Global Partnership for Sustainable Development Data

TReNDS
Thematic Research Network on Data and Statistics

Handpump Data Improves Water Access

Case Study by SDSN TReNDS

With two-thirds of the world's population facing water scarcity at some point during a year, and with one-third of handpumps in rural Africa inoperable at any time, increasing the reliability and functionality of water services is essential to sustainable development. The Smart Handpump Project, initiated at the University of Oxford, is improving water services in rural Kenya through sensors installed on handpumps in the region. Pairing real-time data from these sensors with a performance-based maintenance service model reduced the average time to repair a broken pump from 27 days to three days. Now continued under a social enterprise called FundiFix, which uses an insurance-based funding model, the concept expanded to a second county in Kenya and recently to Bangladesh. The Smart Handpump Project illustrates how new information flows from innovative sensor data can improve key services. Such low-cost and scalable data interventions strengthen the governance and management of resources critical to sustainable development.

Context

Target 6.1 of the Sustainable Development Goals (SDGs) commits to achieving universal and equitable access to safe and affordable drinking water by 2030 (WHO/UNICEF 2017). Analysis shows that four billion people face severe water scarcity for at least one month out of the year, and half a billion face severe water scarcity year round (Mekonnen and Hoekstra 2016). This challenge is acute in rural Africa, where some 275 million residents need improved water access (University of Oxford 2014). According to the Oxford Water Network, hundreds of millions of British pounds are spent annually by governments, non-governmental organizations, and others to increase water access in poor, rural communities (OxWater Ltd., n.d.). Yet the dispersed locations of rural communities, along with low incomes and weak institutions, make monitoring rural water services difficult (Thomson, Hope, and Foster 2012b). The operational status of a water point might be checked only once a year, leaving much unknown about the impact of investments into water services (University of Oxford 2014). Furthermore, the lack of standardized and aggregated administrative data in the water, sanitation, and hygiene sector (WASH) undermines system-level operations (Fischer, 2017).

**275 million rural Africans need improved water access.
– University of Oxford 2014**

Handpumps are a preferred technology for water access in rural Africa, but it is estimated that one out of three pumps are inoperable at any given time (Thomson, Hope, and Foster 2012a). Even though handpumps should be usable for over a decade, many are abandoned within the first couple years due to maintenance issues (Thomson, Hope, and Foster 2012a). In Kenya, the operation and maintenance of handpumps is one of the few responsibilities delegated to local communities (University of Oxford 2014). But maintenance is a huge burden for these communities and repairs can be delayed for weeks as they struggle to collect the necessary finances (Thomson, Hope, and Foster 2012a). Piped water schemes provide increased water access at special water kiosks, but these more complex systems are vulnerable to prolonged maintenance issues (Katuva 2018). There has been no coordinated management of water infrastructure in rural Kenya, and financial sustainability is often overlooked in water projects (University of Oxford 2015).

> **An estimated one out of every three handpumps in rural sub-Saharan Africa are inoperable at any given time.**
> **– Thomson, Hope, and Foster 2012a**

Improving the reliability of handpumps and piped schemes will be critical to addressing water sustainability. Water from handpumps costs half to one-quarter of the price of water supplied by kiosks for piped schemes (University of Oxford 2015); although kiosks generate greater revenue, they supply less water. Furthermore, climate change will impact all water resources in Africa, but ground water is expected to be less affected, so managed use of aquifers will be important to overall water security (Thomson, Hope, and Foster 2012a). Estimates suggest that increasing the reliability of service for 1 million handpumps would improve water access for around 200 million Africans (University of Oxford 2014).

Description of Data Intervention

A team at the University of Oxford has advanced the use of technology and data collection to improve drinking water security for millions (OxWater Ltd., n.d.). They initiated the Smart Handpump Project in Kenya, which launched remote monitoring and automated data collection for rural handpumps.

Remote monitoring is facilitated by mobile network coverage. African villages that lack regular water services or monitoring often have mobile network coverage, offering an opportunity to provide data more quickly and reliably than field visits (Thomson, Hope, and Foster 2012b). Automated data collection can mitigate difficulties of unaggregated administrative data or crowdsourced approaches, where community members might delay reporting due to sociodemographic

barriers, concerns about retaliation from service providers, and other issues (Thomson, Hope, and Foster 2012b). Existing technology for measuring the flow of water was not appropriate for monitoring the use of handpumps, and mobile technology had not been previously applied to rural pumps (Thomson, Hope, and Foster 2012a). Laboratory research on a novel data solution began in May 2011 (Behar et al. 2013), and field tests were conducted in July 2012.

Equipment and Software

Water, engineering, and business researchers collaborated on the Smart Handpump Project to develop a system for remotely monitoring handpumps in real time. A waterpoint data transmitter (WDT) was created that can be attached to or housed within the handle of an existing pump (Thomson, Hope, and Foster 2012a). The unit was designed to be durable, lightweight, and inexpensive, using off-the-shelf equipment and no moving parts. A built-in accelerometer detects when the pump handle is moved, and a microprocessor calculates the pump handle's angle of tilt. By monitoring the angle over a period, the microprocessor can count the number of pump strokes and estimate the volume of water pumped. Finally, the microprocessor sends commands to a network modem, which shares data through SMS.

The WDT system collects data on an hourly basis and then transmits a summary every six hours through the broadband network to a central server (Behar et al. 2013). To minimize the loss of data, a duplicate message is sent three hours later. SMS messages are handled by FrontlineSMS, which is an open-source platform that does not require an internet connection (Behar et al. 2013). This information provides objective measures of pump operation for policy planning and monitoring of maintenance (University of Oxford 2014).

A modular database and user interface were created with the Kenyan government (University of Oxford 2014). Researchers used Linux-compatible open-source software so that the platform could run on older computers without requiring infrastructure changes (Behar et al. 2013). Users are able to view data through a web interface, although information is still accessible when offline (Behar et al.

2013). The interface includes a map of handpump locations and a color code indicates a pump's status, ranging from operational to "in need of repair." Administrators are able to view daily events and filter transmitters to quickly identify issues.

Other Applications of the Technology

Analysis has shown the potential for pump data to deliver additional benefits (OxWater Ltd., n.d.). Researchers have developed algorithms through machine learning to analyze the high-frequency noise in pump handle movement and can identify when a pump is beginning to experience operational difficulties (OxWater Ltd., n.d.). The hope is that this technique will eventually allow for repairs to be made before the pump fails, ensuring a continuous service. The researchers also believe that data can provide indicators of groundwater depth and could support the sustainable management of water resources. Additionally, the machine learning techniques are being developed to detect the differences in pumping behaviors by men, women, and children, and this information could provide social benefits, such as determining if children are absent from school (OxWater Ltd., n.d.).

Community Management and Financing

Local context regarding community management and financing also shaped the setup of the Smart Handpump Project. A 2014 survey in rural Kenya found that the most common model of individual communities managing their own handpumps was the least popular option from a list of alternatives (Hope 2015), suggesting the need for a different financial model. Thomson, Hope, and Foster (2012) proposed the idea of a "super community" that could manage multiple handpumps together; this would reduce the average cost of repairs (Hope, Foster, and Thomson 2012). The proposal depended on information to hold maintenance providers accountable and reduce the risk to participating communities. The collection of data on pump operation has the potential to bridge the gap between communities and policymakers and to increase the reliability of pumps. The researchers have pursued this model under a social enterprise that uses WDT data to direct maintenance activity and create financial accountability.

Implementation

The implementation of the WDT technology has taken place in three stages: a proof of concept in Lusaka, Zambia; a pilot study in Kyuso District, Kenya; and most recently the development of a maintenance business model for widespread deployment. This model aims to improve operational and financial efficiency by combining data availability with the logic of an insurance plan (University of Oxford 2014).

Proof of Concept

An initial test of the Smart Handpump technology was performed in Lusaka, Zambia in July 2011 (Thomson, Hope, and Foster 2012a). Researchers gained unlimited access to a pump for initial testing and measurement, and then undertook live testing with three additional pumps in the Valley View Community. Researchers observed pump usage over four days and determined that the real-time monitoring of handpumps was feasible.

Pilot Study

During a pilot project, 66 handpumps serving around 20,000 people were fitted with mobile devices (University of Oxford 2014). The initial implementation was in Kyuso District, located 267 kilometers east of Nairobi in Kitui County, Kenya (University of Oxford 2014). The district's population of 26,848 households is almost completely rural. Two out of three households are classified as "poor," and 54 percent use "unimproved" water sources. Another 39 percent use wells or boreholes. This area was selected following a 2011 water point survey because it has handpump dependency and faces hydrological risk (University of Oxford 2014). The district also has areas with variable broadband coverage, and the researchers wanted to test the design under more extreme conditions.

Permission and support for the study was gained from Kenya's Ministry of Water and Irrigation and other federal regulators, as well as the local communities (University of Oxford 2014). The first installation was in the town of Kyuso in August 2012, and full implementation then followed from January through December 2013 (University of Oxford 2014).

The study included two classes of pumps: one with transmitters and another that only provided a telephone hotline for community members to report maintenance issues (University of Oxford 2014). The project would send out a maintenance person in response to either real-time data or community reports. Due to ethical constraints, the study design could not charge communities for maintenance during the first year of implementation (University of Oxford 2014).

Maintenance Business Model

Following the proof of concept and pilot, the third phase of implementation has focused on making responses to handpump data financially sustainable. The Oxford team supported the initial launch of a maintenance service provider in 2015 called FundiFix (University of Oxford 2015). As of 2018, Fundifix is an independent entity but continues to receive technical advice from Oxford researchers (Hope 2018).

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> **– FundiFix Director Jacob Katuva**

The approach applies the logic of insurance to water services, with FundiFix receiving information flows from smart handpumps and mobile financing. This is distinct from a water service provider, because FundiFix is only responsible for insuring the technical operation of pumps, not the management of water resources. FundiFix Director Jacob Katuva explained, "We offer these services for a premium every month from the communities, which is based on the amount of water that they sell" (Katuva 2018). He went on to explain the insurance logic: "You pay [US]$10 every month for a whole year, but then you are covered for a repair cost of up to, for example, $400. In a year, you would have only payed $120, but you

are covered for up to $400 worth of repairs"(Katuva 2018). FundiFix follows a performance-based model, now led by local entrepreneurs and based on collaboration with government, communities, and investors (REACH, n.d.). Katuva noted, "We are a social enterprise, and in case one day we make a profit, the profit will simply go back to the communities" (Katuva 2018).

FundiFix can remotely monitor a pump's operating status over the internet (University of Oxford 2015). Data-based validation of repairs is intended to create accountability in rural areas, and formal contracts are created with communities to provide a professional service. Payment schemes are determined separately for every pump according to demand and the availability of other water sources, and communities then make pre-paid contributions through the open platform M-PESA. FundiFix is able to send payment reminders and notifications to community members but if a community should miss a payment, the service is continued for several months to accommodate variable cash flows. FundiFix has made a commitment to repair all technical pump problems within three days, and it provides a month of free service if it fails to meet this commitment (Koehler and Katuva 2018).

FundiFix aims to support sustainable water supply for all communities and schools, but work has begun on the sub-national level with a focus on the most vulnerable (REACH, n.d.). The operation began in Kitui County, Kenya and another franchise has since been established in nearby Kwale County (Koehler and Katuva 2018). Kwale was chosen as a 2012 audit of Kwale County identified 570 handpumps, of which only 300 were operational (Koehler and Katuva 2018).

FundiFix has also expanded operations to piped water schemes. A July 2016 water audit of a sub-county in Kitui County documented 48 piped water schemes, covering 430 villages and serving over 110,000 water users (UK Department for International Development 2016). At that time, over US$2 million had been invested into the area's water infrastructure, half of this since 2006. 94 percent of the water for piped systems comes from groundwater, and nearly all schemes lack quality monitoring and treatment. The audit found that only 55 percent of schemes were functional, and an additional 10 percent were partly functional. Issues include pump failure, and poor maintenance by local communities with limited income. Repairs could take between three and 10 months depending on severity. FundiFix has generally not been able to automate the collection of data for piped schemes as with handpumps, so members of staff need to manually collect observations (Katuva 2018). The contract for piped schemes is also different, with FundiFix committing to examine issues within 48 hours and make repairs within five days (Koehler and Katuva 2018). These differences reflect the added complexity of monitoring and maintaining a piped scheme (Katuva 2018).

As of 2018, FundiFix has created a physical office with a team of engineers (Koehler and Katuva 2018). Between the two counties, there are 14 members of staff, including six full-time technicians (Katuva 2018). The technicians on staff are able to address most regular maintenance issues, but FundiFix will bring in contracted experts for more challenging situations (Katuva 2018).

Funding

Initial funding for the research and proof of concept was provided in 2010 by the UK's Department for International Development (DFID) under a program focused on new and emerging technologies (University of Oxford 2014). Financing also came from the University of Oxford's John Fell Fund. The project has since received additional research grants (REACH, n.d.). Collaborators have included UNICEF and private partners, such as engineering and development consultancy Rural Focus (REACH, n.d.).

The total cost of maintenance during the pilot was US$8,368, with an annualized cost per repair of US$62, and a crude average of US$127 per pump (University of Oxford 2014). The creation of FundiFix was meant to cover these costs, but initial contributions did not meet expectations. The income over the first six months was US$1,057; 72 percent of which came from monthly payments while the remaining 28 percent came from registration fees (University of Oxford 2015). Registration was low, so this income did not offset the cost of US$2,156 for maintenance service, transportation, equipment, and information (University of Oxford 2015).

The FundiFix team quickly realized that the amount that participating communities were initially able to pay could not sustain a service provider (Katuva 2018). In response, FundiFix led the creation of water services trust funds at the county level in Kitui and Kwale Counties. The trusts help to direct government funds towards pump maintenance while also ensuring accountability. As Katuva explained, "The trust fund will provide for county governments to put some money in there earmarked for maintenance services, and then that money from there will be transferred to the maintenance service providers based on results" (Katuva 2018). The project is also seeking private sector backers; already, mining company Base Titanium Limited and marketing company doTerra have invested into the Kwale water services trust fund (Koehler and Katuva 2018).

As of 2018, the FundiFix operation has expanded, but only 15 to 20 percent of the working costs are being covered by the communities alone (Katuva 2018). The remaining 80 to 85 percent of costs are being covered by the trust funds. The project aims to sign up more schemes so that increased economies of scale can be realized. According to Katuva, "Communities have to agree amongst themselves that they want the service, and this takes a while. [...] You need someone to underwrite the shortfall until it gets to that critical mass" (Katuva 2018).

Impact

Smart handpump data has the ability to be low-cost, reliable, and scalable, and their application can support better environmental, operational, and governance outcomes (Thomson, Hope, and Foster 2012a).

Impact on Functionality and Rural Service Models

Prior to implementation of the pilot in July 2012, a survey of 112 respondents from the pilot district found that handpumps were experiencing an average of two breakdowns per year (University of Oxford 2014). The median average repair time was six days but the mean average was 27 days, and 7 percent of pumps were down for an entire year. Difficulty in collecting the needed funds for maintenance was partly responsible for these delays.

The pilot study saw a tenfold decrease in pump downtime, from 27 days on average to three days (University of Oxford 2014). 89 percent of repairs were made within three days, and 98 percent of participating handpumps were operating at any given time. Furthermore, the actively managed pumps were 50 percent more likely to be fixed within two days compared to crowdsourced pumps. Communities indicated in a follow-up survey that they would be willing to pay a collective fee of around US$10 per month to continue the maintenance service (Katuva 2018).

Prior to the Smart Handpump pilot in Kitui, the average handpump repair time was 27 days. The pilot study saw a tenfold decrease in average repair times, down to just three days.
– University of Oxford 2014

The introduction of FundiFix helped continue this success. From February to June 2015, FundiFix made 56 repairs to 18 pumps, all but two of which were made within two days (University of Oxford 2015). The average downtime was 1.1 days. Over this period, 48 percent of repairs were made on just two handpumps, underscoring the value of pooling resources. 18 percent of handpumps did not require any repairs, and one community decided to withdraw from the program. As of 2018, Rob Hope said, "They generally get these things repaired very quickly, which creates value for the community. […] The handpumps, [they] do it within a day or the day of [when a repair need is indicated]" (Hope 2018).

Expansion

FundiFix has continued operating in Mwingi North Sub-County, where the pilot study was performed; this is one of the eight sub-counties in Kitui County with a population of 180,000 (Katuva 2018). Out of the 66 pumps from the pilot study, 22 pumps were initially registered with FundiFix, and as of November 2018, there were 28 pumps being served (Koehler and Katuva 2018; Katuva 2018).

FundiFix enterprise was created to improve maintenance services for rural water points using real-time data from handpumps and now has franchises in Kitui County and Kwale County, Kenya.

FundiFix has also been working with Kitui County government to expand services to piped water schemes since 2017, with three schemes joining in June and July of that year (Koehler and Katuva 2018). By February 2018, 29 piped water schemes had registered, serving some 40,000 people (Koehler and Katuva 2018). During the water audit of a Kitui County sub-county, eight out of 10 piped water schemes reported they would consider joining (DFID 2016).

As of October 2018, FundiFix serves 28 handpumps and 29 piped water schemes in Kitui (Katuva 2018). This includes 18,000 students at 55 schools and 16 health clinics. There are 20 additional collapsed pumps in the area that FundiFix is hoping to restore, and it is seeking financial partners to support this work (Katuva 2018).

FundiFix also operates in three of the four sub-counties in Kwale County (Katuva 2018). There are 73 pumps registered in Kwale County, which provide water for around 14,000 people and nine schools (Koehler and Katuva 2018).

Use of Data for Monitoring and Service Provider Accountability

The real-time monitoring of water services has changed institutional expectations, with data ensuring accountability and fostering community trust (Fischer 2018). Field data has played a direct, but not exclusive, role in alerting FundiFix to maintenance issues. Katuva said, “We don’t rely 100 percent on technology. We have a mix of both technology and [communities calling in]” (Katuva 2018). At the start of implementation, the data transmitters played a dominant role in identifying issues but as of 2018, more issues are first being realized through the community hotline. This shift is in part because

the communities now know that if they call, a person will respond (Katuva 2018). Hope elaborated: "The way it's evolved is when the communities sign up to the program—because they're paying a regular payment—they often sense that there's a problem with the handpump and will call it in before it actually breaks, because if it does break, they're losing money" (Katuva 2018).

Additionally, the piped schemes that have been introduced are not as automated as the handpumps, so community members are better positioned to report. According to Katuva, "Pipe bursts are very common [...] so the household next to the particular point where there is a leakage, they call" (Katuva 2018). Yet Katuva agreed "100 percent" that the availability and use of data at the beginning of the project was important to establishing community trust (Katuva 2018).

> **"If you don't have the performance indicators [to show to investors], then you don't get your shortfall covered, so it is very important that we keep track of this every month."**
> **– FundiFix Director Jacob Katuva**

Data on operations are also important to determining key performance indicators that are reported to the trustees. Katuva explained that, "If you don't have the performance indicators, then you don't get your shortfall covered, so it is very important that we keep track of this every month" (Katuva 2018). According to Rob Hope, the ability to present performance-based outcomes has attracted social investors that appreciate the availability of objective, verifiable data on operations and finance (Hope 2018). Hope said, "The data that we generate from the smart handpumps really gives a certain type of investor a lot more encouragement that this is a good investment to go forward with, and if results aren't coming through, then they need not pay into the system" (Hope 2018).

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Ongoing Challenges

The Smart Handpump Project has faced both practical and technical challenges. The initial study had several limitations, including a non-random sample and the lack of a control group (University of Oxford 2014). The researchers were also unable to consider how other factors may have impacted handpump performance, such as the community's use of different water sources (University of Oxford 2014).

The Smart Handpump model depends on the broadband network, but mobile service can be highly unreliable in rural Kenya (Behar et al. 2013). As Hope explained, "It's often not the data loggers or the sensors that are the problem, it's the network coverage" (Hope 2018). Network towers are mostly powered by diesel engines that risk breaking down or running out of fuel (Behar et al. 2013). During the pilot study, 40 percent of SMS messages were lost (Behar et al. 2013), so only 61 of the 66 handpumps were considered in the first analysis (University of Oxford 2014). The project has continued to deal with network intermittency, and the data transmitter will now repeat attempted sending of SMS messages on three occasions (Hope 2018).

The project has continued to face some difficulties following the creation of FundiFix. The initial enrollment into FundiFix was lower than expected, and the underlying factors cannot be easily addressed by the business model. Environmental issues were the primary reason given for non-enrollment; communities were more concerned about the actual availability of water resources than the pump operation. Additionally, longer delays were the result of unavoidable issues, including livestock interference, human conflict, and the need to wait for water levels to decline (University of Oxford 2015). Volumetric data was not always available, and member communities had some organizational difficulties with collecting payments (University of Oxford 2015).

Replication

There is work being done to extend the FundiFix model both within Kenya and around the world. Turkana County, Kenya is interested in developing a FundiFix model (REACH 2018). Also, the Bangladeshi government and UNICEF have invested US$150,000 to install 500 smart handpumps to monitor publicly subsidized handpumps (REACH 2018). The initial deployment in Bangladesh is focused on 240 schools serving an estimated 55,000 pupils (Fischer 2018). Zimbabwe and Ethiopia have also expressed interest in replicating FundiFix (REACH 2018).

Additionally, FundiFix has begun testing the use of electronic ATMs at water kiosks (Katuva, 2018). Households can purchase water from the ATM using a special fob that is loaded with mobile money credit. The system has the ability to set individualized water tariffs and it provides additional water use data while increasing financial transparency (Katuva 2018).

There are also other emerging handpump monitoring technologies from groups including Sweetsense and MoMo (Sweetsense, N.D.) (MoMo, N.D.). Similar to the Smart Handpump Project, these companies have employed their sensors in rural Africa and provide data for decision makers. These alternatives, though, are traditional flow meters installed into the pump nozzle, rather than the handle (Fischer, 2018).

Conclusion

Access to safe and reliable drinking water is a systemic challenge in Sub-Saharan Africa and throughout the world. This challenge is magnified by the technical and financial issues that reduce the reliability of handpumps and leave communities struggling to afford basic maintenance. The Smart Handpump Project in Kenya demonstrates an innovative way of remotely collecting data about handpump operation. Combining data with an alternative business model has reduced the pump downtime tenfold in participating communities and improved the reliability of water access. The solution is being expanded to other parts of Kenya and in Bangladesh. This application shows the potential of investments into new data collection technologies to improve the health and financial security of rural communities.

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