsibility of two main public actors: the Ghana Water Company Limited (GWCL) and the Community Water and Sanitation Agency (CWSA), who are responsible for providing water to urban and rural areas, respectively. The two public sector implementing agencies (GWCL and CWSA) directly own or operate the majority of water systems in Ghana and serve over 23 million (two-thirds) of the country's population. However, with recent deployments of digital technologies into the Ghanaian urban water governance landscape, research is needed to understand how digital systems impact actors and stakeholders across the water value chain, particularly within public utilities.

Ghana Water Company Limited (GWCL) was selected as the case for this study due to the implementation of digital technologies in its operations. We employed a case study approach to address the research aims to enable in-depth research on digital technologies and their impact (Yin 2014). GWCL is the sole government-owned water utility company, and it is responsible for the production, transmission and distribution of water in urban areas in Ghana. The company started in the colonial era and has undergone several changes. Between 1965 and 1999, it operated as the Ghana Water and Sewerage Corporation until it was changed to the GWCL. Over the past years, GWCL has gone through a couple of evolutions, including being run via a management contract by Aqua Vitens Rand Ltd (AVRL), a collaboration of Vitens International, Netherlands and Rand Water Services of South Africa, which began in June 2006 and ran until May 2011 (GWCL, 2019). Despite past privatisation attempts to cede the operation and management of water supply in Ghana to private sector actors (Acheampong et al., 2016), water is back in state hands, and GWCL is delivering centralised water services to urban areas.

The Company currently manages 90 water systems serving about 11 million people nationwide. It operates in 15 regional and 90 district offices (GWCL, 2022). In terms of governance structure, the Ministry of Sanitation and Water Resources is responsible for formulating water supply policy, overseeing the operations of GWCL, sourcing funds from external support agencies and coordinating sector investment plans (GWCL, 2022). Under the general direction of the Ministry, GWCL is governed by an eleven-member Board of Directors, which is responsible for setting sector policies and controlling corporate programmes. The company's day-to-day affairs are managed by a Managing Director and Deputy Managing Directors, who are assisted by Chief Managers who head various departments. At the district level, the District Managers supervise and control the various districts of GWCL throughout the country (GWCL, 2018a).

Methodologically, this paper adopted a mainly qualitative empirical approach drawing on four datasets from research carried out at different intervals between November 2020 and December 2021. The first dataset is drawn from 22 (16 online and six in-person) professional and expert interviews conducted from November 2020 to April 2021, with 17 GWCL professionals (senior officers and mid- and operational-level staff), one representative of an international water organisation who had previously worked for a water-related civil society organisation in Ghana, one civil society organisation official in Ghana with expertise in governance, water and social policy, two GWCL external partners, and one United Nations Capital Development Fund consultant who was working on public utility digital water innovations in Ghana. These people were selected to triangulate evidence sources because of their explicit knowledge of digital innovations in the urban water sector. The interviews were designed around issues identified from the literature: the type and nature of technology implemented, drivers of implementation, issues around value created, and broader impacts associated with digital transformation. Due to COVID-19 restrictions, some interviews were conducted online using Microsoft Teams and Zoom or via phone. All interviews were conducted in English and were 30–50 min long. Interviews were audio-recorded, or the researcher (first author) took notes by hand when respondents were uncomfortable with recording.

The second dataset draws on data from the field and GWCL's digital control room visits and observations undertaken between late April 2021 and early May 2021. This method targeted the nature of digital systems and technologies' operation, design, and usage and involved observing what was happening, asking designated officials or workers questions and listening to feedback. The first author was "walked through" most of the digital technologies used and observed and monitored station control rooms, providing a glimpse into the infrastructure from GWCL's perspective. Observations and follow-up questions were captured as fieldwork notes.

The third dataset is from 26 semi-structured interviews with GWCL-connected customers with smart meters in Accra, who were selected based on the depth of insights and experiences with smart meters they proffered, coupled with a willingness to participate as part of a more extensive study on smart water metering, conducted between June and December 2021 (see Amankwaa et al., 2023).

The fourth dataset was secondary data from GWCL made up of water use, customer billing and meter installation records. Company reports and internal documents were also sourced from GWCL, and broader policy documents on digital and water in Ghana were downloaded from government, international, civil society and other organisations.

Interview data from the different sources (professionals, experts and customers) were transcribed as text, coded, and thematically analysed alongside the field observation notes by comparing the responses to identify common trends, themes, similarities and contrasts. The analysis of secondary data, policy documents and company reports also complemented these primary data sources to refine the final themes. Therefore, the study combined methodological and case (stakeholder) triangulation by coding all data, drawing first on the topics identified from the literature and further categorisation in NVivo 12. The dominant categories were the type and nature of technology, implementation drivers, value created, and broader impacts of digital transformation. Also, guided by the dominant themes emerging from the initial triangulation and using interpretive methods to compare findings to elicit key analytical themes by looking at different respondents' positions on implementation and impacts of digital technologies, the code list was adjusted during the analysis as new themes emerged. To ensure that this largely qualitative research adequately reflected participants' views about the topic, in the analysis, verbatim quotes were included and juxtaposed with researchers' interpretation, as well as descriptive summaries of some responses, observations and documentary analysis. The following section reports on the deployments and impact themes emerging from analysing the triangulated data.

4. Results

Three related core considerations from the triangulation are reported in the results. We want to stress that the descriptive nature of results and the division into three core sub-sections is an analytical simplification done to provide context, particularly to the interrelated link between digitalisation processes and outcomes, and to answer the two main research questions. The first sub-section, primarily focused on digitalisation processes, draws on qualitative data and documentary analysis to report on the drivers and approach to digitalisation within the utility, which helps answer the first question about how digital technologies were implemented and deployed by GWCL. This approach also sets the background for reporting the other two sub-sections, which move from processes to impact and outcomes. In the second sub-section, we show responses on the value and impact of digital transformation across GWCL's different areas of activity in the water value chain. The third sub-section shows how digitalisation and data technologies have impacted and configured everyday governance and organisational structures within and outside the utility. The last two sub-sections answer the second research question on how digital innovations have impacted water service management and governance.

4.1. The making of a digital public water utility: developing smart responses to key challenges?

The history of deploying technology in water sector management systems in Ghana dates back to colonial times, which was focused on simple physical infrastructure such as pumping machines and acquisition of purification equipment and then later to water source technologies, water processing technologies and water distribution technologies, after Ghana's independence (Bohman, 2012; GWCL Senior Official 2). New computerised technologies were introduced at the turn of the millennium to support sustainable urban water supply systems (Bediako et al., 2018; GWCL Senior Official 2). Post-independence transition regimes witnessed a renewed interest in reforms towards implementing neo-liberal economic policies recommended by the lending institutions and regarded as a panacea for establishing a financially self-sustaining water sector capable of attracting private capital investment (Acheampong et al., 2016). The transition later saw the adoption of innovation and digitalisation processes as part of the management reforms and as a response to ageing infrastructure, non-revenue water, water rationing, pollution to water sources and increasing population pressures (GWCL Manager 1; GWCL, 2017). The ongoing digital infrastructure by GWCL has been developed over the years through partnerships, bilateral or multilateral development projects, and the company's initiative, and it has focused on individual segments of the water value chain (see Table 1).

As a start with this renewed interest, digitalisation processes primarily centred on implementing institutional frameworks, visions and mission statements that guided efforts in expanding the integration of digital systems within GWCL departments for business processes and later also for interfacing with users. Having created ICT-based and technology-related units or subdivisions and working with external actors and donors, GWCL started implementing foundational internet and hardware infrastructure and GIS-related facilities. Under the AVRL management contract, for example, a GIS unit was tasked with mapping

Table 1
Examples of digital innovations implemented by GWCL.

Stages of the Value Chain	Focus	Key Innovations Implemented
Source	Water treatment	SCADA system and sensors for water quality testing and monitoring
Distribution and delivery	Water distribution and monitoring	Geographic information system (GIS) Hydraulic modelling Sensors (such as SCADA and flow and pressure loggers) Telemetry systems
End-users	Water consumption - Consumption monitoring and revenue collection - Service Feedback	Smart (ultrasonic) meters with 'drive-by' radio technology Electronic billing and payment system Online customer feedback services (e.g., customer mobile apps and portal) Customer engagement channels, including. Call systems, Telegram and WhatsApp
Internal	Procurement (materials), HR, accounting	Enterprise resource planning system

pipelines and taking inventory of its pipe networks and assets, and the ICT division was tasked with ensuring better integration of the different digital systems being developed (GWCL External Partner 2). More recently, the Technology and Innovation (T&I) Department was created, leading the company's drive towards change and implementing innovative technologies to improve operational processes (GWCL, 2017). Since then, the scope of urban water digitalisation has grown to become increasingly shaped by a multifaceted range of technologies such as e-billing and digital payment platforms for reading bills and managing water bill payments and user records and the establishment of a state-of-the-art call centre for managing customer services, handling complaints and queries (GWCL, 2017). Others, such as the use of an enterprise resource planning system, are in operation across procurement, HR, accounting and other departments, and more advanced systems, such as sensors (e.g., SCADA) for large water distribution systems, pumps and water treatment have been deployed, with data fed into an "Ultra-Modern Telemetry Control Room". There has also been the rollout of smart ultrasonic meters, which can be read using the 'drive-by' technology with a 1km range.

Within our analysis and as discussed next in further detail, two key objectives were observed to be motivating these digitalisation processes by GWCL: (1) to improve efficiency and management (internal issues with regards to non-revenue water, network upgrade, increased accuracy), and (2) to improve service efficiency and response (external to the customer, that is in terms of improving customer services).

The primary motivation and emphasis of digital development have been to create a more efficient water infrastructure, something reflected in the various management contracts and privatisation attempts by GWCL from the 2000s onwards (GWCL, 2017; Former Civil Society Organisation Coordinator). The main arguments for these management contracts have centred around the belief that such approaches can improve management and make water provision relatively more efficient. The same rationale around a need to address increased non-revenue water levels (supply of water that was not paid for through leaks, losses, non-payment, and theft), perceptions of corruption, data unavailability and degradation of infrastructure in large part pushed digitalisation in the sector. Further impetus was given by the perception that the introduction of new actors and technologies would help fix these problems (GWCL, 2019; GWCL Engineer 2).

Evidence from GWCL explains that the digitalisation processes were part of, and grounded in, the company's ambitious strategic goal of becoming a world-class utility and helping address critical problems faced by the company (GWCL, 2017; GWCL Senior Official 1). Specific aims included improving billing accuracy and data communication and monitoring of household consumption, reducing non-revenue water to 20%, and expanding digital meter coverage to 100% (GWCL, 2017; 2018a; GWCL Senior Official 1). As part of its 2015 Technology Roadmap to help turn the company's fortunes around, various innovations were rolled out at different levels of the water value chain.

For instance, battling various degrees of water treatment, quality and production problems, GWCL introduced digital infrastructure and online systems to make these water processes more legible to management. By legible, digital technologies have provided different volumes of water information and data for GWCL, making it easier for oversight and monitoring. GWCL started with remote monitoring of raw water quality at treatment plants and has deployed SCADA at some of its treatment plants (GWCL Engineer 2). Also, at the distribution and delivery levels, some data capture, data processing and decision support technologies, such as sensors and telemetry systems, have been deployed (GWCL Engineer 4; GWCL, 2019). A supervisory control and data acquisition system has been implemented within GWCL regional boundaries for accurate water budgeting among all three regions in the Greater Accra Metropolitan Area (GAMA). This system can be accessed in real-time bi-directional communication (GWCL Meter Technician, 2). A telemetry system has been implemented within the GAMA water supply area to help monitor flow and pressure levels and provide real-time operational data and control from a centralised point. As of 2019, it was estimated that about 20 water meters of various sizes and pressure sensors had been installed as boundary meters between the three GAMA regions (GWCL, 2019).

The other main driver or push factor for the deployment of digital technologies by GWCL was to improve water service delivery and responsiveness to customers because the company was being increasingly portrayed by users, especially in poor neighbourhoods, as "disengaged", ineffective and unreliable (GWCL Senior Official 1). Digital innovations were meant to bridge the gap between users and GWCL, bringing the two into more contact through ICT mediation and delivering more reliable customer service. Specifically, this rationale was highlighted as a motivator for deploying user-level innovations such as smart water metering and customer engagement systems. Smart meters, for instance, were seen as a means to build customers' trust in the utility by enabling them to only pay for "what they consume" (GWCL Meter Reader 3). The ability of meters to accurately measure and monitor consumption while also identifying anomalies like supply-side leakages was believed by those in the utility as likely to improve the trust of customers, especially in terms of water bills: "If the consumer knows all these, they won't have the perceptions of been cheated …" (GWCL Engineer 2). Through the e-billing system operationalised in 2017, aimed at computerising and mobilising billing and revenue collection, customers also had the option of receiving their water bills via SMS and email and could make their monthly bill payments via digital platforms (GWCL Officer 1; Amankwaa et al., 2020). Also, the company introduced customer engagement channels, including a call centre management system and messaging platforms like Telegram and WhatsApp, as part of the day-to-day management of water services communication (GWCL Official 4).

Overall, the preceding shows two salient features associated with GWCL digitalisation. First, while most of these innovations are relatively recent, GWCL can nonetheless be seen as having passed beyond its initial wave of digitalisation processes, with most systems operational for a number of years. Second, in their deployment of digital technologies, GWCL has prioritised corporate and technocratic goals, such as increasing billing and revenue collection efficiency and maximising and focusing on cost recovery to improve service efficiency.

However, its digital transition has been gradual and incremental (GWCL Senior Official 2). Human and technical factors have slowed the implementation of these digital systems, even though these have not prevented that implementation. Digital water innovations may still be at a relatively early stage, but they are sufficiently embedded to make a study of their impacts practicable, as discussed in the next section.

4.2. On organisational value and decision-making practices

The data revealed that the digitalisation of water management and governance has contributed to operational, monitoring and datafication practices and value as discussed in relation to GWCL's different areas of activity in the water value chain.

4.2.1. Monitoring oversight and data for water treatment and distribution

The digitalisation of processes has provided centralised monitoring and supervision of water distribution based on implementing the SCADA sensor system in GWCL's water infrastructure. Most of the water treatment and production plants are now all automated in terms of water quality testing using SCADA, which digitally monitors basic physical and chemical parameters. An online portal enables workers to view water quality (such as turbidity and pH) in real time at the company's production and treatment plants (GWCL Senior Official 1).

Concerning water distribution, the main (transmission) boundary pipeline networks of the operational areas in Accra and the larger distribution lines in the network now use a combination of SCADA sensors and telemetry systems to automatically report falls in water pressure or faults, with instant alarm notifications sounding in GWCL's central control room. When this happens, an instrumentation engineer in the control room can identify the likely location of the problem. In some cases, it can now be resolved remotely, or if a field officer needs to be despatched, they can be directed to the likely location so that fault location and resolution are more efficient (GWCL Engineer 4). All of this is facilitated by mapping the network, which, as a GWCL Technician explained, has given location IDs to all main elements of the water network, including customer locations. In sum, digitalisation has been associated with better and faster monitoring, fault location and resolution. The reports continuously coming in through the SCADA systems and other monitoring platforms offer information on the function of the water infrastructure through the eyes of the service provider, which thus facilitates rapid response to faults and bursts without necessarily having to rely solely on reporting by residents. Digitalisation has thus been used as a tool for monitoring and *regulation*—overseeing and providing oversight for water distribution dynamics for field engineers and technicians and helping the utility cut non-revenue water levels in the overall piped systems. For instance, non-revenue water in 2021 was reported to have reduced from slightly 55%–46%[2] after four years of implementing digital-related systems and management practices (GWCL, 2022).

These deployments also now offer real-time data for the day-to-day operation of water systems at the distribution level. As a GWCL Engineer indicated, "… the SCADA systems and boundaries give us a clear picture on how much water is going in and out of the three regions: Tema, Accra West and Accra East. This offers a basis on where to ration water or not on a daily basis". Likewise, data from telemetry and SCADA has now helped GWCL allocate water and ration water to regions and know how much water is distributed to particular regions. The digital technologies are, therefore, allowing a better understanding and intervention in terms of routing and rationing of water in the company's different regions of operation (GWCL Meter Technician; GWCL Manager 1).

Additionally, the spatially fine-grained (household scale) and monthly updated data from distribution pipelines and household consumption meters provide information to GWCL on the functioning of its water distribution system, allowing for more accurate billing of the water consumed (as discussed next) and offering insights and evidence to detect any tampering attempts by customers or front-line staff, as well as identifying possible issues in the water infrastructure such as leakages or clandestine consumption (GWCL, 2022; GWCL Manager 1). It was observed that water provisioning and management is now made more legible[3] than previously through the functioning, data and information from GWCL's digital water infrastructure. Therefore, datafication (data and information) from digital infrastructure is seen as an essential tool for monitoring the functioning of GWCL's infrastructure and reducing non-revenue water levels in their system (GWCL, 2022).

4.2.2. Creating value and legible practices for water consumption and internal operations

Internally, one key area is how digitalisation has made everyday operational practices at the consumption level legible. For instance, general billing was reported to be more accurate and faster than previously. Previously, analogue meters might not be present at all or, if present, might not be read (so-called "armchair meter reading") with the entered number being some mix of guesswork, intuition and experience of the meter readers (GWCL Engineer 1). For large-volume users, usage is recorded automatically: "Using bulk meters with sensors has informed us the right amount of water a particular industrial customer uses to enable accurate billing" (GWCL Meter Technician 1). For smaller scales, including domestic consumers, meters are read using handheld devices with an e-reader app. This method includes the option to take a picture of the meter, which can be referred to later in case of any query or challenge to the reading, and it also allows remote co-monitoring of readings by supervisors and middle managers.

Although the direct causal link to digital technology is hard to establish, it is noted that a marginal increase in billing performance has occurred in recent years with, for example, a 4.2% increase in billing performance (total billings, reduced errors and corresponding collection) in 2018 compared to 2017 (GWCL, 2018b, 2019). The internal cost-benefit analysis also indicates that using digital payment channels rather than cash payments saves the company about 10% of the administration cost of collecting and processing bills (Digital Water Consultant; GWCL Officer 3). Linking digital technology to broader impacts is difficult. However, GWCL saw a 14.1% increase in revenue for 2018 (GWCL, 2019), and GWCL officials largely attribute this to the introduction of digital billing and payment systems (GWCL Engineer 1). Also, through the digitalisation of customer engagement with a new call centre management system and the use of messaging platforms like Telegram and WhatsApp, it was observed that the number of customer complaints at the district level per *day* was said to have decreased because of these systems, and rectification time for complaints is reported to have also decreased significantly (GWCL District Officer 1; GWCL, 2019).

From an end-user perspective, digitalising water bill payments has brought benefits. An earlier survey by the first author estimated that customers who pay their monthly water bills via digital payment channels save around 27 min from reduced time in making bill payments, with an average saving of USD 0.79 per bill payment (Amankwaa, 2018). Similarly, the reports continuously coming in through the contact centre offer information on the function of the water infrastructure through the eyes of the customers (GWCL Senior Official 1). Customers are thus allowed to self-report issues that affect them and help GWCL capture issues that would otherwise go unreported.

Based on the overall pattern, digitalisation does appear to be adding monitoring and improved internal value to the operations of this public water utility. If we look at it in terms of operational, tactical, and

[2] Figures based on GWCL's internal assessments and audit of non-revenue water levels; from water supply lost through revenue collection and leakages. Though this could be open to biases and does not establish causality, it supports the evidence about the impact of digital technologies.

[3] By legible, we mean GWCL now has good oversight on water service monitoring (mainly in real-time) due to its high volume of water data and information.

strategic levels,[4] then almost all of the value to date is derived from operational decisions and processes. While these may aggregate to impact organisational performance indicators – perhaps, for example, in terms of overall revenue – they are doing so only incrementally and with limited impacts on higher-level decisions and processes. The large quantities of data now being gathered via GWCL's growing digital infrastructure are being used directly for operational processes but have yet to be pooled as big data and analysed to produce longer-term actionable insights.

4.3. Digitalisation and changes in water management and governance dynamics

Alongside the everyday organisational value of digitalisation processes to water management, we found other ways these digital technologies reconfigured the landscape of water management and governance.

The first component was a change in some organisational structures and responsibilities. We found that there has been a centralisation of power and focus on digitalisation in the organisation. The new T&I Department was responsible for overseeing all issues relating to digital transformation within GWCL, including implementation and strategic decision-making (GWCL Engineer 2). This structure integrates a series of previously distributed and separate responsibilities, covering three technology-related bodies (the Geographic Information Systems Department, the ICT Department, the Metering, Instrumentation and Non-Revenue Water Reduction Department) and the Research Unit (GWCL, 2019).

Given the growing role of digital within GWCL, T&I have increased outreach and connections with the rest of the organisation. Because of the introduction of e-billing and smart meters, for example, T&I officers and managers link out to meter readers and technicians, providing support and running training programmes. Because of the sensor and telemetry systems, they support and train field officers. Because of the growing role of digital in operations, they support and train regional and district managers. These were tasks not previously undertaken or not previously centralised in one department, being the responsibility of commercial and operations departments in the organisation, thus increasing the workload of the T&I officials (GWCL Engineer 1). Where the scope and reach of earlier incarnations would have been restricted mainly to corporate headquarters, "T&I managers and officers have now become central points in dealing with most technical field complaints associated with digital technologies such as meter reading" (GWCL Engineer 1). An institutional equivalent of the central control room with its panopticon-style overview of the whole water distribution network, the T&I Department now has a digital overview of the whole organisation, linked through the threads of its digital systems to every part of GWCL and its operations. Other changes include new ways in which the roles of operational level staff, such as those in the utility's Data Processing Units (DPUs) and meter readers, were now rethought to perform and support new commercial and *marketing-related* activities in the utility due to the emergence and deployment of e-billing and smart metering infrastructure respectively. For instance, in addition to reading meters using electronic devices, meter readers also support customer engagement work within the utility (GWCL Senior Official 1).

Second, digitalisation has been associated with some shifts in the locus of power within and outside the utility. First, there has been an upward shift in power to management from operational staff (mainly meter readers and some technicians). All meter readers interviewed raised this issue. Previously, these staff mainly lay beyond the direct gaze of management, but this is no longer the case. For instance, middle and senior managers can now monitor how lower-level staff operate and get data on their performance. Even the company's managing director can now monitor the operational performance of all meter readers (GWCL Meter Reader 2). A meter reader recounted: "I got my appraisal delayed because my performance information on the system indicated I hadn't achieved the 100% targets for the past three months. Data about work and our information is everywhere, even to the Chief Managers, so there is no room for shoddy works". Middle- and senior-level managers have thus gained greater power through their access to and capacity to use digital data as a managerial and epistemic resource within the organisation. Via digital technology, they have been able to cut through organisational layers that previously interceded between the top and bottom of the organisation.

Second, there has been a potential shift of some power to private sector actors, though this has continuously been contested as part of a historical pattern. This shift began shortly after the turn of the century when Indian company Aquamet was issued a contract in 2004 to supply, install and collect revenue from prepaid water meters (Shang-Quartey, 2017). Though the digital component of this project was limited, technical faults, along with the clash between profit and public welfare logic, led to the contract being abandoned. However, the connection between digital and privatisation continued with the management contract issued to Aqua Vitens Rand Ltd in 2006. During the five years of the contract, the foundations were laid for many of the digitalisations described above, including metering, mapping and customer engagement (Abubakari et al., 2013). However, due to human and technical implementation issues, these did not deliver the desired impacts and, driven much more by wider failure to improve water services and conflict between public and private sector culture and objectives, the contract was not renewed when it ended in 2011. These experiences stymied a further attempt in 2014 and 2015 to roll out prepaid meters. Despite this being a GWCL initiative, huge opposition by civil society organisations, shaped by past experiences of private operators and feeling that these meters "contributed to attempts in privatising 'public' water in the country" (Former Civil Society Organisation Coordinator), led to these initiatives being abandoned.

More recently, the implementation of the electronic billing project gave some form of de facto ownership or control of the system to a private operator, SOFTtribe. SOFTtribe is a Ghanaian software development company contracted to develop, manage, operate, and provide data integration services for GWCL's e-billing and e-payment systems (Digital Water Consultant). After about two years, SOFTtribe's control over key aspects of the system led to disagreements on the operationalisation, management and ownership of the system and its related data. This situation ultimately led to the termination of the contract between GWCL and SOFTtribe and was, therefore, just the most recent example of concerns about how private sector deployment of digital systems has led to a loss of power and control from the public to private sectors. This shift has derived from the power of the rights, processes and resources, including data and knowledge, that are bound up into digital systems, with those powers increasing as digitalisation spreads within the organisation.

A third potential power shift could be between the public utility and its customers. When asked how customers are represented in the digital water value chain, GWCL engineers and meter readers believed that smart meters offer customers elements of greater operational transparency and service benefits. For example, smart meters enable customers to pay only for "what they consume" and afford them the data resources necessary to monitor and challenge water bills (GWCL Meter Reader 3). However, such empowerment has been mainly hypothetical, with interviews showing very few customers taking advantage of the data smart meters offer. Conversely, customers and their actions become more transparent to GWCL, with the company knowing locations,

[4] By strategic level, we refer to how digital technologies are incorporated across business processes, high level operational priorities and long-term planning such as using advanced analytics and data integration services for decision making and foresight. Operational level focuses on the day-to-day activities and short-term decisions mostly by low-level managers such as using customer data for billing etc.

accurate usage levels and other information about their customers. For instance, some GWCL customers in Accra indicated that innovations such as smart meters have become devices used by GWCL to monitor their water usage and increase their bills.

5. Discussion

This paper focused on examining two main questions: (i) How are digital innovations implemented and deployed by a public utility (GWCL) in the urban global South, and (ii) how have those digital innovations impacted water service management and governance? Our findings underscore three implications for the digital transformation of water services, which are discussed below and derived from the three main contributions of the findings. First, while developing smart responses to solve key utility challenges in its digital infrastructure deployment, this utility's digitalisation approach and transition have been gradual and incremental. Second, the impact of digital water innovations is incremental, having limited impact in more strategic terms but already delivering value at the operational level. Third, digitalisation and datafication of water management present new avenues for reconfigurations, power shifts and contestations between and within organisations, as well as changes in organisational structures and responsibilities in water governance. Below, we discuss these findings and implications for water service management and governance in more detail.

5.1. Approach to water management digitalisation

Our findings demonstrate how digital deployments have been utility-led and gradual over the years but also shaped by the business case to improve efficient water management and service responsiveness. As we observed even from the historical context to date, there has been a gradual transition in the digitalisation processes as part of a broader 'regime of digitalisation' (involving a constellation of innovations such as electronic billing, sensors, smart meters, and customer engagement platforms) by GWCL, embedding different sets of technologies, at different times into broader digital infrastructures and becoming part of a broader transition of water infrastructures that are seeking to achieve greater sustainability and efficiency. Perhaps problems of existing innovation capabilities (e.g., human, financial, technological) do not allow (public) water service providers and innovators to venture into costly radical innovations, especially in African cities (Mvulirwenande and Wehn, 2020), and this explains this form and content of incremental water innovation within the utility, rather than in a disruptive manner. It can also partly be explained by the short-term financing of (often donor-funded) projects, which pose barriers to the sustainability of innovative approaches in utilities. Embracing digitalisation in organisational governance, service delivery, and water management processes may, therefore, be in line with achieving SDG 16 targets of building effective, accountable and inclusive institutions at all levels and SDG 6.1 of ensuring safe, reliable, and affordable drinking water for all, but financial and other capabilities and management culture will shape the extent of delivery against these goals.

5.2. Value and impact of digital transformation processes

The paper also demonstrates that a few years into the implementation of a digital transformation programme, the value from digitalisation was emerging slowly and incrementally, mirroring existing water management practices within GWCL and may be making some contribution to a few organisational goals. While some literature assumes that digital water innovations will be applied to strategic and outward-facing purposes (Antzoulatos et al., 2020), in GWCL they were instead focused on operational-level activities and decisions such as using technologies for accurate meter reading, pipeline monitoring, and producing real-time data for the day-to-day operation of water systems. This concentration of digital value at the lower levels of the organisation may reflect the relative recency of digitalisation and the continuous intermediation of humans in digitalisation processes within the company. It is beyond the scope of this study to undertake a cost-benefit analysis, but as the cost-saving findings show, there is potential that digital systems may make a positive contribution to the financial bottom line, particularly as growing numbers of customers adopt digital payment. Indeed, studies have reported more strategic benefits in the global North (Beal and Flynn, 2015; Owen, 2018).

Similarly, the study helps understand the incrementalism associated with water service digitalisation and digital water infrastructures within Southern countries regarding data's limited use and processing. It illustrates the lack of strategic value extraction from the large quantities of data generated by GWCL's new digital systems, with the existing impacts of datafication being operational. Hence, the datafication of water (the growing presence, use, and impact of data in water management processes) was largely unrealised by the utility. Within the study, for instance, we could not identify anyone within GWCL with responsibilities for extracting strategic value from data, and there was thus no clear mechanism to process and analyse the new digital data within the organisation and present it to middle and senior managers for their use. This lack of strategic data structures and processes could be linked to the relative recency of digital within the organisation, the lack of capability to verify the reliability and analyse big data for strategic decision-making, and the limited focus in the organisation on the potential strategic value of the data being generated. This finding reinforces existing literature on the under-utilisation by utilities of digital data to create insights due to a lack of competencies related to management, technology, and security and due to the siloing of activities and data within utilities (Sirkiä et al., 2017; Tutusaus et al., 2018). Therefore, this study questions the narrative of "digital water transformation" (Hoolohan et al., 2021) and highlights the much more incremental value being delivered by digital water innovations.

5.3. Socio-technical reconfigurations from digital transformation processes

Within the socio-technical configuration literature, infrastructures and their relationship with digital technologies have been seen to be associated with new forms of materialities, systemic power relationships and dynamic changes (Geels, 2002; Heiberg et al., 2022; Hoolohan et al., 2021). Our analysis offers insights about changes in roles and power and maps them in a global South context, which has implications for water governance and many actors within the water value chain in three ways.

First, internally, digitalisation has either increased the workload of some existing utility workforce or made others redundant, as well as changed some workers' roles. Contrary to the findings of earlier literature (Owen, 2018; Sarni et al., 2019), we found that – rather than automating human labour – the focus of some of those interviewed was how digitalisation increased the workload of some utility staff, especially those at the forefront of digital operations (e.g., officers and engineers in the T&I department) and at the same time reducing the workload of others. As digitalisation introduces new equipment and new systems to the water sector, the emphasis here, as predicted by Sarni et al. (2019), has been a need to employ new expertise and talent as well as to redeploy existing talents to core areas or to do other related work, rather than freeing them by automation. For instance, the meter reader role was rethought due to the emergence and deployment of smart metering infrastructure.

Second, our findings highlight how digitalisation has been associated with and even triggered power shifts and contestations with external partners such as Aquamet and SOFTtribe. There has been contestation over data systems ownership and control due to the involvement and power shift to private sector actors. The findings align with those of earlier literature, which links digital water innovations to shifts in power from the public to the private sector (Taylor and Richter, 2017) and similar findings in other public utilities (Heeks et al., 2021). While the rationality and automation associated with digitalisation might suggest eliminating or reducing power struggles through its decentralised or bottom-up networks (Hoolohan et al., 2021; Grievson et al., 2022), our findings present the opposite.

Third, the findings suggest and imply, perhaps unsurprisingly, that the digitalisation of water service provision and management had already introduced power shifts and contestations within GWCL by simultaneous empowerment and disempowerment of some actors. Our study found that central management and specific central departments (e.g., T&I) within the company seem to have epistemic control over different aspects of digital water innovation. Internally, then, digital systems have provided central management and supervisors with direct monitoring and epistemic control over the activities of some field and other lower-level staffs. The latter has thus been disempowered in relative terms. Also, though it is argued that digital infrastructure such as smart metering provides transparency to users, they are simultaneously used as tools (e.g., relative to differential datafication) for the relative empowerment of the utility vis-à-vis customers. Last, the centralisation and relative empowerment of the T&I Department will likely lead to tensions with other departments about who leads new digital initiatives and who controls digital systems and their related powers. Insight into power relations and digital water politics is essential for designing, implementing, and governing digital systems and water services. Therefore, the analysis here will be vital for understanding how digitalisation transforms, reproduces and reconfigures relations, power dynamics and knowledge systems within the water sector.

6. Conclusion

This article draws on multiple qualitative datasets to analyse the digital transformation of water management in Ghana's state water utility company. As a response to recent calls by scholars like Hoolohan et al. (2021) and Amankwaa et al. (2021) on the need for systematic examination of the impacts of digital water innovations within a wider socio-technical lens, the paper has provided real-world case evidence and empirical insights into the impacts and implications associated with water service digitalisation in the global South. We find digital water innovations to be recent, utility-driven and incrementally deployed across the water value chain. These innovations also deliver relatively limited and incremental impacts, with value mainly accruing at the utility's operational rather than strategic level. Digitalisation and datafication also present avenues for power shifts, contestations and struggles internally and externally, as well as changes in water management structures, roles and responsibilities. These findings have brought perspectives and clarity to some of the contemporary issues on digital water – i.e., difficulty in distinguishing between the hype and hope of digital technologies to tackle water sector challenges, especially in developing countries, as often evidenced in earlier putative and adoption-related studies or studies focused on private utilities (e.g. GSMA, 2022; Sarni et al., 2019), by extending space for understanding water sector transformation within a government-run public water utility in Africa. In addition to providing actual case evidence of digital transformation impacts, this paper adds to the literature on STS and organisational studies on the changes induced by technology in the water sector by providing a socio-technical lens showing how digital technologies come to be rooted in everyday realities and practices, norms and intermediaries within organisations.

While the largely qualitative approach adopted in this paper, self-selection/recall bias and the limited timeframe for impact assessment may limit the representativeness and generalisability of study findings, as explanatory research, we believe the evidence provided is valuable and can aid both water researchers and practitioners in the need to recognise both the value and political impacts of digital water innovations. Water service providers need to understand the "value gap" between the impact digital systems could have and what they currently have; for example, seeking more ways to extract strategic value from the datafication these systems enable. They need to grasp the politics of digital, seeing that these systems cannot simply be understood in technocratic terms, and particularly understand how digital may change the relationship with their customers. For example, there is a need for more inclusive water management models that could be applied to the growing diffusion of digital water innovations. We also recommend that water providers and funders invest in and develop agile structures with low levels of hierarchy and internalise digital and analytical functional skills within the utility to use data and information generated from digital water infrastructure to improve services to users. For researchers, more work on these issues is required, including analysis of digital systems over time; for example, to see if they start to have more strategic and transformative impacts within water service providers and externally to understand more fully the way that digital impacts power balances and relations with external stakeholders including customers. These studies can draw on longitudinal research design and core impact and organisational metrics such as KPIs and Return on Investments (ROIs) to understand digital impacts.

CRediT authorship contribution statement

Godfred Amankwaa: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Richard Heeks:** Writing – review & editing, Supervision. **Alison L. Browne:** Writing – review & editing, Supervision.

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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