CHAPTER 5

Technology, data, and people: opportunities and pitfalls of using ICT to monitor sustainable WASH service delivery

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Innovations in information and communication technology (ICT) provide new opportunities to open up monitoring practices to more stakeholders. Accurate data on the level of service received by users and the performance of service providers makes it possible to improve water, sanitation, and hygiene (WASH) services. However, WASH data alone is not enough to encourage action. There remain technological and governance challenges to lasting WASH improvements. Data collection remains infrequent in many countries and many ICT-related innovations are limited to 'islands of success'. Technological glitches are still prevalent and often unaddressed. ICT builds on processes that are already in place and by itself cannot strengthen the processes required in order to act on monitoring data; for improved services, ICT design and application need to go hand in hand with changes in people, processes, and institutions.

Keywords: information and communication technology, transparency, national inventories, mobile phones, automated data collection

Introduction

Information and communication technology (ICT) 'consists of the hardware, software, networks, and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images), as well as related services' according to the World Bank's ICT glossary. Established ICTs include radio, television, video, and compact disc, while new ICTs relate specifically to cell phones and the internet (World Bank, n.d.; Juma and Yee-Cheong, 2005).

Within the context of water, sanitation, and hygiene (WASH) monitoring, ICT commonly includes internet services, mobile telecommunication networks, smartphones, and feature phones. Throughout this chapter the term

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'ICT innovation' is used to describe any innovation in ICT hardware, software, networks, and services. ICT tools refer to both hardware and software. ICT e-services include software updates, websites, databases, and other cloud or networked services that are provided on a regular or continuous basis to ICT users.

ICT is a key driver for long-term economic transformation, serving as an 'enabler of development of key sectors of the economy' (Juma and Yee-Cheong, 2005; Dzidonu, 2010). Rapid reductions in the costs of ICT services alongside increasing efficiency and quality have encouraged wide investment in ICT over the past two decades (Okogun et al., 2012). In the context of global development, ICTs make important contributions to achieving the millennium development goals (MDGs) as they stimulate economic growth by increasing productivity as they become embedded within public and private practice (Dzidonu, 2010).

Through better information flows and communication, the use of ICTs can improve service delivery in the public sector. Furthermore, ICTs can facilitate new communication channels between government, the private sector, and citizens. In so doing, ICT-supported public service delivery has the potential to increase the transparency of government services and to make them more responsive to citizens' concerns (Deloitte, 2012). The use of mobile phones has the potential to make government available anytime, anywhere, to anyone (World Bank, 2012).

Increases in mobile phone penetration and in access to mobile internet in rural areas in developing countries are encouraging the use of ICT to monitor rural water supplies, but there are still important gaps, as illustrated in Box 5.1.

However, ICTs are not, in themselves, sufficient to improve the effectiveness of service delivery. While they can facilitate new ways of engagement through information and feedback flows, the enabling role of ICT is subject to other governance factors such as public administration reforms, basic infrastructure, the availability of human resources, and skill sets at decentralized levels. Gaps between government policies, ICTs, the economy, and service providers need

Box 5.1 Mobile and internet penetration worldwide and in developing countries

Worldwide, mobile broadband grew by 45 per cent annually between 2007 and 2011, and between 2008 and 2010 there was a 22 per cent drop in the price of mobile broadband in developing countries (ITU, 2012). Even with these great improvements, per 100 people, there were only 5.3 mobile broadband subscriptions in developing countries compared with 46.2 in developed countries in 2010. In developing countries, subscribers paid almost 75 times more for wired broadband and almost six times more for mobile broadband than in developed countries. In most developing countries, households, schools, hospitals, and other public institutions located outside major urban areas were not yet connected to high-speed internet (ITU, 2012). In order to deal with these challenges, it is still critical to ensure that implemented services can operate in low bandwidth settings and do not require constant mobile network connections for use in rural areas (Dickinson and Bostoen, 2013).

to be bridged in order to harness the expanding potential of ICTs within the field of development (Okogun et al., 2012).

Harnessing ICT innovations for monitoring WASH services

Between 1990 and 2010, more than 2 billion people gained access to improved drinking water sources, and the MDG for water supply has been met five years ahead of time. However, 780 million people lack access to safe water (UNICEF and WHO, 2012). As coverage increases, the need to monitor and ensure sustainability of water services grows.

A particular challenge in rural water supply is the high non-functionality rate of water supply schemes of over 30 per cent (RWSN, 2009). The low sustainability of water services makes reaching everyone more difficult than expected, and obtaining up-to-date information on scheme sustainability is particularly urgent in the rural water supply sub-sector. In many of the countries that are facing major WASH challenges, national water supply scheme inventories are not updated regularly and routine monitoring data for the sector is not considered reliable. Both ICT- and WASH-related challenges will need to be addressed in these contexts in order to improve both the speed of information updates and the actions that are required until everyone has access to water and sanitation services.

High-income countries and countries with relatively stable institutions and high population densities are often better positioned to establish innovative ICT than lower-income and lower-density countries – a situation that often parallels WASH sector progress. Governments, donors, non-governmental organizations (NGOs), and other stakeholders need to tackle the dual challenges of ICT and WASH together to ensure sustainable rural water services for everyone.

Overview of ICT applications used for WASH monitoring

WASH-related ICT-based monitoring innovations have grown steadily since the early 2000s. The many early attempts to use ICT for monitoring included the use of Microsoft Access and other local computer databases and management information systems to organize and distribute monitoring data collected on paper. However, in recent years, the ubiquity and low cost of mobile telecommunications and internet access in the South have prompted innovations in the use of mobile technologies to collect and distribute information; for instance, a recent study of mWASH monitoring identified 40 mobile initiatives in the sector (Hutchings et al., 2012). The use of mobile telecommunications, internet-based cloud services, and smartphones is revolutionizing monitoring in the WASH sector. Table 5.1 includes examples of ICT use within the various steps of sector-wide WASH monitoring. Individual WASH ICT methodologies are described in more detail in Table 5.2.

Table 5.1 ICT within the flow of monitoring information

Steps in the sector-wide monitoring information flow		WASH example
Collection	Capturing data in a format that can be recorded. ICT technologies support different methods of data collection, such as crowd sourcing, administered surveys, and automated data collection. The technologies used include digital sensors and loggers, smartphones, and web, mobile, and computer software to support data entry.	Mapping facilities using Android phones with Akvo FLOW[1]
Transfer and communication	Transporting data from the field and storing the information temporarily. The most common forms of transport include physical transport of digital media, wireless data transfer through GSM networks or WIFI, and wired data transfer.	Using FrontlineSMS to send monitoring surveys via SMS[2]
Data management	Storing and organizing data and enabling access after the information has been stored for data cleaning, reconciliation, and other purposes. Data storage technologies include storage media or hardware, storage architecture, and the way in which data is organized, and the software used to manage the data. In general, storage is increasingly decentralized, with the use of cloud services and websites to store and manage data.	Using Manobi to manage asset inventories of piped systems in small towns[3]
Analysis and reporting	Manipulating the data and related information to understand patterns and answer questions about rural water supplies and their sustainability. There is a broad range of tools and innovations possible, including reports and visualization, analysis and statistics, knowledge management, decision support systems, and surveillance and alert systems.	Using Water Point Mapper to generate maps of water quality or water point functionality[4]
Use	Applying the information to guide decisions at district, regional, and national levels. This includes enforcing sector guidelines, repairing facilities, supporting service providers, monitoring standards, and planning the equitable extension of services.	The M4W project sending an SMS to a hand-pump mechanic to request the repair of a pump after a problem is reported[5]

Table 5.2 Methodologies for ICT-based data collection in WASH

Methodology	Technologies	Description
	Open Data Kit (ODK)	ODK is an open-source set of tools that assists in creating and managing data collection processes. ODK functions include building data collection forms, collecting data on mobile devices, aggregating data on a server, and exporting the data for analysis. It is used by governments, NGOs, academic institutions, and the private sector for monitoring in water and sanitation. The ODK software can be downloaded free from the ODK website. A vibrant user community shares experiences and developments.
Smartphone data collection	Akvo Field Level Operations Watch (FLOW)	Akvo FLOW, started by Water for People, enables survey-based data collection and is offered as a supported software service by Akvo. A contract is required for its use but the software may also be downloaded and run separately, although there is limited community support for running a separate version of the application. This service has been used by the governments of Liberia and Ghana, IRC, and others.
	mWater.co	mWater.co was developed to identify water sources and record water quality data as open data available online. It can be used for water point mapping surveys. The mWater app is free to download from the Google app store. UN Habitat has used mWater in Kenya and Tanzania.
Feature phone data collection	FrontlineSMS	This enables users to design, build, send, and receive forms via SMS. It is simple, fast, and easy to set up, and there are working examples from all continents.
	M4Water	This enables survey-based data to be collected using simple, low-cost feature phones that support Java applications. In addition, it allows reporting by communities of hand-pump breakdowns using SMS. M4Water was developed by Makerere University and is supported by a private company in Uganda.
Automated data collection	Oxford smart hand pumps	Motion sensor technology coupled with a communications device has been fitted to hand-pump handles and can record and send data about frequency of use. Information is sent via SMS and is received by hand-pump mechanics. WaterAid's Water Point Mapper software has been used to analyse the data.
	MoMo	This is a flow rate sensor that can be embedded into hand pumps or piped systems. Initial tests are still ongoing.

Typically, a single technology will not cut across all these steps. Instead, sector monitoring information systems will include a number of different technologies, requiring different skills and resources. These information systems are usually customized and/or configured for a specific country, organization, or project.

Technologies for data collection

Common ICTs for data collection can be divided into three categories based on the type of device used: smartphones, feature phones,[6] and smart devices embedded in water facilities. Table 5.2 provides some examples of these; however, it should be noted that the features and support provided for each tool change very quickly and this table provides only a snapshot at the time of writing. It should be noted that the FrontlineSMS and the smartphone data collection tools are the most mature tools in terms of reliability and usability at the time of publication. Smart hand pumps and other affordable embedded devices have not yet undergone mass production, are still being piloted, and usually require specialized skills for implementation.

The increasing availability and affordability of smartphones makes it likely that applications will continue to improve and they will become increasingly accessible and prominent, especially in urban areas. The use of visual interfaces can overcome some language issues. However, challenges to smartphone data collection include battery life, different operating systems, and uneven implementation of GPS.

The use of feature phones for data collection is significant among field workers in both rural and urban areas. As a result, there is still substantial demand for applications that use SMS, voice, and shortcodes (for example, the user enters a code, such as *334#, and is provided with a text-based menu) that can work on all low-cost feature phones. SeeSaw, based in South Africa, has piloted an innovative technology that allows entrepreneurs to report maintenance issues using a simple list of phone numbers that no one answers (a 'missed' call). Calling the number costs nothing.

In the near future, we are likely to see an increasing use of mobile applications using a combination of both basic mobile services and smartphones, depending on the differing needs of organizations collecting the data, access to smartphones, and the requirement to work without having to install software on phones.

In order to integrate the data collection tools with sector monitoring, there is also a need to ensure that the data collected feeds into monitoring and decision making. This may require linking the data collection systems to the national- and district-level databases as well as to tools for analysis. While some of these tools support some data management and visualization, it is not likely that any of them can provide a complete system for sector monitoring. Repeat data collection functions are critical – these allow existing entities such as water points to be updated while seeing the results of previous surveys on the data collection tool – and will need to be tested further in future applications of any of these tools in order to support monitoring data collection effectively. Enabling enumerators to search for data based on their location in the field or keywords can help them easily update information on water points nearby and ensure that data is kept up to date. Finally, one way to reduce the data collection burden but gain access to useful monitoring information is to automate data collection. This is treated in more detail later in this chapter.

Technologies for management and analysis

In the last decade, many new tools have become available to facilitate the management of data and to analyse geospatial data. However, local governments and community-based service providers often lack the technical capacity or training to use the software. In response, WaterAid developed a spreadsheet-based tool called the Water Point Mapper (WPM). The WPM, operated via Microsoft Excel, is capable of generating maps that can be viewed in Google Earth or Google Maps. Spreadsheet-enabled mapping has become a popular solution for government-led monitoring initiatives that lack the resources, finance, and skills required to implement smartphone data collection, cloud-based data storage, or online dashboards for spatial representation and graphical analysis. The Excel-based option remains locally accessible, has a minimal cost, can be managed offline, and is simple to operate and customize while generating effective spatial analysis.

At a national level, Microsoft Access database systems and Excel spreadsheets, as well as a variety of other relational databases, have commonly been used for national monitoring and for storing data by both WASH projects and governments. Not all of these relational systems, such as Microsoft Access, are easily available from computer browsers or on mobile devices and so the scalability of these systems to district level using mobile networks is limited. In addition, many of the Access databases and relational systems were expensive to develop and are difficult to update. Offline relational databases encouraged a centralization of data while responsibilities for monitoring water supply have typically been decentralized to districts. In the future, it is likely that web-based and mobile-friendly portals to WASH data and analysis will become increasingly common and user friendly. This is essential to ensure that, as mobile network coverage increases, so does access to data management and analysis for monitoring.

There is a new category of applications that have both data collection functions and data management and analysis tools (see Table 5.3 for a snapshot of some of these functions). The strongest tools will provide options for both online and offline access, relational data types, an application programming interface (API) that allows the third party tool to communicate with national databases, and visualization such as maps, charts, and time series. The most sophisticated tools will also include some statistical analysis and the computation of indicators, such as coverage based on several input questions. For the moment, complete monitoring systems will probably still

Table 5.3 Some applications that support data management or visualization 'out of the box'

Tool	Data				Analysis			
	Online access	Offline access	Tables	Relational database	API	Maps	Charts	Time series
WPM	✗	✓	✓	✗	✗	✓	✓	✗
Akvo FLOW	✓	→	✓	✗	→	✓	✓	→
FulcrumApp[7]	✓	✓	✓	✗	✓	✓	✓	✓
WASHCost Calculator[8]	✓	✗	✗	✓	✓	✗	✓	→
SIASAR[9]	✓	✗	✓	✓	→	✓	✓	→

Key: ✓ = yes; ✗ = no; → = planned.

include a combination of the software below with custom-built databases. However, as third party tools and e-government policies on data storage and open data mature, it is likely that more and more functions will be available to governments at national and local level 'out of the box'.

Automated monitoring and operational data

Automated ICT can be used in the WASH sector to remotely monitor services and address systematic and predictable tasks or challenges. These systems can be used across the monitoring information flow, from the use of remote sensors to collect and transfer data to the automation of data management, analysis, and report generation. In addition, some actions can be triggered through alerts and information targeted to specific individuals. Some examples are automated reports about breakdowns sent to area mechanics, the ordering and delivery of spare parts, and letting water committees know that their mobile money account is getting low. Some such technologies are identified in Table 5.4.

The most common forms of automation are software applications that generate automatic reports in standard formats or web-based maps from data collected (such as SweetData and mWater.co). Much automation occurs without the knowledge of the users, such as recording the date when the functionality of a water point is reported.

Advanced ICT that is available for monitoring rural water supply services incorporates the relatively low-cost functionality monitoring of SMS and mobile data technology embedded in the water supply infrastructure, whether a piped system or a hand pump. Small devices, such as digital sensors and loggers, are installed to measure the flow of water in piped networks or the movement of the hand-pump mechanism, and they transmit the data to a server where it can be disseminated to field staff or mobile mechanics. This development promises to generate information at scale that can be used by institutions for improving management and service delivery. It has the benefit of providing fine-grained operational-level data that can inform improvements

Table 5.4 Some automatic technologies for data collection

	Digital sensors and loggers	Computers and integrated devices	Software applications	Implications for data
Automated data collection	Flow and pressure sensors to monitor water use, satellite imagery to track changes in water bodies	Smart hand pumps and other devices with integrated sensors	Platforms and customized software for automated data management and visualization and for triggering actions with messages to users	Quantity and quality can be configured but quantity can also be overwhelming; the frequency of collection depends on a connection to the network; malfunctions in devices or connectivity can corrupt data

in service delivery. Some 'all-in-one' automated systems even incorporate payment and billing as well as monitoring the usage (by households) of rural water supplies. An example of such a system is the Grundfos Lifelink,[10] which is currently used by both Grundfos and Water Missions International to provide a solar-powered water source with a standpipe and allows payment with credit purchased in advance. So far, these systems have not been used on a significant scale. High capital costs and slow cost recovery from user payments may be reasons for this, but such systems may play a greater role in the future as capital costs are expected to decrease dramatically. These technologies also often create dependency on a virtual financial system of credits, and it may be that the prepaid financial models in place are not yet working for the poor and ultra-poor who have variable access to cash.

Oxford University has been piloting smart hand pumps. The device is capable of measuring water point handle movements and sending data over SMS messages, as demonstrated in Figure 5.1. The device consists of three essential elements: 1) an ICT-based accelerometer; 2) a microprocessor; and 3) a GSM modem (Thompson et al., 2012). Tested first in Zambia, by Oxford University and a local private service provider, these devices have now been fitted to water points in 70 village hand pumps in the Kyuso district of Kenya (University of Oxford, 2012). Areas with these smart hand pumps have reported a reduction in non-functional days from 40 per year to four per year. This provides a positive indication of how smart hand pumps could facilitate successful business models for rural service delivery.

It still remains to be seen whether these devices will continue to operate reliably outside research settings. The MoMo device, developed by the organization WellDone, found a clear example of the challenges involved in the application of innovations in ICT. The devices, which work by transmitting data received through sensors via SMS messages from the water point to a server, failed to transmit data during one early pilot because they were installed in an environment lacking mobile phone reception. The Oxford pilots found

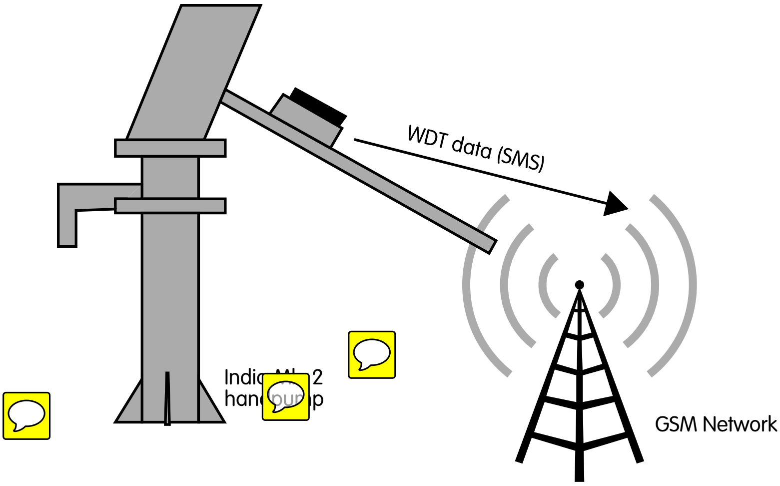

Figure 5.1 Water point data transmitter, sending data periodically by SMS, attached to an India Mk 2 hand pump

Source: Adapted from Thompson et al., 2012.

that a high proportion of SMS messages were lost due to irregular network connectivity. Even with these challenges, remote monitoring of rural water supplies is likely to increase and could revolutionize both service delivery models and the ways in which these services are monitored.

In evaluating these devices, key considerations will be whether the remote monitoring devices will be serviced and repaired when they break down and whether they are reliable enough in real-world applications to reduce the overall costs relating to travelling to water points to check, maintain, and repair them consistently. Other factors include the unit costs for installation, the cost of maintaining and running the systems that collect the data, the costs of mobile data and/or SMS and power for the devices, security, spare parts, the lifespan of the technology, and the availability of a constant mobile network connection.

Case studies: using ICT for sector monitoring

This section explores country studies from Liberia and Timor-Leste to examine sector-wide uses of ICT for WASH monitoring. The experiences of these countries underline the potential for ICT to provide improved data for investment decisions and planning. They also help highlight some common challenges that may be faced when ICT is rolled out at a national scale, especially in relation to ensuring that improved information is kept up to date.

Liberia

In 2003 Liberia emerged from a 14-year civil war that decimated infrastructure and led to a dramatic deterioration of WASH services, including safe water points, and to the looting and damage of all data on facilities. The signing of the Comprehensive Peace Accord in August 2003 initiated emergency WASH interventions, providing critical relief after the war. However, these were ad hoc and often uncoordinated and limited; still only 51 per cent of the population has access to safe drinking water (UNICEF and WHO, 2012).

Planning and data collection became of critical importance and the Ministry of Public Works (MoPW) took the lead to address this shortcoming. With targeted investment following 2010's HIPC (heavily indebted poor countries) debt relief and additional support from the Water and Sanitation Program of the World Bank (WSP) and UNICEF, MoPW mapped 10,000 rural and urban water points across all 15 counties between December 2010 and May 2011. Aiming to gain greater insight into the planning and allocation of resources, MoPW created the nation's first comprehensive inventory of water point assets. The inventory has improved analysis with regards to water infrastructure and has improved the accuracy of data used for fund mobilization.

The ICT used for the exercise enabled rapid data collection and represented a national-scale pilot for using mobile technology for data collection. Surveys were assigned to Android smartphones with Akvo FLOW enabling enumerators to complete the surveys via their touchscreens. In addition, they could use the phone camera and GPS to capture images and geographical coordinates of the water points. Data was then automatically submitted to the web-based dashboard for data management, cleaning, and analysis.

Attributes of water points were identified and verified, including the source type, functionality, construction details, and the prevalence of water committees. Water quality testing, which analysed biological and chemical composition, was carried out on sample wells in the capital, Monrovia.

Since the baseline collection in 2011, the main challenge has been updating the database with newly developed infrastructure and keeping the status of existing water points up to date. This is both a technical and a logistical challenge. To overcome this, a framework was developed involving the Ministry of Health and community health volunteers to collect data continuously. They utilized existing networks as well as engaging focal points at community, district, county, and national levels (see Figure 5.2). At the time of writing, Akvo is planning a repeat data collection tool to support the updating of existing data points when there is no internet connection in the field. The repeat data collection tool will help FLOW graduate from a baseline data collection tool to a continuous monitoring tool.

Many NGOs delivering water services in Liberia now have FLOW applications on phones with digitized standard questionnaires. Additionally, a website has been developed featuring Akvo RSR (Really Simple Reporting) tools to facilitate the piloting of continuous monitoring of projects in Liberia (not only water points). Nevertheless, prevailing challenges involve slow adaptation to new technologies or systems, and the capacity and motivation to collect data remain issues at sub-national level.

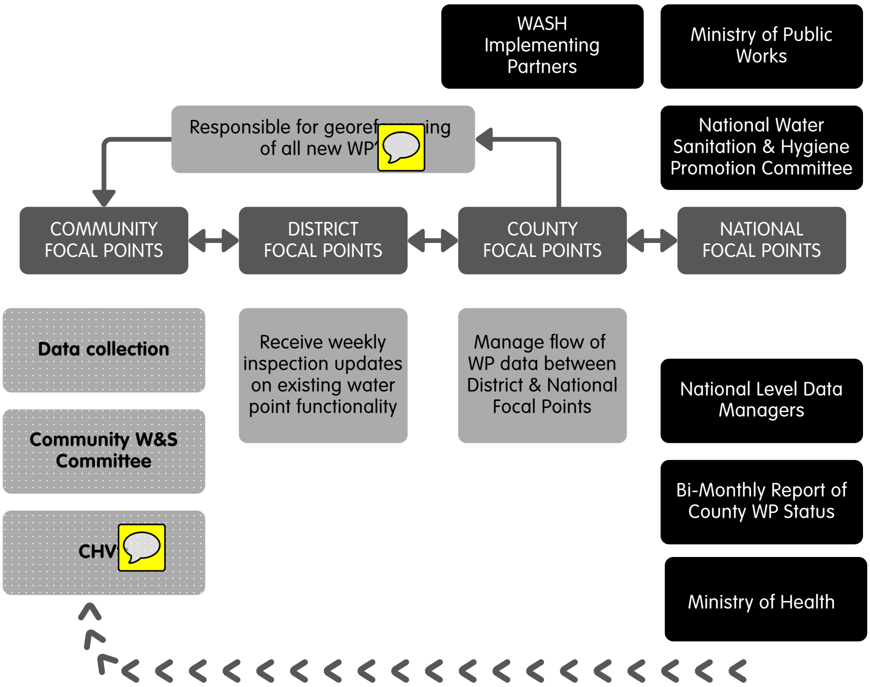

Figure 5.2 A framework for updating water point data in Liberia

Source: Koroma, 2013.

One definite success of this process was the production of a quarterly report on access and coverage. This has been partially updated using a template completed by NGOs and government partners to capture new construction and rehabilitation work. However, this fails to capture the functional status of existing water points.

While there are significant difficulties, the Liberia case provides an example of how incorporating NGOs into monitoring ICT systems can help address challenges to sustainable monitoring at scale. However, there is still a need to continue to incentivize at sub-national levels due to failures of existing water points, and local capacity building is required in the use of new tools in order for this to become a driver for sustainability. The addition of repeated data collection tools that provide access to previous data on phones and that encourage the use of data in planning can help create the right environment to stimulate repeated data collection.

Timor-Leste

Until recently, Timor-Leste has been marked by civil war and violence resulting in poverty, insecurity, and challenges for the WASH sector, including shortfalls in administrative and human resource capacity to implement policies and programmes (ISF-UTS, 2011). However, since independence in 2002, the government has significantly built the profile and priority of the WASH sector, moving away from donor finance dominance and towards improving WASH services and sector management through the Ministries of Finance, Infrastructure and Health, with continued support from the Australian government's Department of Foreign Affairs and Trade (DFAT).

Prior to 2010, Timor-Leste had a water supply monitoring system, but much data was collected on paper, there were different indicators collected, partners were not engaged, many geographical areas were neglected, and there was a lack of system functionality and service-level data. In addition, there was no scaled-up updating mechanism and no sanitation information. As a result, data analysis for decision making was limited and it was not easy to use the monitoring system as a management tool. Improving the sustainability of rural water service provision in Timor-Leste thus required a reorientation of the sector – from an infrastructure focus with poor monitoring to a service delivery approach, where progress is measured.

Between 2010 and 2012, the Water and Sanitation Information System (SIBS) was developed as a national monitoring tool, funded by DFAT through the BESIK Rural Water Supply and Sanitation Programme. In order to provide data for use at sub-district, district, and national level, government staff, as part of their day-to-day work, collected water and sanitation data in all rural villages in Timor-Leste. As a government system, the monitoring indicators were aligned with national standards and policies. This tool was designed to manage and monitor rural water and sanitation services at national, district, and sub-district level, as well as to measure functionality down to village level.

To overcome the challenges of data entry from paper-based forms, SIBS used feature phone SMS mobile technology for data transfer and Timor-Leste's limited internet and mobile data access. Mobile network services are available across approximately 85 per cent of Timor-Leste, enabling 88 government-employed WASH facilitators to collect data by downloading and inputting forms, storing the information, and then transmitting the data by SMS when mobile network coverage is available. In principle, updated information is sent every three months by SMS to a central database held at national level.

The data collection process involved creating baseline community profiles (56 questions) and collecting water system asset information and social information. It includes quarterly updating of information through regular visits by sub-district facilitators as part of their role to support WASH community management. The collected information is analysed using Microsoft Excel. Presented data is shared at district and national level, where staff have been trained in data analysis and use, but also at sub-district level; at this level, printed copies are used due to the lack of computer availability. Next steps involve making information openly available to all in order to hold service providers to account.

Some of the elements required by SIBS, and that relate to the costs of the system, are:

- FrontlineSMS open-source software;
- an ICT technician for 1.5 years to establish the system;
- simple feature phones for 88 WASH facilitators, with a small Java app for data collection;
- SMS for water and sanitation forms – two SMS messages were needed for each village, at a cost of US$0.08 per SMS, so covering 2,225 villages cost approximately US$35.60 for data transfer;
- community visits as part of the ongoing role of WASH facilitators;
- information management system support – establishing the database and SMS system and for ongoing systems support;
- equipment for users to access maps or data;
- bringing key people together to analyse and respond to data;
- investments in data checks (of 5 per cent of the data) to ensure accuracy.

By early 2013, there had been limited improvement to the scheme's functionality. This highlights the importance of being able to act on the data provided by ICT-driven monitoring systems and the need for planning on the basis of the data and corrective action to take place. It may also take more time than initially anticipated to make use of the information coming from new ICT systems. There are still lessons to be learned on how to effectively use ICT systems to improve services.

Overall, however, a national monitoring tool has been established in Timor-Leste, utilizing mobile technologies to monitor water and sanitation information at national, district, sub-district, and village levels. Staff training and external technical support are likely to continue for some time. Yet by updating data every three months, the government staff of Timor-Leste demonstrate the great potential of using ICT for monitoring WASH services in fragile states.

Discussion of country cases

The two case studies highlight the use of ICT to manage and monitor rural water and sanitation services at national, district, and sub-district level. They illustrate different ways in which ICTs can capture functionality at the level of facilities and villages, support the implementation and analysis of service delivery indicators, and measure national performance. Being government-led, the data collected was aligned with national standards and policies. It is important to examine these country cases to counterbalance the many small-scale pilots of ICT innovations in the WASH sector, which do not provide sufficient lessons on the scaling of sustainable monitoring ICTs.

The leadership in both countries also helped to clarify the respective roles and responsibilities of those who were collecting the data, validating data, and planning. It is clear that introducing new technologies must go hand in hand with changes in sector governance, and this requires a clear vision and leadership. The same level of leadership needs to go into the use of the data and enforcing sector standards in order to ensure that monitoring makes a difference when applied at scale.

At the same time, in both countries, staff turnover and a need for ongoing training also constrained the use of new technologies and monitoring processes, especially at district level. This required constant investment from outside sources of funding. Both countries face challenges, albeit different ones, in keeping their data inventories 'live', but Timor-Leste seems to be able to keep its data relatively up to date in some areas.

The case of Liberia also offers an example of how non-government actors can be used to provide updated information for national inventories. In many countries, NGOs are required to report their plans and the installation of new facilities. Providing these actors with national or district monitoring tools could strengthen national monitoring systems. However, even these actors require training, and the use of these systems will need to be enforced in order for them to be cost-effective. Additionally, it is still critical that government does at least some sampled repeat data collection to cross-check and verify data, even if that data is provided by service providers or NGOs.

By contextualizing processes, acknowledging stakeholder responsibilities, and encouraging high-frequency reporting by government staff and existing health networks, ICT tools are being enhanced. Forthcoming challenges, however, involve strengthening administrative systems, enhancing absorptive capacity, clarifying institutional arrangements for ongoing monitoring, and dedicating investment in sustainable service provision.

Finally, the cases highlight the capacity and time required to analyse data locally. District governments are further limited by a lack of internet connectivity and by electricity breakdowns. It is crucial that data is analysed and understood by the local stakeholders who will use it.

Successful design of ICT for improving services

This section presents and discusses lessons from the country cases above, from presentations under the ICT theme at the 2013 IRC Monitoring Sustainable WASH Service Delivery symposium, and from the wider sector literature for successfully using ICTs to support WASH monitoring. The lessons are organized along questions of social, operational, and programme design.

Social design

The social design of an application is the way in which the ICT is matched to a given social context or dynamic. The use of ICT is ultimately driven by a combination of people, institutions, and technology and how they interact. While some ICT functions are seemingly generic, such as using a mobile phone to make a normal voice call, the ways in which they are used are still largely shaped by the needs and the social and cultural norms of users and whether or not they are familiar with the particular use of that technology.

Monitoring is usually driven by the needs of a particular institution or set of stakeholders: for example, national governments might need to track access to water and sanitation services by their constituents, or an NGO might need to show donors how their money has been spent to achieve the new water and sanitation services. Because of this, it requires extra effort to ensure that those intended to *use* the system are also included during the design phase. For example, if national monitoring is being designed for use by local governments but has been initiated by national government or international donor agencies, then it is essential that local governments are involved in the design and testing phases of the ICT and that they help set the objectives of the monitoring system.

User perceptions and acceptance. User perceptions are critical to the use of ICTs. The emotional response of a user to a new technology – whether fear, interest, or excitement – can have an impact on adoption. For example, young users may find it easier to adopt new smartphones for data collection. Older users may benefit from their additional care. Hutchings et al. (2012) underline the importance of developing ICT tools that are customized to fit the local context in numerous ways, even going beyond the use of local language or terminology. Interactions can be localized based on social hierarchy, which has an impact on who has access to technologies or who is allowed to express dissent. Economic, socio-cultural, and environmental factors should be considered.

At a more fundamental level, the perceived ownership and objectives of monitoring systems shape the ways in which people use an ICT in the long term. A project-monitoring system may be designed to support project objectives and the collection and analysis of monitoring data may be supported financially by the project. However, if the perceived benefit to local users and institutions does not outweigh the costs of the system, data collection and analysis are unlikely to continue after the project period. National monitoring systems may face the same challenge with regard to ensuring that local governments and other stakeholders use the mobile data collection tools, databases, and web portals that have been developed.

The Community Water and Sanitation Agency and IRC piloted the monitoring of water services and the performance of community-based water service providers in three districts in Ghana. The data revealed that some systems were not performing well enough and that communities had not received enough support from the district. The focus on analysing and using the data with district water department staff and presenting it to assembly members encouraged repeat data collection without pilot funding and suggests the strength of local ownership of data and analysis (Ryan and Sulemani, 2013). WaterAid's WPM focuses on the use of a locally stored Excel spreadsheet to ensure that data is owned and analysed locally. Even when scaling up these types of monitoring systems to national level, sufficient attention and support must be provided so that ICT meets the needs of local stakeholders and so that they are aware of the role of ICT.

User perception is also greatly shaped by how the data is used and by the actions that are taken after monitoring and reporting have taken place. If users repeatedly see that reported problems persist, then they may stop reporting without external motivation (Taylor, 2012). In fact, reporting may never start if people do not believe that action will take place. Another problem may be that people have alternative ways of reporting and resolving issues. Both the costs and benefits of using the ICT systems, in comparison with either not using those systems or using alternatives, should be taken into account. The actual choice of technology is almost irrelevant if the people meant to collect the data do not see any benefit in reporting.

Finally, the legitimacy and credibility of the data are another key issue. In both small-scale and large-scale monitoring systems, verification of data through triangulation and spot checks can be an important way to ensure that data is both accurate and taken seriously by all users. It is worth noting that ICT can play an important role in improving the reliability of data by, for example, cutting out data entry and reducing the time taken between data collection and verification. Tools such as Akvo FLOW have allowed remote monitoring experts to check for errors and inconsistencies on an online dashboard and to call the data collector directly to correct any potential mistakes that have been made before the data collection is finished. In the Water Missions Trade Water project (Armstrong et al., 2013), the financial accountability of agents was verified by checking the volume of water dispensed against the money deposited into the bank. However, for high-quality data, sampled spot checks by independent enumerators may be the best way to ensure that data is not manipulated.

Participation. Each ICT tool supporting a monitoring process almost inevitably creates barriers and opportunities for participation in monitoring. A new web-based portal may provide access to data for new stakeholders, while simultaneously reducing the perceived need for paper-based reports and therefore excluding those without internet access.

Participation can be affected along the whole monitoring cycle, from those who are involved in data collection, to the people who have access to and use the data for corrective action. Familiar technologies (such as voice calls and SMS) may encourage participation (for example, SeeSaw's use of 'missed' calls; Schaub-Jones, 2013). Software installation requirements or training can equally provide barriers to participation and consequently have an impact on the cost of scaling the use of monitoring systems. Engaging users in system design can eliminate barriers to using technology, and working with users provides information and insight often beyond what is expected. There is value in involving primary users throughout the design and development stages; this can develop appropriate expectations of the tool's purpose and capabilities, as well as preparing users to begin utilizing the technology once implemented.

Improvements in sustained system uptake and relevancy can be made if user needs and preferences are addressed throughout the design and development of an ICT system. Greater involvement of communities and WASH stakeholders is required to build systems that meet the true needs of end users. A participatory process can be used in order to identify user requirements, which then inform the design of contextually appropriate technology.

Privacy and security. Monitoring data has the potential to reveal personal details about water users, community-based water providers, and other WASH sector stakeholders. These details can include names, phone numbers, place of residence, and income. Monitoring data needs to be accessible to those who should use it. However, this access to personal information could be abused due to negligence (unwittingly publishing it on an online map) during the standard use of ICT products, or from a motivation to use the information for personal gain.

Some governments have policies on the security of data and who should have access rights to different ICT system features and relevant databases. The privacy and security of data are key issues that need to be taken into account in the social design of a product. If a product is geared only to open data, it will not be the right tool for a government that requires access to information to be limited to specific WASH sector staff.

Technical design

The choice of technology, and how it is implemented, can have a strong impact on the scalability of systems. Technical considerations for the use of particular ICTs may include the geographical coverage of mobile phone networks, the battery life of devices (and backup chargers) in places with limited electricity, the cost of devices and services, and the ability of the technology to operate with intermittent internet connections in local offices.

In Ghana, the version of the district monitoring and evaluation system (DiMES) based on Microsoft Access, which was developed in 2007, requires a working computer, electricity, and training for each district: conditions that are difficult to maintain across all districts. A new version is being developed in order to overcome these challenges and will be partly web-based. In Timor-Leste, simple feature phones and FrontlineSMS software were used to implement a simple survey-based monitoring system. Saiful Islam Raju, from BRAC in Bangladesh, shares lessons for improving the sustainability of ICT systems, including developing lighter versions of the tools with a few key indicators, designing systems that fit within capabilities and existing organizational capacity, and designing for the existing capacities of staff responsible for implementing the system (Raju, 2013).

Data collection. Increasingly, evidence shows that mobile and automated data collection can have a significant impact on the ability to monitor at low cost and greatly speed up data collection and verification. Ranijiv Khush from Aquaya presents lessons on the use of mobile data collection in Mozambique and emphasizes that manual data management is a problem that leads to uninformed resource use and an uninformed public. As a result of Aquaya's work, data was available at upper administrative levels in Mozambique (Ball et al., 2013).

The choice of type of technology, whether smartphone, feature phone-based or paper, will ultimately depend on the context. Surveys have been administered in national monitoring exercises using smartphones and feature phones. Access to the device is critical and may determine the choice of data collection application. When communities in developing countries have to monitor or report information, systems that require the use of simple phones to either make a call or dial a shortcode (USSD) are likely to remain common where internet access and mobile coverage are limited. Paper-based data collection will still play an important role in some cases, especially when the data is being collected on a regular basis and logged locally, such as in local service provider offices.

Data management. The technical design also takes into account the technologies used for data management. Some key aspects of technical design include the location of data, the application used to manage the data, and functions such as the ability to run custom queries and analysis and to communicate with third party applications.

The location of the data storage, whether in country or distributed in the cloud, may be determined by e-government policies on preferred suppliers, the reliability of the service required, and the cost. International services can often provide cost-effective solutions for smaller WASH sector organizations and agencies. Some organizations or governments may choose their own solutions for security reasons and because they have the scale required to lower costs. Another consideration will be the expected quantity of data. In sector information systems that require the storage of images, or near real-time data, it is likely that data storage requirements will increase over time as devices produce high-quality images and send more data. This can render ICT systems obsolete if growth in data storage and bandwidth is not taken into account. The same can be true for web-based and mobile-based portals that disseminate the information collected. As the use of these systems increases along with mobile data coverage and access to browser-based devices, these portals must have the capacity to absorb new users.

The interoperability of an ICT – how easily it can operate with other systems to share data and functionalities – is another technical design element that is sometimes forgotten. It can be valuable to share data management services and responsibilities across different organizations, which may use different information systems. BRAC's Integrated Collaboration and Rapid Emergency

Support Services (iCRESS) system (Raju, 2013) is designed to integrate data across different sectors that traditionally have used a variety of data storage systems for their monitoring data, including simple Excel spreadsheets. Communication between these Excel spreadsheets and iCRESS had to be programmed manually, which represents a relatively high investment cost. Newer web-enabled technologies, and some mobile data collection tools, include API or data import and export functions, which can greatly simplify data exchange between systems. Through the use of APIs, BRAC has the capability to align with government and Red Cross information systems within the WASH sector. An interesting lesson from BRAC was that the system is more resilient because it uses many different sources of information: if one information input fails, another one can be used.

Programme design

Programme design refers to the management of the system and its institutional location to ensure the sustainability of the ICT and its related monitoring system. Hutchings et al. (2012) outline three key components: financing, technical partnerships, and metrics for effectiveness. In terms of sources of financing, the monitoring ICT can be funded through external donors, project partners, local or national agencies, internal funds (e.g. districts funding their own data collection), or even profits where the private sector is involved. More simply, options exist in terms of taxes, tariffs, and transfers.

While the cost of running baseline data collection is crucial, financing models must also be able to match the recurring costs of ICT services for technical support and for updating and debugging software over time. Even with the cost savings associated with the implementation of some ICTs, the cost of maintaining these systems can be difficult to budget when there is no precedent of budgeting for information systems and new activities (such as regular retraining for mobile data collection). This is particularly the case when funding is channelled through one- to three-year projects funded by external donors.

New ICT business models, such as Software as a Service (SaaS), require periodic fees to be paid for access to the ICT, which is kept up to date and improved over time. This contrasts with software that is bought once and installed and then never changes. The goal of SaaS is to spread the costs for software improvements over a larger number of users. Building monitoring systems with SaaS models can be cost-effective but requires long-term budget commitments and technical partnerships to ensure that these monitoring systems are not undermined by cash flow problems or changing suppliers. Sometimes, strategic technical partners may help provide long-term support for aspects of the system. Local telecoms, for example, may receive benefits from using a monitoring system on their network, for example more users on their network.

There are numerous examples of custom-built ICT systems that have been started but not yet finished due to contractual problems with the service provider. In these conflicts, licensing and ownership of the software code can become critical issues if they are not well defined in advance. Choices can include ownership being retained by the client or the establishment of a common open-source licence. Some intellectual property rights associated with the code can become a source of contention and lock a client into a particular software development firm. Some alternative choices include purchasing software that can be configured 'out of the box' or purchasing subscriptions paid over time. Typically, a custom-built system will need to be developed over time and tested with stakeholders in an iterative manner.

Measuring the effectiveness of a monitoring system should ideally be built into the system itself, for example by tracking the users of mobile systems, the volume and comprehensiveness of data collected, and the costs of maintaining the services. This is helpful when developing a monitoring system incrementally and in guiding how investment over time and recurrent costs can lead to improved ICT for monitoring. In addition, annual reviews of progress by users and key sector stakeholders can help to renew objectives and ensure that the system design goals are adjusted where necessary.

Conclusions: participation in producing, access to, and use of ICT-related data for improving water and sanitation

This chapter has explored and presented current examples of ICT innovations and their application within water and sanitation monitoring, with much of the information emanating from a wealth of papers and presentations authored for the IRC 2013 symposium on Monitoring Sustainable WASH Service Delivery. We show how ICTs can improve communication flows and service delivery and provide new opportunities for governments, institutions, and citizens. ICT can increase the transparency of government-regulated services and ensure that governments are more responsive to citizens.

As the availability of ICT increases, so does the potential for integrating technical solutions to fix existing problems. With the rise in ICT, we have the opportunity to collect and access greater knowledge about the sustainability of service delivery. New tools can identify trends and inform improvements in planning in ways that could address factors such as equity and ensure sustainable service provision.

In order to be successful, monitoring with ICT needs to take account of all three aspects of system design – social design (user perceptions, participation, privacy), technical design (the choice of technologies), and programme design (recurrent funding and resources). Successful monitoring systems match their users very well, as there are likely to be significant investments and recurrent costs if, for example, the tools require complicated training and support. Few if any ICT systems for national WASH monitoring are capable of including participation from all sector stakeholders (communities, district government, national government, NGOs, and the private sector), which suggests that ICT system designers should be careful not to be overambitious; rather, they should define exactly who their target users are and why. At the same time, broad access to the information generated and its wide dissemination are likely to increase the value of ICT systems.

The country cases have shown how difficult it is to pilot new technologies at a national level. For this reason, we argue that adaptive design and frequent user testing in regular and small iterative steps are required for large-scale ICT systems to be implemented successfully. Using ICT to potentially reduce the costs per unit of data still requires regular investments over time to ensure that the relevant ICT systems and monitoring processes are in place. Regular investments in interoperability between the systems of different agencies, training, product support, user testing, recurrent software costs, and data verification are just some of these budget items.

The focus on current tools is undergoing a much needed shift from data collection or database management only to using ICT to build sector monitoring systems for long-term use, with many stakeholders able to access and use the data. This means covering the entire monitoring process as outlined in this chapter. Future systems should encourage the use of information to improve sustainable services, enhance learning, and aid coordination between different actors. This will also require buy-in from sector leadership. Ultimately, monitoring systems will need to be enjoyable to use, provide trusted information, and add value to the different actors involved in improving WASH services.

From early attempts to integrate ICT for monitoring water and sanitation programmes, we have gained knowledge that we have used to build a basis for establishing shared understandings and defining best practice. Platforms such as the Rural Water Supply Network's mapping topic have provided a space for sharing and debate, much of which continues to inform ideas and influence actions. The plethora of mobile data collection tools available are an indication of the interest and investment in accessing better-quality information. However, there is still a limited number of accounts that detail cases where the availability of data has improved access to WASH services. This chapter shows that we are now struggling with issues that ICT solutions may solve only partly. Part of the challenge is the result of government-led monitoring supported by external agencies on a project basis with a short time frame. In this environment, only a few national water and sanitation inventories have been updated and it will take more time to establish the processes required to complement these ICT systems. But lessons are being learned and there is increasing opportunity for greater coordination of ICT interventions across organizations and governments. There is a growing need to share and document honest experiences of ICT, both the successes and the failures, as we move away from small-scale and short-term pilots. As the monitoring tools continue to improve – with more repeat data collection functions, automated monitoring, and improved dashboards for analysis and dissemination – we will still need to get right the social, technical, and programmatic aspects of updating monitoring data and improving WASH services.

Endnotes

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