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Research, part of a Special Feature on The Next Wave in Water Governance

Managing contractual uncertainty for drinking water services in rural Mali

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ABSTRACT. Contracts allocate rights, obligations, and risks between various parties to achieve specific results. In response to slow progress to deliver safe drinking water to rural populations, governments across Africa are increasingly introducing contracts with professional service providers. Contracts for drinking water service provision are designed to align operational outcomes with financial objectives. Yet, professional drinking water service providers generally miss revenue goals despite meeting their contractually agreed service delivery obligations. This mismatch between contractual expectations and outcomes in implementation speaks to wider issues of contract incompleteness. Contract theory indicates that renegotiation is a critical mechanism to adapt an incomplete contract design to uncertainties in operational and financial performance materializing during contract implementation. In this article we examine how contract incompleteness affects the sustainability of professional rural water service delivery and explore how and to what extent an incomplete contract might be addressed. Applying contract theory to a professional service delivery model operating in rural Mali, the empirical analysis uses qualitative methods to provide new insights on the process and consequences of contract renegotiation. Results of our case study show that contract renegotiation is conditional on the original parties' agreement to adapt the contract and also requires the involvement of external actors and capital to address the shortcomings of an incomplete contract design. In the Mali case, we find that the contract is incomplete because of the inability to enforce local water demand, hindering progress to revenue targets aligned with commercial finance. This condition is likely to hold in most rural contexts requiring contracting models for rural water services to combine public and philanthropic funding and private finance to deliver on desired outcomes.

Key Words: *Africa; contract theory; drinking water; Mali; professional service delivery; SDG 6*

INTRODUCTION

Contracts are part of everyday life. They govern interactions in a wide array of sectors and structure related activities, including employment, bank services, utilities (e.g., energy, water, or sanitation), insurance, or mobile phones. In its most basic form, a contract is an arrangement between two or more parties that allocates rights and obligations that can be legally enforced. Such an arrangement involves the exchange of goods or services, or a promise to exchange those at a future date and defines expected outcomes. Finally, a contract provides a process for resolution of contract infringements and termination (Hart and Moore 1988, North 1990).

We explore the extent to which contracts may provide a mechanism to support safe drinking water services in rural Africa where formal contracts are not usually applied. Rural water services are commonly delivered through informal community-based management. Despite significant investments in community approaches, progress has been largely unsatisfactory in maintaining rural water infrastructure (RWSN 2010, Foster 2013, van den Broek and Brown 2015, Whaley et al. 2019), leaving approximately 25%–30% of waterpoints in rural Africa non-functional (Foster et al. 2020).

In response to this limited performance, professional service providers are increasingly being mandated across rural Africa to ensure the operational sustainability of water supplies (McNicholl et al. 2021, Nilsson et al. 2021, WHO et al. 2022). This institutional shift toward more formal service delivery is organized through contracts that are designed to align operational outcomes with financial objectives (Hope and Rouse 2013, Hope et al. 2020). Contracts between professional service providers and governments may offer a suitable means to attract investment and capacity to accelerate progress toward the Sustainable Development Goal for Water, SDG 6.

Criteria pertaining to the drinking water service ladder (UNICEF and WHO 2023) can provide guidance on specific service outcomes that a rural water contract may define. Once contractually agreed, outcomes, such as water quantity, quality, or service reliability can be tracked over time to assess compliance, inform enforcement, and increase efficiency. In exchange, it is expected that a contract clarifies the service provider's revenue base, mainly by granting the right to collect tariffs from users (Gia and Fugelsnes 2010, Kleemeier and Narkevic 2010, Kleemeier and Lockwood 2012, McNicholl et al. 2019). This is in line with a policy principle, widely established across sub-Saharan Africa, stipulating that operation and maintenance costs of drinking water services are to be covered through tariffs paid by users (Foster 2016, Hope et al. 2019).

Although these policy objectives inform contract design for sustainable rural water services, in practice, contracts fall short of achieving anticipated results. Evidence indicates that professional service providers generally deliver on their obligation to provide drinking water services in accordance with contracted performance indicators. Yet, these service providers only rarely generate sufficient revenue via user payments to cover operating costs (McNicholl et al. 2020, 2021, Foster et al. 2022, Smith et al. 2023). In other words, while operational results are achieved, revenue goals are missed, despite contracts that are meant to promote financial sustainability are in place.

This mismatch between contractual expectations and outcomes in implementation speaks to wider issues of contractual incompleteness, a phenomenon well-studied by contract theory (Hart and Moore 1988, 2008, Hart 2003, 2017). Hart and Moore (1988) demonstrate that contracts are necessarily incomplete, yet adaptable throughout implementation. An important mechanism for adaptation consists in renegotiation allowing parties to adapt an incomplete contract design to uncertainties regarding

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anticipated performance. Even though contract theory appears as a salient conceptual tool, it has not yet been applied to rural water services. Therefore, in this article we draw on contract theory to provide a comprehensive understanding of the prospects and limitations of formal contracts with professional providers for delivering sustainable rural water services. What can contract parties do when contractually defined outcomes are not achieved? What are the implications for performance when changes to a contract are made? We explore these and related questions to generate new evidence on how to effectively sustain rural drinking water services.

CONCEPTUAL FOUNDATIONS

Incomplete contract design and renegotiation

Formal contracts form part of the human-made strategies for organizing and sustaining societal relations and economic performance and are established to reduce "uncertainties involved in human interaction" (North 1990:25). Any contract design may vary regarding the number of parties involved, the duration of the contract, or still the specific characteristics of the contracted outcomes. Yet, their common feature is that they provide the structure necessary to exchange goods and services over time. Here, Hart and Moore (2008) demonstrate that contracts act as reference points, shaping future performance by anchoring initial expectations of the contracting parties. When signing a contract, parties know how future payoffs will be distributed amongst them, how resources flow, or how risks are allocated.

This reduction of uncertainty is particularly relevant for more complex exchanges of services or goods that involve asset-specific investments (Goldberg and Erickson 1987, Hart and Moore 1988, Williamson 1995, 2002, Hart 2003). Long-term contracts may mitigate risks associated with the lock-in effect of asset-specificity where "buyers cannot easily turn to alternative sources of supply, while suppliers can redeploy the specialized assets to their next best use or user only at a loss of productive value" (Williamson 2002:176). Hence, when specific investments, such as infrastructure, are required for an exchange, parties may write a long-term contract, providing the necessary foundation for relevant investments.

Regarding the outcomes permitted by a contract, parties must navigate trade-offs between flexibility and rigidity (Hart and Moore 2008, Fehr et al. 2011). A rigid contract anchors parties' expectations through a fixed price and clearly defines the specific characteristics of the relevant good or service. A flexible contract, on the other hand, seeks to set a price range for a good or service whose specific characteristics will be defined during contract implementation. This allows parties to adjust the outcomes permitted by the contract to the contingent states of the world but may lead to friction and inefficiencies as the buyer and seller may have different preferences regarding which outcome to choose: "when the contract permits more than one outcome, each party may feel entitled to a different outcome" (Hart and Moore 2008:3). Besides, costs associated with writing and implementing a flexible contract are generally high (Hart and Moore 2008, Gottardi et al. 2017, Hart 2017), and the relative simplicity of a rigid contract seems to be appealing to contracting parties (Fehr et al. 2011, Gottardi et al. 2017). Therefore, in practice, parties tend to write more rigid contracts, particularly when asset-specific investments are involved (Hart and Moore 2008, Hart 2017).

Regardless of its rigidity or flexibility, contract theory suggests that any contract is necessarily incomplete (Hart and Moore 1988, 2008, Hart 2003, 2017). This inherent incompleteness is likely to become apparent during contract implementation when parties realize that specific issues have been overlooked in the initial contract design and expected outcomes will not be achieved (Hart and Moore 1988, Sansom et al. 2003, OECD 2011, Awortwi 2012). As gaps between contractually agreed and actual performance outcomes arise, specific mechanisms internal to the arrangement may be mobilized to address such shortcomings (Ménard 2004).

One such mechanism to address the inherent flaws of an incomplete contract, as demonstrated by Hart and Moore (1988), is renegotiation. Through renegotiation, contracting parties can adjust contractual terms to the uncertainties and contingent circumstances unfolding during contract execution, thereby adapting an initial contract design to observed performance. For instance, renegotiation can improve the efficiency of a contract as it enables the parties to readjust the expected outcomes to information from implementation (Hart and Moore 2008, Fehr et al. 2011). Besides, adapting contractual arrangements through experimentation (Huitema et al. 2009) may provide opportunities for wider learning to inform contract design and service delivery practice.

In addition to challenges related to incompleteness, for a contract to perform, the wider institutional environment matters, that is, the capacity of the contract parties or external actors to enforce contractual terms (North 1990, Messick 2005). The legal enforceability and regulation of contracts varies in a spectrum from conditions of mature contract markets to more informal social contexts. As such, it may be challenging to introduce formal contracting approaches to rural areas of developing countries where the reach of enforcement capabilities of state authorities is limited (North 1990, Messick 2005, Herbst 2015).

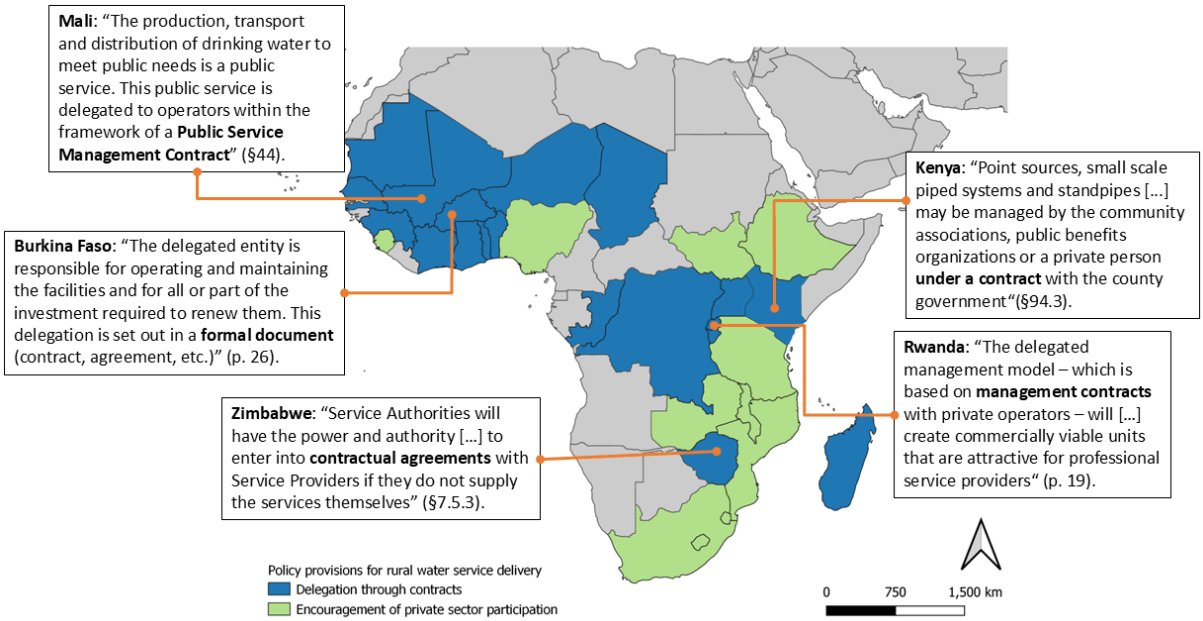
Finally, the scope of renegotiation is dependent on the willingness of the parties to renegotiate (Frydlinger and Hart 2024). Reputation and loyalty between the contracting parties can enable renegotiation to address incomplete contracts (Athias and Saussier 2018, Beuve and Saussier 2021), particularly when formal enforcement mechanisms are missing (North 1990, Messick 2005). Frydlinger and Hart (2024) demonstrate that frequent and transparent communication between the parties during contract implementation can help when changes to a contract are needed.

Rural water service delivery in Africa

The delegation of service delivery functions through contracts is widely established as a policy principle in rural water supply (Gia and Fugelsnes 2010, Kleemeier and Narkevic 2010, Kleemeier and Lockwood 2012, Simone et al. 2016). In various countries across sub-Saharan Africa, service authorities holding the infrastructure assets must delegate service delivery to a service provider, which can either be a public entity, private enterprise, or a legally recognized water user association. In several other countries, the involvement of the private sector in rural water service delivery is encouraged but the modalities of this participation are not further specified (Fig. 1).

The increasing interest in contractual approaches to service delegation is part of a wider institutional shift in rural water (Nilsson et al. 2021). In comparison to traditional community-based management, professional service providers deploy formal contracts tailored toward long-term service delivery, including

Fig. 1. Examples of delegation and private sector participation in rural water service delivery. Results of a desk review of national water policies, laws, and regulations. Quotations taken from the following sources: National Strategy for Drinking Water Services in Rural Areas (Ministry of Water and Sanitation of Burkina Faso 2018), Water Act of Kenya (Republic of Kenya 2016), Water Act of Mali (Republique du Mali 2002), National Water Supply Policy (Ministry of Infrastructure of Rwanda 2016), National Water Policy (Ministry of Water Resources Development and Management of Zimbabwe 2013). This overview of policy provisions does not draw conclusions about their implementation in practice.



repairs and wider support services for rural drinking water infrastructure (Lockwood et al. 2021). By defining expected service outcomes through contractual frameworks, results can be tracked by key performance metrics such as volume of water, local revenue, water quality, or repair time (McNicholl et al. 2019, Charles et al. 2023). This provides a basis for accountability, oversight, and user protection (Gerlach 2019, Lockwood 2021). In exchange, the contract defines a tariff that users are expected to pay for the service received (Gia and Fugelsnes 2010, Kleemeier and Narkevic 2010, Janssens 2011, Koehler et al. 2018, McNicholl et al. 2019).

In addition to the specific service outcomes that a contract may define, the particular type of contract in place has implications on how risks are distributed amongst contracting authority and service provider. In the literature three main contract types have been identified for rural water services, ranging from management, over lease, or *affermage*, to concession contracts (Table 1).

Generally, delegation involves a transfer of financial risk from the asset holder to the operator. Depending on the scope of delegated service functions and associated risks, the duration of the contract will vary (Sansom et al. 2003, Gia and Fugelsnes 2010, Janssens 2011, OECD 2011, Hydrophil 2013, WSP 2014). For instance, if a contract requires the service provider to make infrastructure investments, creating major financial risks, the time frame for the contract will typically be of at least 15 years to allow for a sufficient pay-back horizon.

Yet, regardless of the particular contract type in place, revenue goals of contracted rural drinking water service delivery models are not achieved in many cases (Katuva et al. 2016, McNicholl et al. 2020, 2021, Koehler et al. 2021, Foster et al. 2022, Smith et al. 2023), pointing to wider issues of contractual incompleteness. Because "contracts are often drawn up using incorrect assumptions" (Gia and Fugelsnes 2010:16), it is only during contract implementation that mismatches between expected and actual outcomes materialize, suggesting that the initial contract design did not adequately consider the specific economics of rural water and associated uncertainties.

Uncertainties related to rural water user behavior

Rural water is characterized by particular geographical, spatial, socio-political, and economic factors shaping its specific economics and uncertainties. Importantly, the prevalence of alternative or seasonal water sources on which rural users potentially rely leads to uncertain demand because rural households can choose between various water sources for different uses (White et al. 1972, Briscoe et al. 1981, Thompson et al. 2001, Martínez-Santos 2017, Hoque and Hope 2018, Gross and Elshiewy 2019).

This specificity may not always be considered in policy and practice, leading to flawed assumptions about the role and obligations of water users. It is assumed that users will use and pay for the service as planned. However, rural water is characterized by a high degree of autonomy of users, leading to

Table 1. Contract types for the delegation of rural water services. Adapted from existing typologies (Sansom et al. 2003, OECD 2011, Hydrophil 2013, WSP 2014, REACH and RWSN 2023).

Type of contract	Management	Lease/*Affermage*	Concession
Obligations of service provider	Provide specific management services	Operate and maintain assets, deliver water services, undertake billing and tariff collection	Finance and construct new infrastructure, operate and maintain assets, deliver services, undertake billing and tariff collection
Typical payment mechanism	Fixed fee	Revenue from customers minus lease fees	Revenue from customers minus concession fees
Capital investments	Contracting authority	Shared (infrastructure from contracting authority, operating assets from service provider)	Service provider
Asset ownership	Contracting authority	Contracting authority	Contracting authority or service provider
Risk transferred to provider	Low	Significant	Major
Typical duration	3–5 years	6–15 years	15–30 years

relative demand uncertainty. The non-exclusive nature of rural water constitutes a fundamental challenge when a contract links revenue to water production and sales, thereby effectively allocating the commercial risk to the service provider (Janssens 2011). Also, the limited ability of rural users to pay may further constrain demand for professional rural water services (Hoque 2023).

In addition, evidence indicates that user demand and payments are contingent on the quality of services provided (Nauges and Whittington 2010, Foster and Hope 2017, Van Houtven et al. 2017, Shongwe and Dlamini 2021). Hence, a service provider has an incentive to influence user demand to generate sufficient revenues. Engaging in value creation by delivering high-quality services that people want and value (Garrick et al. 2017, 2020, Hope et al. 2020) appears as an adequate strategy for service providers to increase their revenue (Carter et al. 2010). Here, contractually agreed service attributes pertaining to water quantity, quality, affordability, proximity, and reliability may provide guidance on key priorities of rural water users (Hope et al. 2020).

Following the rationale that contracts can be renegotiated during contract implementation (Hart and Moore 1988), contractually agreed outcomes and conditions may be revisited to promote more sustainable services. In the case of rural water services, such contractually agreed outcomes may reflect service attributes pertaining to water quantity, quality, affordability, proximity, and reliability (UNGA 2015).

To examine the role of formal contracts and the implications of renegotiation and service adaptations for sustainable rural water services, we investigate how contract incompleteness affects the sustainability of professional service delivery and explore how and to what extent an incomplete contract design might be addressed. Using the contractual model of a professional drinking water service provider in rural Mali as a case study, we analyze how different actors behave to overcome the limitations of an incomplete contract and assess how service adaptations allow to address these shortcomings. Drawing on contracting documents, interviews, and field reports, we illustrate how renegotiation and changes in service attributes influence contractual outcomes.

Similar to Frydlinger and Hart (2024), we use contract theory to qualitatively illustrate the prospects and limitations of implementing formal contracts in a specific context. Following a pragmatic research philosophy (Feilzer 2010, Kaushik and Walsh 2019), the paper integrates contract theory, grounded in a positivist epistemology, with a constructivist methodological design. This approach constitutes the originality of our paper, providing new conceptual and empirical insights into the extent to which contracts with professional service providers can serve as an effective mechanism to enhance the operational and financial sustainability of drinking water services in rural Africa.

CASE PRESENTATION

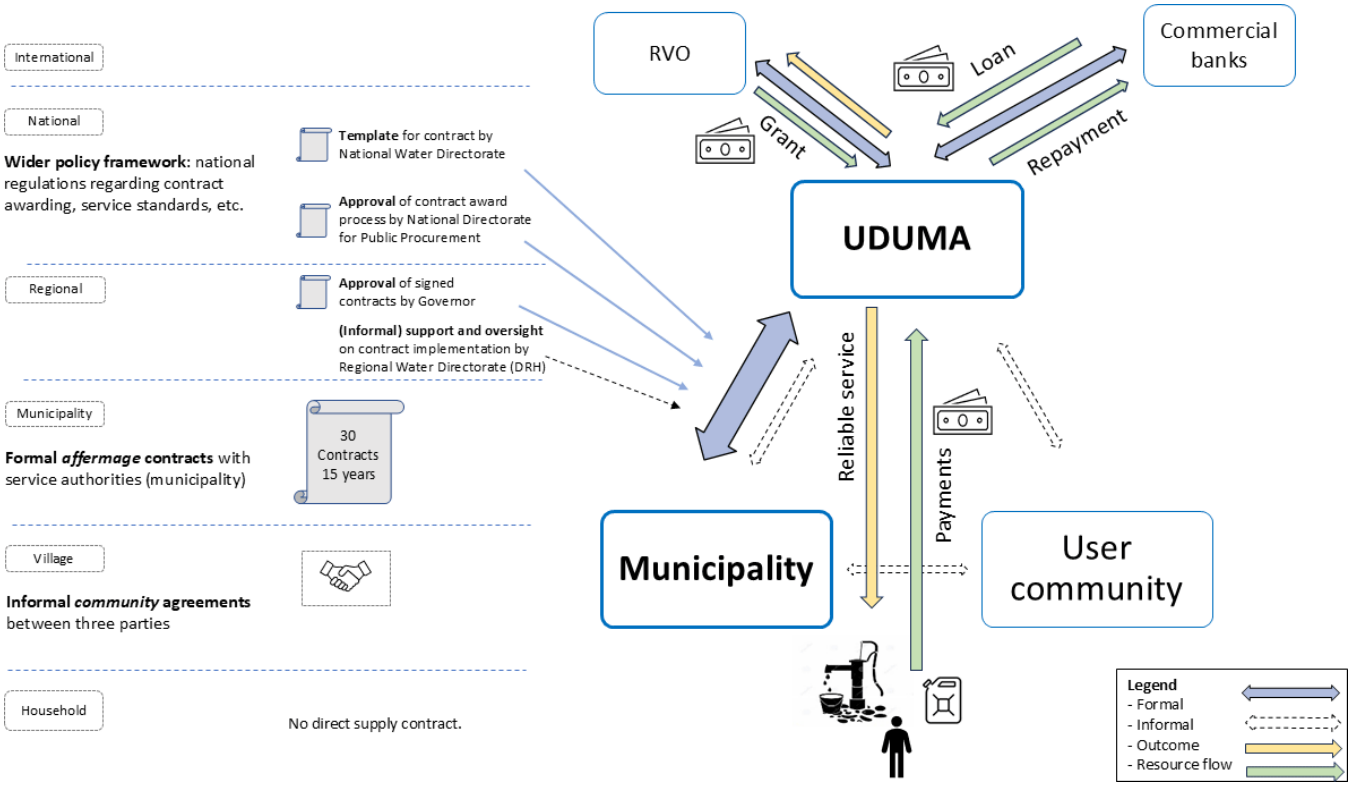
Context

Mali's water sector is based on the Water Act (Republique du Mali 2002), which defines the general institutional framework, stipulating local governments as service authorities for rural water supply (Article 49). Municipalities, Mali's lowest government level, bear the ultimate responsibility for drinking water services on their territory (Article 50) but must delegate service provision to a provider, which can either be a private or public entity, or a legally recognized water user association (Article 45). The delegation must be organized via a formal contract (Article 51) including a service level agreement that clarifies terms and conditions of the service (DNH 2007). In our case, 30 local governments in the Region of Sikasso, located in the south of Mali, decided to contract UDUMA, a professional service delivery company with a business model based on full cost recovery through user payments (van der Wilk 2019).

UDUMA's service delivery model

Through the initial contracts signed in November 2018 (UDUMA 2018, *unpublished report*), these municipalities grant UDUMA for a duration of 15 years (§ 5) the exclusive right (§ 6) to set up its service model in their respective territories, covering all existing hand pumps for community drinking water supply, and to collect tariffs from users (§ 1). In exchange, the provider invests in the rehabilitation of the water supply infrastructure, which will be handed over to the service authorities after the end of the contract (§ 7), and commits to their subsequent operation and maintenance. This contractual relationship, where an operator invests in existing infrastructure and is responsible for its operations and maintenance and bill collection from customers, is a particular type of a lease contract, called *affermage* (see Table 1). As part of the contract, UDUMA must ensure a bi-annual financial and technical reporting to the service authorities for accountability purposes (§ 12) and pay a fee of 3% on its annual billed and paid turnover (§ 20). Local governments have hence a financial incentive to adhere to the contractual agreement (UDUMA 2017, *unpublished report*).

Fig. 2. Illustration of UDUMA's contractual model.



Regarding the user-provider relationship, UDUMA commits to providing a reliable service, guaranteeing a maximum downtime of 72 hours per waterpoint, and must conduct regular water quality monitoring and relevant interventions in case bacterial contamination is detected (Annex 2 of the contract). In exchange, water users must pay a volumetric, pay-as-you fetch tariff of 500 FCFA ($0.80) per m³ (§ 21 and Annex 2), in accordance with Mali's tariff policy for rural water supply (DNH 2007). Under a pay-as-you-fetch (PAYF) approach, users must directly pay the caretaker for the amount of water they collect from the hand pump.

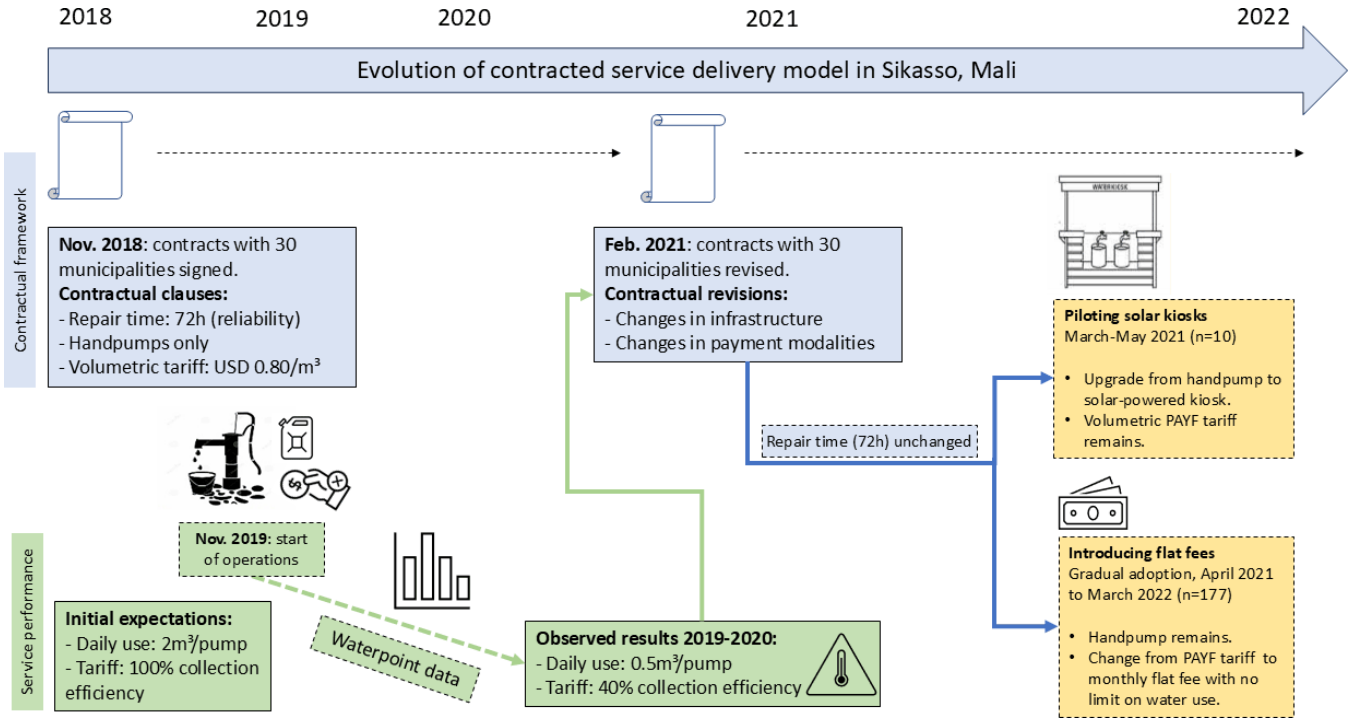
Through the guaranteed service, users are insured against operational risks of hand pump failure and can mitigate financial risks of high repair costs, which constitute a major factor for sustained downtime (Jones 2013, Foster 2013, Foster and Hope 2016). Environmental risks related to groundwater pollution are addressed to some extent through regular water quality testing and water safety plans implemented at the village level (§ 14 and Annex 2). UDUMA's contract may be considered rigid as it defines expected outcomes clearly and "take[s] price off the table" (Hart and Moore 2008:25).

UDUMA's initial business model assumes a daily water usage of at least 2 m³ per hand pump and projects no default in volumetric payments (100% payment collection), effectively tying revenue to water demand, billing, and bill collection. Because its financial model is based on cost recovery through user payments, UDUMA has clear expectations about the outcomes of its exclusive contracts. Once contracts are in place, officializing a shared understanding of the terms of the agreement, financial sustainability will be achieved because people will use and pay for the service provided (UDUMA 2017, 2018, *unpublished reports*).

The formal contracts are complemented by informal community agreements (§ 15 and Annex 4), linking UDUMA with local governments and user communities (Fig. 2). These arrangements at the local level are signed by representatives of the three parties and are meant to ensure social acceptance of the service delivery approach, contributing to "institutional sustainability" (UDUMA 2017:12, *unpublished report*).

To cover a share of the initial capital costs required for rehabilitating hand pumps at scale, UDUMA received funding from the Netherlands Enterprise Agency (RVO), providing a grant of €3 million through its Sustainable Water Fund (RVO 2017). In addition, the long-term contracts signed with the municipalities enabled UDUMA to secure private loans at market rates of a total amount of €2 million, thereby creating liabilities. Because the French commercial banks required guarantees (van der Wilk 2019), the *affermage* contracts turned into an "essential asset" (personal communication with UDUMA team, 19 July 2021). They mattered to build confidence in the long-term nature of the investment case, especially because the "political risk associated with investing in developing countries ... caused hesitation" (van der Wilk 2019:7). The business model at scale was meant to allow "for reimbursing the initial 40% private capital investment" while generating an adequate return on investment (van der Wilk 2019:5).

Fig. 3. The evolution of UDUMA's contractual model.



Evolution of the contractual model

Yet, the contracts encountered implementation issues on the operational level, leading to unexpected revenue shortfalls. As outlined above, UDUMA's initial business model assumed an average daily water usage of 2 m³ per hand pump and projected no default in volumetric payments, effectively tying revenue to water demand and payment collection. Operational and financial data from the first two years of operations, however, revealed that these assumptions were flawed. Only a quarter of the anticipated daily water volume was actually used, and users paid only 40% of water collected, emphasizing that its contracts were incomplete because of the inability to guarantee water demand and enforce volumetric payments. The payment enforcement challenge encountered at hand pumps under the volumetric payment modality is related to the fact that waterpoint caretakers in charge of payment collection did "not have the capacity to impose themselves when needed" (UDUMA 2021:28, *unpublished report*). This illustrates wider issues of enforcing formal contracts in settings where more informal social practices and specific community dynamics may be at play.

In response to the observed performance, UDUMA used Article 33 of its contract to renegotiate contractual conditions with local governments prompting two service adaptations related to water quantity and tariff design (UDUMA 2021, *unpublished report*). Figure 3 provides an overview of the evolution of and relevant changes to UDUMA's contractual model.

UDUMA proposed to local governments to initially trial solar-powered water kiosks in 10 villages, reflecting the diverse geographical, socioeconomic, and environmental conditions of its service area. The infrastructure upgrade increased the production capacity of the existing waterpoint initially equipped with a manual pump supplying one spout to a solar kiosk supplying three on-demand taps. As part of the contractual revisions, UDUMA changed payment modalities at hand pumps by replacing direct volumetric payments through a monthly flat fee of 15,000 FCFA ($24) per waterpoint, with no limit on water use (UDUMA 2021, *unpublished report*).

METHODOLOGY

UDUMA's contractual model emerges from dialogue involving multiple stakeholders. Because "important aspects of institutions and institutional change appear in the form of qualitative evidence" (Skarbek 2020:409), conducting a qualitative case study seems appropriate as it presents an opportunity for in-depth learning and exploratory investigation (Gerring 2004, Flyvbjerg 2006, 2011, Yin 2009).

We justify the case selection with the "revelatory" and "longitudinal" nature of the UDUMA case (Yin 2009). First, investigating UDUMA's model may be revelatory for other contexts. The role of commercial, long-term contracts in the delivery of rural water services remains empirically underexplored. This gap is mainly due to the limited availability of cases in Africa, where "most countries have not demanded significant investments in infrastructure from their private partners" (Kleemeier and Lockwood 2012:1). That a private enterprise commits to carrying sizable commercial risks is rare for the provision of rural water services and may thus be revelatory for other contexts. Because professional service delivery is a wider trend in rural water across sub-Saharan Africa, empirical insights from this case study may be of relevance for other service delivery models and contexts. Second, "studying the same single case at

two or more different points in time" (Yin 2009:49) allows to analyze how a contract-based service delivery model evolves over time. This can provide insights on the underlying processes and consequences of contractual changes in service delivery.

To unpack the process and outcomes of contract renegotiation, the empirical research applies qualitative approaches to data collection and analysis that will be presented in detail in the following sections. Prior to any data collection and analysis, ethical approval was obtained from the Research Ethics Committee at the corresponding author's university (SOGE 1A2020-195 and SOGE 1A2020-210).

Data sources and collection

The study draws on various sources of primary and secondary evidence. For the collection of the empirical material, specific sampling strategies were developed, guiding the data collection process. To contextualize the study case in Mali's national water policy context, semi-structured expert interviews with representatives (n = 14) from organizations intervening in the water sector in Mali were conducted online throughout the year 2021. To ground the implementation of UDUMA's contractual model and understand the implications of the service adaptations, in-person fieldwork was conducted in May 2022 in 9 villages of UDUMA's service area to interview a total of 36 water users, 8 representatives of local governments, 9 representatives of village committees, and 3 UDUMA field staff. In addition, the lead author conducted 6 in-person workshops and 13 online meetings with staff from UDUMA France between 2020 and 2023 to understand the service model and trace its evolution. Finally, interviews with representatives of relevant funding agencies were conducted to clarify their role in UDUMA's model.

Fieldwork in Mali: interviews with local stakeholders

In recognition of UDUMA's institutional model (Fig. 2), the corresponding author conducted in-person fieldwork in May 2022 in 9 villages that are part of UDUMA's service area to interview representatives from municipalities as contracting authorities, drinking water users using and paying for UDUMA's service, and community representatives. During interviews with the respective stakeholders, notes using pen and paper were taken to limit any perceived power imbalances between participants and researcher (Fetterman 2010, Mannay and Morgan 2015). Subsequently, these notes were transcribed for further analysis.

The field sites (see Appendix 1, Table S1 and Fig. S1) were purposely chosen. As presented above, UDUMA selected 10 sites across 9 municipalities to trial solar kiosks. The selected waterpoints were upgraded between March and May 2021. Payment modalities at the remaining hand pumps were shifted from volumetric payments to monthly flat fees. One year after these changes, allowing relevant stakeholders to gain experience with the new infrastructure and payment modality, fieldwork was conducted to understand their perceptions of the service changes prompted by the contract revisions.

UDUMA facilitated the fieldwork by providing support in terms of logistics (dispatching a car and driver). In addition, UDUMA's field officer in charge of community engagement acted as a door-opener to the various stakeholders and ensured translation between French and Bambara. Although the UDUMA employee's intimate understanding of the fieldwork setting was crucial for enabling the data collection, this set-up may have created an interviewer bias because the interviewees' opinions may have interfered with the relationship existing between them and UDUMA as the target organization.

A total of 36 semi-structured interviews with water users asking open-ended questions (Tong et al. 2007, Narayanasamy 2009) were conducted to understand their subjective perceptions, opinions, and experiences of the services delivered by UDUMA. Three to five users were interviewed at each site. The interviews (see questionnaire in Appendix 2) covered key themes such as the degree of user satisfaction, practices, motivations, and interpretations regarding UDUMA's service and related service adaptations. The sample strategy for the user interviews was informed by purposive sampling to recruit participants who have the potential to provide rich and diverse data pertinent to the research question (Tong et al. 2007).

In addition, contextual data through waterpoint mappings were collected. The main alternative water sources in each village (e.g., community wells, hand pumps, small piped systems, surface water sources) were identified and source characteristics, such as functionality, perceived water quality, and management arrangements (e.g., ownership and water price), were recorded using a mobile data collection tool (https://odk.ona.io/). In case people were fetching water at alternative sources, short questions were asked to understand their motivations and perceptions of UDUMA's service.

Semi-structured interviews with eight representatives from local governments were conducted to gather insights on the perspective of the service authorities as formal party to the bilateral contract. The interview respondents were either the municipality's mayor, Secretary General, or the officer in charge of Water, Sanitation, and Hygiene (WASH). The interviews focused on understanding the municipality's rationale for initially joining the arrangement and its perception of the relationship with UDUMA.

Informal discussions with village and community representatives were designed to unpack collective perceptions of UDUMA's service. Because the community agreements were meant to ensure community buy-in, the conversations were tailored to understand the communities' perceptions and motivations shaping the outcomes of the contract arrangements.

Data on the provider's perspective: interviews and project documents

Three interviews with local UDUMA staff in Mali were conducted to collect information on the provider's perspective regarding the implementation of the contract. Particularly, insights on the application of specific contractual clauses, such as payment enforcement, as well as the wider processes of renegotiation were gathered.

In addition to the in-person interviews with staff from UDUMA Mali, the lead author conducted a total of 19 in-person and online meetings with staff from UDUMA France throughout the research process spanning 2020 to 2023 (see anonymized list of meetings in Appendix 3). These exchanges allowed to build a detailed understanding of UDUMA's service model and its evolution.

Lastly, the formal service delegation contracts (initial version from 2018 and revised in 2021) and related appendices were retrieved from UDUMA (UDUMA 2018, 2021, 2021, *unpublished reports*). In addition, relevant project documents were compiled, consisting of UDUMA's initial project proposal to RVO (UDUMA 2017, *unpublished report*), various annual progress reports (UDUMA 2018, 2019, 2020, 2021, 2022, *unpublished reports*), a report from the Regional Water Directorate (DRH) from 2020 (DRH 2020), and UDUMA's formal request to RVO for a strategy change of the initial project (UDUMA 2021, *unpublished report*).

Data collection at the national level: expert interviews
For the interviews at the national level, a combination of purposive (seeking representatives of government, donors, civil society, and NGOs) and snowball sampling was used to identify 14 key informants from relevant technical and political organizations intervening in the water sector in Mali (see anonymized list of interviews in Appendix 4). The semi-structured expert interviews were conducted based on problem-centered expert interview methods (Merton and Kendall 1946, Witzel 1985) that restrict the information that is expected from interviewees but still allow respondents to identify aspects that are not addressed in the interview guideline (see questionnaire in Appendix 5). The interviews lasted approximately one hour and were conducted online in French by the corresponding author throughout the year 2021. Notes were taken during the interviews and subsequently transcribed for further analysis.

Data on the perspective of donors: interviews and project reports
Interviews with representatives of RVO and a private foundation were conducted to understand their role in the initial arrangement and for the evolution of UDUMA's model. The semi-structured expert interviews (see questionnaire in Appendix 6) were conducted online by the corresponding author. Notes were taken during the interviews, and subsequently transcribed for further analysis. In addition, documentation (RVO 2022) and project data (RVO 2017) were retrieved online.

Data analysis
A single case study design attempts to provide an intensive analysis, characterized by detail, richness, and completeness. The internal validity of a case study is likely to improve when it combines various data sources to generate complementary insights that substantiate an argument (Ragin 1992, Gerring 2004, Flyvbjerg 2006, 2011). Therefore, we make use of triangulation of multiple sources of empirical material (Johnson et al. 2007, Yin 2009) to develop a coherent understanding of UDUMA's contractual model and its evolution over time.

First, UDUMA's initial and revised contracts were systematically reviewed to identify changes in contractual provisions. Subsequently, interview notes and project reports were qualitatively analyzed to generate insights on the respective perceptions and experiences of the various stakeholders to unravel the process leading to the identified changes in UDUMA's contracts. Coding was done following an inductive, data-driven approach building on the concrete empirical material, while being guided by the research questions. The open-coding approach allowed to extract relevant information pertaining to perceptions and underlying motivations of the respective actors (Ercan and Marsh 2016, Silverman 2017). The qualitative analysis focused on identifying key relationships and recurring motives to trace changes of the contractual model. Synthesis of findings across the interviews and documents allowed to provide an expanded understanding of UDUMA's contract design and evolution. Finally, user interviews were analyzed regarding factors related to water quantity, quality, affordability, reliability, and proximity and their relative priority. Importantly, we use interview excerpts to illustrate whether and how user responses change in regard to the contractually agreed adaptations in service delivery. Through the corroboration of empirical insights, we seek to establish coherent evidence for our conclusions.

For the use of direct quotations from expert interviews, expressed approval from interviewees was received because attribution to individuals may be possible despite anonymization. To avoid misinterpretation and to build credibility for the research's conclusions, informant feedback was sought by sharing the manuscript with key informants, thereby further strengthening the study's internal validity (Onwuegbuzie and Leech 2007).

RESULTS

In exploring the implementation of formal contracts for drinking water service delivery in rural Mali, we found evidence that rigid conditions do not necessarily allocate risks effectively. A certain degree of flexibility in UDUMA's financial arrangements was required for the service model to continue. The results emphasize the role outside actors to the formal contracts played in shaping the renegotiation process of UDUMA's initial contracts. Finally, we illustrate how contractual incompleteness was partially addressed by adapting specific service attributes, so that services better aligned with the preferences of water users and increased the enforceability of the contract.

Does a more rigid contract effectively allocate risks and responsibilities?

Within the first months since UDUMA had started its service in Sikasso, evidence indicated that the initial contract was incomplete. Although the first year of operations was deemed too early to draw conclusions about the sustainability of the model (UDUMA 2020:25f, *unpublished report*), UDUMA stated in its third progress report to RVO: "The past year (April 2020 to March 2021) has been eventful for Uduma. ... We have been forced to rethink our model" (2021:2, *unpublished report*). With an "average daily water use of 544 liters per pump" instead of the anticipated daily volume of 2 m^3 and users paying "only 40% of total water used" (UDUMA 2021:31, *unpublished report*), the provider missed its viability target by a margin. The commercial risk of linking revenue to water production and sales materialized, suggesting that the initial contract had overlooked relevant contingencies (Hart and Moore 1988).

Despite the revenue shortfalls, UDUMA remained responsible for guaranteeing a reliable service in line with the performance indicators of its service level agreement, thereby covering operational risks related to hand pump failure. Because of the recurring commercial losses, UDUMA was "determined to take the necessary actions to adapt the model" (2021:6, *unpublished report*). Yet, the company was dependent on the agreement of the municipalities as contract authorities to permit changes to its rigid contracts.

Here, the Regional Water Directorate (DRH) came into play. With its role steered toward supporting contract implementation, DRH staff conducted four field missions in Sikasso in April 2020 to exchange with water users, village leaders, municipalities, and UDUMA to understand the reasons for non-compliance with the contractual arrangements. DRH recommended that UDUMA should consider installing solar-powered water kiosks or water ATMs to respond to the user population's increasing demand for higher service levels (DRH 2020). Other donors such as UNICEF and Helvetas already had started investing in small solar-powered drinking water systems in the region of Sikasso, providing a precedent for user communities and local governments (interviews with Donor-ML-1, Donor-ML-2, Donor-ML-3 in 2021, and with UDUMA-1 in 2022).

Because the initial contracts limited the infrastructure portfolio to hand pumps (UDUMA 2018, §1, *unpublished report*), an amendment of the contract with the local governments was necessary. All 30 municipalities expressed their agreement with the proposed change in strategy. Because upgrading all existing hand pumps to solar kiosks was not feasible due to economic, technical, or environmental constraints, UDUMA proposed to change modalities for collecting user payments at hand pumps as the volumetric payment approach was contested by the user population (DRH 2020; UDUMA 2021, *unpublished report*). The municipalities signed amendments to the formal contracts with UDUMA allowing the installation of solar kiosks and the introduction of monthly flat fees at hand pumps (UDUMA 2021, *unpublished reports*).

By doing so, the municipalities not only ensured a reliable service to their populations but as well received improved infrastructure without having to provide additional commitments as UDUMA continued to carry the commercial and operational risks. Yet, the municipalities' agreement to revise the contracts may not only be related to strategic considerations. Through UDUMA's bi-annual reporting, the municipalities were aware of the significant operational and commercial challenges. Annual in-person meetings between UDUMA and the local governments were held to discuss problems related to contract implementation and fostered a "climate of trust" between the contracting parties (UDUMA 2021:15, *unpublished report*). As findings from contract theory suggest, frequent and transparent communication can promote a constructive relationship where contracting parties are more likely to apply principles of fairness or loyalty when changes to a contract are needed (Frydlinger and Hart 2024). During interviews, representatives of local governments indicated an appreciation of UDUMA's continued commitment, despite the difficulties related to contract execution.

Although the formal parties to the bilateral contracts agreed to revise some of the rigid clauses, upgrading infrastructure required additional financial resources. However, the provider's capital was constrained, providing no room for further investments, and potential losses. Because the revenue generated in Mali was insufficient to fulfil the loan obligations, ODIAL SOLUTIONS, UDUMA's holding company, ensured the repayment of the €2 million loan, taking on the financial risks associated with the private capital investment (interview, UDUMA-3, 4 October 2023).

In October 2020, UDUMA presented the conclusions of the DRH report and a financial analysis to RVO to demand a re-allocation of funds toward the installation of solar kiosks. According to UDUMA (interview, UDUMA-2, 19 May 2022), RVO requested a proof-of-concept regarding the financial and operational sustainability of solar kiosks. RVO had committed to funding a public-private partnership tailored to installing 1400 hand pumps and subsequently maintaining them throughout 15 years, expecting to reach about 500,000 beneficiaries at relatively low costs (RVO 2017; UDUMA 2017, *unpublished report*).

In December 2020, a foundation supporting UDUMA's wider work, agreed to fund the installation of 10 solar kiosks as a pilot project in nine municipalities (UDUMA 2021, *unpublished report*). When asked for the reasons to support piloting solar kiosks in Mali, the foundation staff commented:

> *Regarding the transition to solar in Mali, we already had a grant in place with UDUMA. This grant covered a broad range of activities in Mali and Burkina. Both countries are priority countries for us [the foundation]. UDUMA said that they wanted to re-allocate the money to pilot solar pumps in Mali. I approved since our grants do provide that flexibility. UDUMA can reallocate the money, as long as they remain within the boundaries of the initial grant approval. We knew that there was the RVO funding as part of the UDUMA model. But it was UDUMA who knew how to use our funding to convince RVO to change the initial strategy and to integrate the solar pumps into the portfolio. In the end, UDUMA used our flexible money to make a point they needed to demonstrate.* (interview, 28 November 2023)

This agreement illustrates the foundation's flexible funding approach, which permits risk taking in comparison to more traditional bilateral donor funding:

> *As part of our funding approach, we try to be non-prescriptive and flexible. We want to align with the grantee's priorities. We give them the freedom to do what they think is best for them and their beneficiaries or clients. We want to be complementary to other funders, so we fund things that others do not want to or cannot fund. And we aim to do things where perceived risks are high. Mali as a context is risky, fine. UDUMA is an established company, linked to Vergnet Hydro. That is not very risky. But UDUMA's business model is. It is a market-based approach for rural drinking water services, this is something very unusual in the rural water sector. I don't think that they managed to really prove their business model yet.* (interview, foundation staff, 28 November 2023)

The solar pilot proved to be catalytic for adapting UDUMA's model. As UDUMA pointed out: "We were able to show that something works in Mali. At least, the revenues improved with the solar kiosks. This was certainly one of the reasons why RVO agreed to re-allocate the funding" (interview, UDUMA-2, 28 November 2023). The results of the pilot allowed UDUMA to secure additional funding from new partners, such as foundations organized in the "WASH Funders Group," and to scale up investments in solar kiosks providing a basis to support continued work (UDUMA 2021, 2022, *unpublished report*).

However, RVO "needed time to come to a decision" regarding the transition to solar as investing in more expensive infrastructure

meant that "the number of beneficiaries decreased significantly. We needed assurance that the proposed model would be accepted by the population and be viable" (interview, RVO staff, 7 December 2023). According to UDUMA, as part of RVO's formal change request process, the Dutch Embassy in Mali was invited to give their perspective on the proposed strategy. In addition, RVO required that the change of the project aligned with the policy priorities of the Government of Mali. Here, the DRH report from 2020 allowed UDUMA to demonstrate its alignment with Mali's official position (interview, UDUMA-2, 28 November 2023).

At the end of 2021, RVO agreed to re-allocate the initial funds permitting investments in solar kiosks:

> *We looked at the changes of the solar pilot and reflected on the implications forward. Data and feedback from the field showed that the willingness to pay, the revenues, and cost-recovery improved. And we saw that other donors were convinced as well. So, we agreed to the change in strategy. I think that we have still been quite flexible in our approach, particularly in comparison to the initial project.* (interview, RVO staff, 7 December 2023)

UDUMA staff indicated that besides the encouraging financial performance registered at solar kiosks, the involvement of other donors was a salient argument for RVO. The additional funding from other partners allowed to mitigate to some extent the reduction of the number of beneficiaries reached (interview, UDUMA-2, 28 November 2023).

As the interview insights illustrate, the respective priorities and constraints of UDUMA and RVO did not necessarily align for permitting a rapid adaptation to changing circumstances. Yet, at the end of the process, an agreement was reached. Here, the entrepreneurial attitude of the provider may have mattered: "UDUMA made suggestions to adapt the project strategy and the solar pilot was part of it. As the private partner, UDUMA had invested €2 million as their own contribution. UDUMA really wanted to achieve results" (interview, RVO staff, 7 December 2023). Besides, RVO's approach must be seen in the light of the requirements attached to spending tax-payers' money for development projects. While tracking the achievement of its political commitments through numbers of people reached, RVO was as well looking for a "systemic change by trying to do new things or [by] doing things differently" (interview, RVO staff, 7 December 2023).

Five years after allocating the initial grant to UDUMA, RVO reflected on wider learnings related to projects supported through its Sustainable Water Fund, putting an emphasis on allowing for more flexibility during project implementation:

> [A] more flexible procedure for future programs will allow (more) room for adjustments ... of contracted projects, and for better exploration of interesting new concepts and ideas that otherwise might be lost (too) early (RVO 2022:6). *[Therefore,] "program design should allow for flexibility and adaptation of a project, while maintaining the focus on sustainability. ... Learning by doing, and the willingness to improve is at the heart of this, rather than monitoring for accountability only* (RVO 2022:18).

UDUMA's rigid contracts with municipalities allocated operational, commercial, and financial risks to the provider while omitting that flexibility in the financial arrangement may be required to allow for navigating uncertainties. The results suggest that contract renegotiation and effective risk allocation is not only conditional on the agreement of the formal parties to the contract but intimately linked to the behavior of outside actors to the contract and the availability of catalytic resources, permitting contractual changes.

How can renegotiation address incomplete rural drinking water service contracts?

Although local water users do not have a direct contract with UDUMA (Fig. 2), they are crucial for the sustainability of the model as they provide the necessary revenue. Because contractual performance essentially depends on the motivation of the parties involved (North 1990), service providers have an incentive to deploy a delivery approach aligned with the priorities of rural water users to make progress toward expected revenue goals.

Table 2 provides an overview of the service attributes defined in UDUMA's contract and summarizes the observed results related to the service adaptations. Water quantity relates to the guaranteed minimum supply of volume of water per day and is linked to the infrastructure's production capacity and borehole yield. Affordability focuses on the tariff design, mainly the tariff structure and level that are defined in a contract in accordance with prevalent tariffing policies. Water quality encompasses actions dedicated to ensuring drinking water is free of fecal and priority chemical contamination and may include measures such as chlorination or regular testing. Reliability defines the maximum time allowed to repair breakdowns. Finally, proximity specifies the distance between the point of source and the household that is related to the source type.

The introduction of the solar kiosks augmented the supply capacity of the waterpoint (water quantity) and reduced the physical effort for pumping as well as the time costs associated with fetching water. In addition to the infrastructure upgrades, the tariff structure at remaining hand pumps was changed, by switching from a volumetric tariff to a monthly flat fee for collecting user payments. The change of the tariff structure complies with Mali's tariff policy for rural water supply, officially recognizing two payment modalities at hand pumps: direct volume-based payments or regular flat fee contributions (DNH 2007).

For the 10 pilot sites, UDUMA reports that water use remained relatively similar after a hand pump was upgraded to a solar kiosk. Yet, the solar kiosks generated higher revenues compared to handpumps as "there is no reluctance to paying for this service" (UDUMA 2021:35, *unpublished report*). Regarding the change in payment modalities, field reports from UDUMA indicate that monthly revenues increased and that flat fees appeared to stimulate water use at handpumps (UDUMA 2022, *unpublished report*). In the following, we contextualize these observed changes by drawing on evidence from interviews conducted with water users in Mali.

Qualitative evidence from the pilot solar kiosks illustrates that users do more readily agree to pay volumetric tariffs at solar kiosks that are professionally managed:

Table 2. UDUMA's contract model and the implications of service adaptations on contractual performance.

Service attribute	Contractual condition (Contracting clause)	Initial contract design	Initial contract performance	Renegotiation option	Contract performance after renegotiation	Remaining uncertainties
Water quantity	Management of manual pumps (§1&2). Maximum supply of 8 m^3/day/pump (§3)	Expected average use of 2 m^3 per day per pump.	Actual average use of 500 liters per day per pump.	Done: (higher service level provided through solar kiosks)	Similar water use. Payment collection improves. Monthly revenues increase.	Uncertain demand: impossible to impose which source and how much water to use. Additional costs
Affordability	User payments as revenue base (§1). Tariff structure: Volumetric (§21) Tariff level: 500 FCFA/m^3 (Annex 2)	100% collection efficiency for volumetric payments (PAYF).	40% collection efficiency	Done: (volumetric tariff structure changed to flat fee)	Water use increases. Payment collection improves. Monthly revenues increase.	Uncertainty about long term effect. Possible to change tariff level but unclear demand and revenue implications.
Water quality	Water quality (§14 and Annex 2). Annual test of bio-physical and bacterial parameters. Shock chlorination in case E. Coli.	Groundwater assumed to be of good quality (UDUMA 2017).	Qualitative data indicate users are satisfied with water quality.	Potential (increase frequency or range of tests, chlorination)	NA	Additional costs.
Reliability	Max. downtime of 72 hours (Annex 2)	Users value fast and guaranteed repairs (van der Wilk 2019).	Qualitative data suggest UDUMA service is appreciated.	Potential (preventive maintenance, < 24h downtime)	NA	Unclear if higher reliability is priority for users. Additional costs.
Proximity	Point sources: manual pumps (§1&2).	Users accept manual pumps.	Qualitative data suggest preference for higher service levels.	Potential (develop standpipes or private connections)	NA	Indicative evidence for user demand but uncertainty prevails. Additional costs.

> *We accept to pay for the tap. But, paying for pumping - that did not work for us!* (Female user, Village 8)

> *The water is fresh, and the service at the solar kiosk is good. I agree to pay per bucket, that works. Before with the hand pump, I came here, too. But the price bothered me. Pumping was really tiring!* (Female user, Village 2)

> *With the solar kiosk, it is really easy. You pay, you get the water, and you leave after only one minute or so. But with the hand pump, you had to work hard - and this for the same price!* (Male user, Village 3)

> *Paying by volume for pumping, this did not work for us. But we accept to pay as we fetch at the solar kiosk. Opening the tap is good - if water is coming when needed. The UDUMA system is reliable, and the water is of good quality. So, I am happy to pay for it.* (Female user, Village 9)

Although these results suggest that adapting services to user preferences can unlock payments and increase revenue, seasonal fluctuations in water demand do affect volume-based revenues. For example, even if a solar kiosk is reliably managed, users may decide not to use the guaranteed service but prefer an alternative source for multiple reasons. Insights from user interviews illustrate, for instance, how environmental factors, economic constraints, or specific preferences do influence user behaviors and their source choice, highlighting the challenges of non-exclusive service settings:

> *In the hot season, I fetch about 10 buckets per day at the solar kiosk. In the rainy season, I use less - maybe five buckets. There is the rainwater, and water is abundant in our wells.* (Female user, Village 2)

> *People are tired of walking - even to the solar kiosk. We want good quality water in proximity, and we would pay our monthly bills. But the solar kiosk does not offer this - I have three wells around me, they are all close by, always available, treated with chlorine bleach, and free of charge.* (Male user, Village 5)

> *Normally I use the UDUMA kiosk. This is closer to my home. But today, I don't have money, so I go to the Health Centre to get water.* (Female user, Village 4)

> *Today, I collected six 20L-buckets from a traditional well. It is much closer to my house and free of charge. The quality is ok - it is treated with chlorine bleach.* (Female user, Village 5)

These insights emphasize that while revising contracts to provide higher service levels by design can lead to improved financial performance, such service adaptations remain a partial response to complex user behaviors. In particular, even if larger quantities of water can be supplied, it is not certain that this level of supply will effectively be demanded by users. As qualitative evidence from Mali suggests, dynamic and contextual water demand is a defining characteristic of rural water supply and a challenge for designing exclusive contracts given the prevalence of alternatives.

The change of the payment modalities at the remaining hand pumps allowed to increase the enforceability of the contract. Under the flat fee approach, the user community self-organizes to collect the required fee and pays UDUMA in advance. As such, the revised contract provides a clear payment enforcement mechanism: if the monthly flat fee is not paid, the UDUMA service is not activated, and the pump is locked by a service area manager until a payment is made (UDUMA 2021, *unpublished report*). This mechanism mitigates the payment enforcement

challenge encountered under the volumetric modality, and simultaneously incentivizes users to make monthly payments against unlimited water use and guaranteed repairs.

However, the strict application of this enforcement mechanism can result in adverse outcomes. When the monthly flat fee is not paid, the pump is closed in the respective month. As a consequence, users are more likely to shift to unimproved water sources, as the following user account illustrates: "Before, I used the hand pump. Now, it is closed - and I rely on the traditional well. I barely use other sources" (Female user, Village 4). In addition to the foregone socioeconomic and health benefits associated with accessing an improved drinking water source (Prüss-Ustün et al. 2019), the provider receives no revenue.

UDUMA may seek to further adapt its services. For instance, the provider could increase its efforts regarding water quality, service reliability, or develop standpipes and household connections to get water closer to the users' households (Table 2). Any of these interventions would require additional investments (Hutton and Varughese 2016). While it is an open question whether such service adaptations would generate additional revenues, it is, however, unlikely that any of these strategies would overcome the structural barrier of uncertain user demand in the short term.

DISCUSSION

Our application of contract theory to Mali illustrates the potential of and barriers to the professional delivery of contracted rural water services. Three findings emerge from our study with implications for the design and implementation of drinking water service contracts in rural Africa. First, we emphasize that external actors and capital play a crucial role in contract execution and renegotiation. Second, we highlight that the financial architecture of rural water service contracts requires flexibility, particularly when long-term investments are involved, and uncertainties are high. Third, our findings suggest that the ability to revise contracts to adapt services is helpful but remains a partial response to uncertain user demand.

Although contract theory stipulates that "the parties always have the option to renegotiate [the contract] later on" (Hart and Moore 1988:756), this fundamental assumption did not really apply to our case in Mali. Neither did the expressed agreement of the formal parties to the bilateral contract really matter for changing the model. UDUMA's case emphasizes the crucial role external actors and non-repayable capital from a foundation played to permit renegotiation and support continued work. Any negotiation between UDUMA and the municipalities would most likely not have allowed for fundamental change to the outcomes as additional resources were required. Without the philanthropic grant funding, UDUMA would have had few options to continue their operations.

This insight may be of relevance for further theory development. Following Ågerfalk (2014), we expand on the theoretical implications of our empirical findings, which emphasize that renegotiating contract arrangements is not only conditional on the agreement of the original contract parties but also depends on the involvement and attitude of external actors. Although contract theory puts the formal contract parties in the driving seat of renegotiation, we highlight that the life of a contract must be understood in its wider context of implementation. Therefore, additional qualitative research that complements the more abstract modeling exercises that characterize contract theory is required (Frydlinger and Hart 2024).

Furthermore, our empirical findings pinpoint to an essential limitation of contractual delegation of service delivery functions that is widely established in rural water policies across Africa (Fig. 1). The principle of delegation is based on the implicit assumption that local governments sign the contract on behalf of users. Although individual users are expected to provide the revenue necessary to sustain services, they are not a formal party to UDUMA's contractual model. Therefore, UDUMA's model is structurally incomplete. It is likely that other delegation contracts for rural water services suffer from similar shortcomings, chiefly when point sources are concerned. We argue that further research is needed to refine our understanding of the performance of contracts where third parties are crucial for achieving expected outcomes but are not a formal party to the contracting arrangement.

The original financial architecture of the initial contract allocated most financial risks on UDUMA. UDUMA made infrastructure investments by attracting private capital and more traditional donor funding to Mali. Although asset-specific investments require longer time horizons to allow for expected outcomes to be realized (Goldberg and Erickson 1987, Hart and Moore 1988) and tend to be facilitated through more rigid contracts (Hart and Moore 2008, Hart 2017), our case study illustrates the importance of financial flexibility to adapt to uncertainties. We emphasize that the willingness and ability of UDUMA's holding company to absorb the financial losses was critical for the model to continue. Yet, ODIAL SOLUTIONS was not willing or able to cover further investment risks related to trialing solar kiosks. As the flexibility of the philanthropic grant illustrates, unconditional funding can allow to buffer such risks, particularly in circumstances where investors are facing high uncertainties. Therefore, we suggest that future rural water service contracts involving infrastructure investments may combine a flexible funding component with a certain risk-appetite, such as philanthropic funds, with more traditional donor funding and commercial finance, allowing to navigate a contract impasse.

Finally, we highlight that the design of contracts is necessarily based on assumptions about future behaviors and conditions. Designing contracts applicable to the delivery of water services in rural Africa constitutes a particular challenge because reliable data on water demand are scarce (Therkildsen 1988, Elliott et al. 2019, Hope et al. 2020, Cronk et al. 2024). Yet, conducting accurate demand forecasts remains a fundamental planning challenge even in well-organized sectors in the Global North where reliable data are more readily available (Flyvbjerg et al. 2005). Formal contracts are often based on stable assumptions throughout the year and for multiple years ahead. This "stability assumption" of long-term contracts, similar to other medium- and long-term planning exercises (Therkildsen 1988, Flyvbjerg et al. 2005), likely misses the complexity and uncertainties characterizing rural water. Therefore, allowing for contractual renegotiation can be desirable in the face of changed circumstances or additional experience. As our analysis reveals, contract renegotiation can be a mechanism to respond to gaps between expected and actual performance by acting upon new

operational knowledge from implementation. Hence, rural water service contracts require adaptability mechanisms to effectively deal with inherent uncertainty and unpredictability of user demand.

Despite adapting its services, UDUMA remained confronted with volatile and low revenues, emphasizing the uncertainties characterizing rural water demand. Although UDUMA's initial contracts assumed that no subsidy for operations was needed, the operational reality indicates that in almost all of its sites some form of subsidy is required to meet recurring costs. We argue that rural water contracts are likely to be defined by increasing economic, climate, and social risks that require more pragmatic financial arrangements for supporting service delivery. Governments, service providers, and donors must recognize and adequately plan for these realities. Here, contract theory may help to propose models that combine rigidity in terms of service quality with flexibility in funding arrangements to sustain services. For instance, contracts can provide for flexible compensation mechanisms to cushion revenue shortfalls (Gottardi et al. 2017) or include minimum income guarantees (Guasch et al. 2006, 2008) to achieve desired social, economic, and health impacts associated with safe drinking water.

STUDY LIMITATIONS

Four limitations are recognized in this study. First, the study site lies in one region of Mali, characterized by a unique cultural, social, and political context. Although certain drinking water problems common to rural Africa may be illustrated by using Mali as an example, we do not claim to generalize our findings.

Second, we emphasize that the contractual arrangements underpinning professional service delivery models must be designed in light of the diverse socioeconomic, cultural, and environmental settings in which they operate. Here, selecting UDUMA as one provider offering guaranteed rural water services excludes other possible service delivery approaches from the analysis.

Third, the purposive sampling in rural communities was biased to UDUMA's upgrades to solar kiosks. We collected data across 8 municipalities, leaving 22 municipalities that also agreed to renegotiate contracts with UDUMA out of the investigation. Because the fieldwork was conducted in collaboration with UDUMA, we were able to get a deep understanding of the model and wider context. However, we also recognize that this may have biased collecting data on the perceptions of the relationship linking the interviewees and UDUMA as the target organization. Therefore, care was taken during analysis to corroborate different sources of empirical data before drawing conclusions.

Fourth, our case-study draws on qualitative data to illustrate how UDUMA's contractual model evolved over time. Although we provide indicative insights on how users respond to service adaptations and how, in turn, changes in water use and payment behaviors affect revenues, this analysis falls short of estimating the size of these revenue effects. Wagner et al. (2024, 2025) have exploited the longitudinal water use and payment data generated by UDUMA to quantitatively assess the revenue implications associated with service attribute changes.

CONCLUSION

Our study from Mali provides evidence that long-term contracts can attract capacity and finance to the rural water sector. We illustrated that contracts do provide an adaptable framework in which services can evolve and that flexibility in the financial architecture of contracts is necessary to navigate investment risks. Here we highlight the role of philanthropic grants that can act as catalytic and complementary resources to more traditional funding and commercial finance.

Furthermore, the results suggest that although contracts can be revised to adapt services to variable water user demand, professional service delivery models are likely to require operational subsidies to mitigate volatile revenues. Results-based contracts can play an enabling role in the allocation of such subsidies by aligning service outcomes with incentive payments. Permitting for a mix of user payments and performance-based funding may mitigate the risk of service failure due to insufficient local revenue. This is illustrated by an emerging approach that uses a standard contract design in 10 countries in sub-Saharan Africa to allocate flexible subsidies against the provision of rigid results, measured through verifiable key performance indicators related to safe drinking water services (Charles et al. 2023, Uptime 2023).

We emphasize that formal contracts with professional service providers are not a definitive solution to complex water problems. We stress that an enabling policy environment, characterized by a clear legal and institutional environment, with strong regulation and accountability practices and effective subsidy mechanisms is fundamental to support the wider shift toward service delivery. We recognize that these are new practices to the rural water sector that is still focused on more infrastructure-driven approaches, largely ignoring the difficulty of maintaining systems over time. Yet, we argue that well-designed contracts may ultimately allow to crowd in new funding sources and to more effectively allocate responsibilities and risks to deliver drinking water service outcomes that so far have not been achieved in rural Africa.

Author Contributions:

Johannes Wagner: Conceptualization, Investigation, Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. Johanna Koehler: Conceptualization, Methodology, Writing – review & editing. Rob Hope: Supervision, Conceptualization, Funding acquisition, Writing – review & editing.

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Data Availability:

The study involved human subjects and the authors certify that prior to all data collection and analysis, ethical approval was obtained from the Research Ethics Committee of the School of Geography and Environment, University of Oxford (SOGE 1A2020-195 and SOGE 1A2020-210). The data that support the findings of this study are available on request from the corresponding author. None of the data are publicly available because of restrictions (i.e., they contain information that could compromise the privacy of research participants).

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Appendix 1 - Supporting Information

Managing contractual uncertainty for drinking water services in rural Mali

This file includes:

Table S1 - Overview of fieldwork sites

Figure S1 - Case study area in Sikasso, Mali

Field sites in Sikasso

The study site comprises the Region of Sikasso, located in the south of Mali. To trial solar kiosks, UDUMA selected 10 sites, reflecting the diverse geographical, socio-economic, and environmental conditions of its service area (Figure S1). Between March and May 2021, UDUMA sequentially converted boreholes equipped with manual handpumps (two pump types are managed by UDUMA: Vergnet-Hydro and India Mark 2) to solar-powered water kiosks. Table S1 presents the population size, illustrating the variability across sites, and provides the dates at which the handpump management started and the upgrade to solar kiosk happened.

UDUMA selected the sites for piloting solar according to the following criteria: socio-political context and local security situation, environmental conditions (borehole yield and pump test) and population size (minimum 700 people per waterpoint). We emphasise that UDUMA targeted sites with potential for success as the involvement of leaders and local authorities supporting the project was considered essential.

In May 2022, the lead-author conducted in-person fieldwork in nine of the ten villages. Due to security reasons, it was not possible to visit one site.

Table S1. Overview of fieldwork sites

Municipality	**Village**	**Start of handpump**	**Upgrade to solar**	**Population of village**
Fakola	Dionkoni	01/09/2020	25/03/2021	2,036
Kebila	Bougoula	16/12/2019	30/03/2021	2,635
	Kebila	23/01/2020	31/03/2021	4,826
Koumantou	Tiefala	21/10/2019	30/04/2021	2,717
Meridiela	N'tenkoni	25/11/2020	10/05/2021	1,227
Sere Moussa Ani Samou	Moribala	28/02/2020	21/05/2021	1,217
Sibirila	Fangala	17/03/2021	19/05/2021	2,100
Sido	Tinkole	05/06/2020	05/05/2021	744
Tagandougou	Binko	09/10/2020	21/05/2021	2,536
Wola*	Dionkala*	08/12/2020	04/05/2021	1,179

*Not possible to visit during fieldwork due to security concerns.

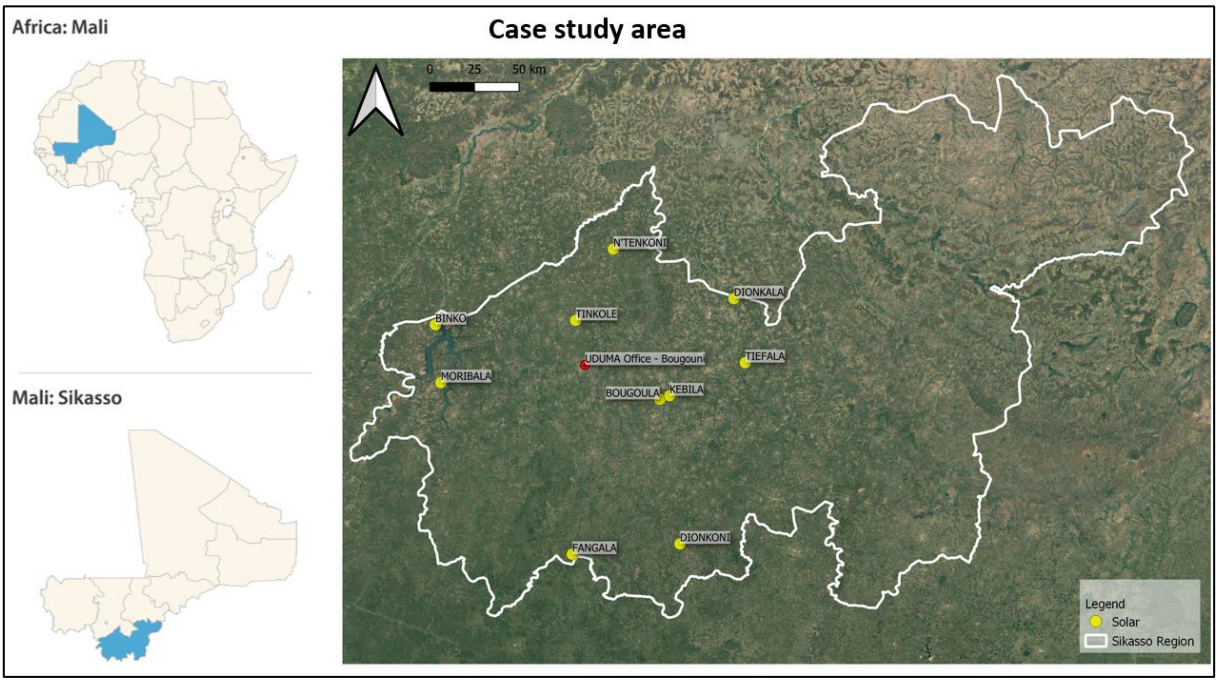

Figure S1. Case study area in Sikasso, Mali.

Appendix 2 – Guiding questions for interviews with water users

The guiding question of the interviews was to understand whether users are more inclined to pay a volumetric tariff for reliable services provided by UDUMA at solar kiosks in comparison to handpumps.

1. Current water-related practices (main waterpoint and its use).

1.1. Is the solar kiosk your main water source? Why do you use this waterpoint?

1.2. For which purpose do you collect water here?

1.3. Is the waterpoint heavily used? Is there queuing in the morning/evening? And if yes, how long do people have to wait to fetch water?

1.4. How many jerry cans did you fetch yesterday? Do you fetch less water from the waterpoint in the rainy season? If yes, why?

1.5. What other (alternative) sources do you use and for which purposes? Are these sources free of charge or do you have to pay, and if yes, how much?

2. Priorities and preferences regarding service provision (value of reliability).

2.1. What is the most important aspect for you regarding your water supply? (Give prompts)

- Fast repairs in case of breakdowns (reliability)
- Amount of water (quantity)
- Proximity to household (convenience /distance)
- Physical effort for fetching water (convenience/pumping)
- Queuing time for fetching water (convenience/time)
- Price of water (affordability)
- Taste of water (Water quality)
- Safety of water (Water quality)

3. Perception of UDUMA and solar kiosk (acceptance of PAYF at solar).

3.1. What do you like the most about UDUMA's service?

3.2. What do you dislike the most about UDUMA's service?

3.3. According to you, what is the biggest advantage of solar compared to a handpump?

3.4. According to you, what is the main disadvantage of solar compared to a handpump?

3.5. Why do you agree to pay a PAYF-tariff now?

4. Demand for further improvements (factors to stimulate demand)

4.1. According to you, what improvements of your waterpoint are necessary so it serves better your needs (increased reliability, HH connections, water quality improvements, etc.)?

Appendix 3 – List of meetings with staff from UDUMA France

As part of the research project, the lead author conducted various in-person and online meetings with staff from UDUMA France to understand UDUMA's service model and stay informed of challenges in its implementation and potential evolutions. This anonymised overview list presents the type and content of meetings that were organised as part of the research during 2020 to 2023. In total, 6 in-person workshops and 13 online meetings with staff from UDUMA France were held throughout the research process, providing opportunities for regular updates from Mali and venues to share research findings and receive feedback. Discussions were generally conducted in French – unless specified otherwise. Notes were taken and short summaries of the exchanges were established.

Date	**Type of meeting and short description**	**Participants from UDUMA**
28/10/2020	**Online meeting** as kick-off of research collaboration, providing an overview on the service model, its assumptions, and available service data.	Managing Director, Chief of Operations for Mali, Data Officer
25/11/2020	**Online meeting**, focusing on implementation challenges of the service model in Mali.	Chief of Operations for Mali
25/01/2021	**Online meeting**, focusing on available service data and their collection.	Chief of Operations for Mali
21/02/2021	**In-person workshop** in Orléans at UDUMA's Head Quarter (HQ). Presentation of research design and preliminary findings of exploratory data analysis.	Managing Director, Project Manager, Finance Officer, Data Officer. Executive Director, Vergnet Hydro
16/03/2021	**Online meeting**, focusing on cost data	Project Manager, Finance Officer
18/05/2021	**In-person workshop**, Orléans. Presentation of revised contracts, installation of solar kiosks, and introduction of flat fees.	Managing Director, Project Manager, Data Officer.
19/07/2021	**In-person workshop**, Orléans. Overview of progress in Mali, up-date from the field, contextualisation of service adaptations.	Chief of Operations for Mali, Managing Director, Project Manager, Data Officer
24/09/2021	**Online meeting**, focusing on scale of operations in Mali and business opportunity in Côte d'Ivoire.	Project Manager, Data Officer

05/01/2022	**In-person workshop**, Orléans. Presentation and discussion of emerging results following the installation of solar kiosks.	Managing Director, Project Manager, Finance Officer, Data Officer. Executive Director, Vergnet Hydro
23/02/2022	**In-person workshop**, London (conducted in English). Discussion of results of solar kiosks, presentation of UDUMA's wider business strategy (Benin, Côte d'Ivoire).	Managing Director Executive Director, Vergnet Hydro
25/03/2022	**Online meeting**, focusing on preparation of fieldwork in Mali regarding site selection and data collection.	Chief of Operations for Mali, Project Manager
14/04/2022	**Online meeting**, focusing on preparation of fieldwork in Mali.	Chief of Operations for Mali
05/07/2022	**Online meeting** (conducted in English), focusing on recapitulation of and reflections on fieldwork, particularly on insights from user interviews.	Managing Director Executive Director, Vergnet Hydro
20/09/2022	**In-person workshop**, Orléans. Presentation and discussion of qualitative and quantitative findings from fieldwork and implications of service adaptations.	Chief of Operations for Mali, Managing Director, Project Manager, Data Officer
13/12/2022	**Online meeting**, focusing on updates from the field.	Chief of Operations for Mali
07/03/2023	**Online meeting,** focusing on updates from the field.	Chief of Operations for Mali, Project Manager
11/07/2023	**Online meeting,** focusing on updates from the field.	Chief of Operations for Mali
04/10/2023	**Online meeting**, focusing on reflections of UDUMA's service delivery model and its evolution over time.	Managing Director
28/11/2023	**Online meeting**, focusing on reflections of UDUMA's service delivery model and its evolution over time.	Chief of Operations for Mali

Appendix 4 – List of interviews with sector experts from Mali

This anonymised list presents the interviewees from various organisations intervening in the water sector in Mali. The 14 semi-structured online interviews were conducted in French and lasted for around 60 minutes each. In advance to the interview, the questionnaire (Appendix 4) was shared with the interviewees to allow for adequate preparation.

Date	**Organisation**	**Position of interviewee**
03/02/2021	UNICEF	WASH Specialist for Mali
05/02/2021	Protos	Country Director
10/02/2021	Malian Association of Municipalities	International Affairs Manager
10/02/2021	National Water Directorate (DNH)	Head of Division "Regulations and Standards"
11/02/2021	National Water Directorate (DNH)	Director
11/02/2021	Helvetas Swiss Intercooperation	Regional Policy Advisor WASH
12/02/2021	SNV	Advisor WASH
12/02/2021	AKVO	Advisor WASH
15/02/2021	USAID	Planning Officer Water and Irrigation
15/02/2021	WaterAid	Advisor WASH Policy and Advocacy
15/03/2021	CN-CIEPA WASH (Civil Society)	Advisor WASH-Advocacy
15/03/2021	National Water Directorate (DNH)	Head of Division "Rural Water Supply"
07/05/2021	STEFI operator (Private entity for Financial and Technical Monitoring of piped water schemes in rural Mali)	Director
10/06/2021	Urban Water Services Regulator (CREE)	Economist

Appendix 5 – Guiding questions for interviews with sector experts from Mali

Overview on research project

Rural water supply, especially when provided via handpumps in remote areas, is characterised by high breakdown rates and poor service levels. Generally, user-communities are managing waterpoints with limited success – roughly 25% to 30% of rural waterpoints in Sub-Saharan Africa are non-functional.

In the context of reaching SDG 6.1 by 2030, new models for reliable rural water service provision are emerging – ensuring that waterpoints are properly operated and maintained. However, the challenge to fund these reliable services has yet to be addressed. Therefore, the overarching research question of the project is: "What are potential ways and necessary conditions to sustainably cover the costs for reliable and affordable rural water services?".

- The UDUMA model in Mali

Mali is advancing new models for rural water service provision at large scale including the UDUMA service model in Sikasso. UDUMA presents a new approach to water service delivery in rural settings by offering professional operation and maintenance services for about 1.400 waterpoints. UDUMA charges a tariff of 500 FCFA per m^3 (in line with national policy), and users are asked to pay according to volume abstracted. The UDUMA model offers hence a window of opportunity to explore use and payment behaviours related to reliable rural water services.

- Contextualise the UDUMA model

Since the UDUMA model is altering customary patterns of rural water in Sikasso, it seems necessary to better understand the context of rural water supply in Mali. The interviews will help to situate the project in its larger context and provide insights into the history, current developments, and potential pathways of rural water supply in Mali – and elsewhere.

Questions:

I. Infrastructure

1.1 What are the prevalent infrastructure types in Mali for rural water supply? Are there prioritized infrastructures for rural water supply to reach SDG 6.1 in Mali?

1.2 How do rural households generally satisfy their water needs?

1.3 Are there differences between different types of infrastructure (wells, handpumps, solar systems, piped systems, etc.) regarding sustainability, management approaches, etc.?

1.4 To what extent do use and payment patterns change regarding infrastructure design in Mali?

II. Institutions

2.1 How do rural users value water in Mali? What are socio-cultural, spiritual, or traditional considerations related to water and payment? Is water valued based on its quality or usage?

2.2 How is rural water supply traditionally managed? What are dominant formal, informal, and traditional management arrangements for rural water supply in Mali?

2.3 Is there a guiding service delivery model for rural water supply in Mali? What are the most important features and challenges of this guiding model?

III. Investments

3.1 How is rural water supply currently financed? What costs are covered by tariffs, transfers, and taxes?

3.2 In Mali, what is considered an appropriate service level worth paying for? Does service reliability unlock user payments for basic water supply?

3.3 Regarding the sustainable financing of reliable water supply in rural areas, what are essential parts missing in the actual sector set-up?

3.4 What is necessary, in your view, to attract financing for service delivery – aiming at covering recurring operation and maintenance costs (and eventually capital maintenance costs)?

IV. Innovations in policy

4.1 What was the main policy for rural water supply before the advent of SDGs?

4.2 Are you aware of policy or practical innovations related to the improvement of rural water services? How do these undertakings positively impact sustainability of rural water services?

4.3 Are there any limitations to these initiatives? What are potential gaps or challenges for a sound implementation?

4.4 According to you, are there institutional arrangements missing to provide enabling conditions for these innovations to be successful?

V. Information

Could you give me advice to whom else to talk to better understand challenges and solutions to rural water services in Mali and to refine my key research questions?

Appendix 6 – Guiding questions for interviews with representatives from donor agencies

The interviews are tailored to unpack how different actors behave and cooperate in overcoming the limitations of an incomplete contract and what they learned from this process.

1. **Process of contract renegotiation.**

Renegotiation appears as a multi-actor process shaped by communication, reputation, and pragmatic interests (or informed by shared experience and interests). Hence, the following questions emerge: Who was involved in the renegotiation process? How and when did this occur? Why did the actors/parties agree to change the model?

- **Questions to the Foundation:**

The foundation played a pivotal role in UDUMA's model by agreeing to fund the installation of ten solar kiosks as a pilot project in nine municipalities.

  - How did UDUMA convince you to fund the upgrades? Why did you accept to fund?
  - What did you learn from the process?
  - What was your wider role besides providing funding for solar pilots?

- **Questions to RVO:**

RVO supports the UDUMA project in Mali through its Sustainable Water Fund since 2017.

- What was the initial motivation for granting funds to the UDUMA project in Mali?
- How did the transition from handpumps to solar come about?
  - Did RVO require a "case" or "proof-of-concept"? If yes, why?
  - What were the implications of the pilot funded by the foundation?
- What was convincing to agree to reallocate funds for solar?
- What did the process look like to reallocate the funds to solar kiosks?
- Where there any additional conditions for permitting the re-allocation of funding?

2. **Wider learnings for designing contracts for drinking water services in rural Africa.**

This report from RVO (2022) reflecting on the Water Fund is quite interesting, hence I am wondering whether there are specific insights emerging from your experience with the UDUMA model in Mali?

- Based on the Mali experience, what do you think are the wider learnings on how to design rural water service contracts?
    - What must be considered in contract design? Which learnings may have relevance for other contexts/countries?
    - What are the implications for funding innovative (but risky) projects?
    - Who should cover investment risks?
    - What is/should be the role of subsidies/income guarantees?