Beyond 'functionality' of handpump-supplied rural water services in developing countries

RICHARD C. CARTER and IAN ROSS

Many rural point-water sources in developing countries consist of wells or boreholes equipped with handpumps. Various estimates have been made of the functionality of such water points, and functionality is now routinely monitored in national and local surveys of service performance. We argue, however, that a single binary (functional/non-functional) indicator is crude and insufficient to provide much information about service sustainability. We set out a categorization of functionality which includes three sub-categories of functional water points and five non-functional sub-categories, with well/handpump water points in mind. We use a simple model to demonstrate that reduction of high rates of early post-construction abandonment and reduction of total downtimes would greatly improve service performance. We show that functionality levels for multi-age populations of wells or boreholes equipped with handpumps would not normally be expected to exceed about 85 per cent. We recommend going beyond functionality monitoring via the collection of quantitative data on rates of abandonment, frequency and duration of breakdown, combined with descriptive narratives of actions to manage and repair water points, in order to generate more nuanced understanding of service performance.

Keywords: functionality, sustainability, rural water supply, handpumps, developing countries

Introduction

Numerous studies of the sustainability of rural water services in developing countries have been undertaken – the organization Improve International catalogues 124 such studies – and an increasing number of monitoring datasets report on the 'functionality' of water points and water supply systems. These are commonly water supply handpumps installed in wells or boreholes, or public taps fed by pumped or gravity-fed piped distribution systems.

This paper deals explicitly with public wells or boreholes equipped with handpumps (well/handpump water points, or WHPs). Although much of the content of this paper applies to other types of public water point, these technologies have particular features as they combine a groundwater abstraction point with a mechanical water-lifting

Richard C. Carter (richard@richard-carter.org) is Director of Richard Carter and Associates Ltd; Senior Research Associate at the Overseas Development Institute; and Visiting Professor at Cranfield University, UK. Ian Ross is Portfolio Manager, Water, at Oxford Policy Management Ltd.

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device, and they are usually managed by the users themselves (perhaps with help from local government, private handpump mechanics, or non-government organizations). Where necessary, we refer specifically to WHPs, but where our observations apply to all types of public water point we use the more general term.

Two broad categories of mishap can occur to such WHPs: either something can go wrong (or be wrong from the outset) with the water resource – its quantity or quality – or a malfunction of the pump may take place. Sometimes, for example in the case of handpump corrosion, the water quality can deteriorate because of a mismatch between pump materials and the physical/chemical properties of the water. These immediate symptoms follow from numerous weaknesses in rural water service implementation, management and financing, which are beyond the scope of this paper. They are, however, the subject of the Hidden Crisis project (Chilton, 2015; UPGro, n.d. a, b) funded through the UPGro research programme.

A WHP consists of two physical components: the well or borehole (the vertical, lined cylindrical structure which penetrates the water-bearing formation, or aquifer); and the pump (which hangs in the water and is secured at the top, usually by being attached to a concrete slab). Wells and boreholes have long design lives, typically exceeding 25 years (Driscoll, 1986). Any permanent failure of a well or borehole within that timescale should normally be seen as symptomatic of poor siting, design or construction. The handpumps which lift water from such sources typically have a shorter life (less than 10 years), but since each component part is replaceable, they too can be seen as long-lived infrastructure components. There is no reason why almost every part of a handpump could not be replaced on a cycle of approximately 10 years (with fast-wearing parts being replaced many times in that period), thereby keeping the water service working continuously (Arlosoroff et al., 1987).

Water users in rural areas of developing countries usually collect water daily, as they tend not to have sufficient hauling capability or storage capacity in the home to permit less frequent journeys (Curtis, 1986). Consequently, unless water users have access to multiple improved water sources, even short-duration breakdowns impose hardship, such as a reversion to further-away unimproved sources in the interim – an outcome with significant health consequences (Hunter et al., 2010). There are exceptions to this generalization, but for this paper we have in mind the least advantaged households for whom the assumption is valid.

The notion of functionality is superficially straightforward, and it has a good pedigree in the World Health Organization's Minimum Evaluation Procedure (WHO, 1983). The approach recommended in that paper drew attention to the functioning and utilization of services, the first being a necessary but not sufficient condition for the second, and the two together making possible the beneficial health and other impacts which are sought in water, sanitation, and hygiene (WASH) programmes.

Monitoring of functionality involves an assessment of whether or not a water point was 'working' at the time it was monitored; this is fraught with difficulties, as discussed later. Reporting of functionality for a district or nation requires the calculation of the ratio of functional water points to the total number of water points in the frame of the analysis, and it is normally quoted as a percentage. Functionality is usually reported as a cross-sectional indicator, looking across water points of various ages. Data collection usually takes place within the bounds of one season, but different water points may be surveyed on different days of the week and at different times of day. (See the Water Point Data Exchange, a publicly accessible web-based repository for water-point mapping data, which contains a great deal of multi-country functionality data.)

A commonly quoted estimate of WHP functionality (specifically handpumps in 20 African countries) is around 60–65 per cent (e.g. RWSN, 2009), a figure which is usually judged to be unacceptably low (see e.g. Improve International, 2015). Levels of functionality which are judged to be low are portrayed as indicating low levels of sustainability of rural water services. Clear distinctions between functionality and sustainability are rarely made, and it is assumed that the first is a reliable pointer to the second. More worryingly, the two are often taken as synonyms. In this paper we first expose seven major flaws in the notion of functionality as a performance indicator and the way it is estimated. Second, we briefly point out some of the links between functionality and sustainability. And third, we develop and model a better way of unpacking the idea of functionality, together with its implications for more relevant monitoring and reporting. In a future paper we will relate the concept of functionality to the wider and more important matter of sustainability of services.

Seven flaws in 'functionality'

The problem of definitions

The distinction between 'functional' and 'non-functional' would appear straightforward, but in fact it is open to interpretation. Is a handpump with a leaky footvalve, which requires many pumping strokes before water is seen, functional or not? Is a pump which delivers water at such a low rate that it takes 10 minutes to fill a bucket functional or not? Does a badly cracked concrete apron surrounding a well or borehole render it non-functional, even though water can still be obtained from it? Unsurprisingly, the notion of 'partial functionality' has had to be coined to fill the gap between the more straightforward full functionality and non-functionality (see for example Adank et al., 2014, in reference to Ghana). However, the description 'partially functional' can encompass many situations of low discharge, poor or variable water quality, inadequate sanitary status, and so on. Inevitably, different definitions of 'functional' and 'partially functional' have been used across studies and monitoring systems, leading to unknown comparability. The problem of definitions is an important one, but it is not insurmountable. If the sector is to persist in the use of functionality as an indicator, then work is needed to develop clear definitions, with comprehensive sets of location-specific examples, and preferably in a manner which allows comparability.

The problem of judgement

Closely related to the matter of definitions is that of the judgement of the monitor or observer. When observing a water point, or interviewing its users, the field worker needs to make a professional judgement about which category to place the water point in. Even the most comprehensive set of definitions and examples is likely to leave gaps which only the judgement of the monitor can fill. However self-consistent an individual monitor is, there remains the matter of potential inconsistency with other monitors. This issue can only really be addressed by regular moderation and 're-calibration' of monitors' judgements in order to constantly strive for consistency. To the best of our knowledge, many of the larger surveys and studies have necessarily used monitors who are not technical experts, but rather more generalist survey enumerators. The minimum qualification for this kind of work is generally a high school diploma or bachelor's degree, depending on the country. This raises the question of whether, even with excellent training, such people would be able to interpret complicated sector-specific definitions.

The problem of seasonality

It is quite common, though not necessarily easy, to separate the assessment of functionality from that of seasonality. The question is whether the water point is not functioning or only partially functioning because of seasonally low yields or groundwater levels, or whether its sub-optimal functionality has another (e.g. mechanical) cause. Service levels can also vary in unpredictable ways over time; it is rarely simply a case of worse service in the 'dry' season. This requires not only judgement, but also diagnostic skills which may be beyond the capability of most monitors.

The snapshot problem

Reporting of functionality is based on a snapshot view, even when it is reported in time series. The functionality or non-functionality of a water point today tells us nothing about its functionality yesterday or tomorrow. Maybe the 30 per cent of water points that are non-functional today will all be fixed by next week, and the next round of monitoring will pick up a different 30 per cent that are non-functional but awaiting repair. After all, a proportion of all cars and bicycles are off the road at any one time, and at least some of them will be repaired. Likewise, a proportion of people currently in hospital awaiting treatment will be cured, so that the next snapshot of hospital occupancy will comprise a different patient list than the present snapshot.

Snapshots or stories?

The snapshot view of the functionality of water points reveals nothing of the experiences of the hydrogeologists and engineers responsible for installation, or the communities and their support organizations responsible for operating, managing, and financing the service. In short, it is a blunt instrument. Perhaps a water point has a noble history of breakdown, struggles to raise funds and find repair technicians, and successful service – or maybe the water user committee gave up at the first breakdown. Perhaps the water users tried hard to repair their water point, but the solution to the problem lay outside their experience or competence. We need to know and understand these stories in order to develop more resilient services.

The denominator problem

The overall functionality of water points of different ages within an administrative unit or nation is calculated as the ratio of the number of functioning water points (or systems) to the total number surveyed. The second number, the denominator, is not necessarily the same as the number 'in existence', and the definition of the denominator will depend on the objectives of the survey or study. The agency leading the study may have a specific remit, e.g. an NGO or government department focused on their programmes or geographical areas. Alternatively, it may be a sample survey wishing to include any 'public' water points constructed in the last 20 years in the sampling frame, or a cohort study of all water points constructed in a given year. These methodological decisions affect the extent to which the denominator should or could include water points which have long ago been abandoned and forgotten, as well as those which have fallen out of service more recently and those which are temporarily non-functional. Abandoned water points may have been omitted inadvertently (if no physical evidence of their existence remains), or they may have been decommissioned and so deliberately removed from the picture. In either case the denominator is under-estimated, and consequently the functionality of water points of a given age tends to be over-estimated.

Taking a service management perspective, abandoned water points should not be part of the denominator, assuming they are not recoverable. However, taking an evaluative perspective, abandoned water points reflect past failures and must absolutely be accounted for. The denominator problem is further discussed and modelled later.

The benchmark problem

Finally, even if we could estimate functionality with reasonable accuracy, we should not expect it to reach 100 per cent. This would be to deny the possibility of breakdown and repair as a normal part of the cycle of any mechanical or physical system. But should we aim for 90 per cent? Or 80 per cent? Is 65 per cent actually quite good? What is a reasonable and realistic value for this indicator? What proportion of handpumps, tapstands, cars, bicycles, human bodies are 'down' at any one time, in the best-run societies, and in the conditions prevailing in low- and middle-income countries?

Functionality and sustainability

The relationship between functionality and sustainability – for they are not the same thing – is the subject of a longer paper in preparation. Here we make a few observations. We acknowledge also the work of others who have demonstrated the inadequacy of 'functionality' as an indicator of service level (Duti, 2012; Adank et al., 2014) and the linkages between various risk factors and functionality (Foster, 2013; Walters and Javernick-Will, 2015).

First, 'sustainability' is itself a contested concept, and the mere word alienates some. We use it here in the simple sense of rural water services which continue to function and provide benefits to their users over time. Abrams et al. (n.d.) promoted this idea as it encapsulates the time dimension of a water supply service in a few simple words, while implying so much in terms of management arrangements, the adequacy of post-construction financing, and the stability of the water resource involved. Today some (in particular the Triple-S and WASHCost programmes of IRC) prefer the expression 'service delivery' as a way of conveying the notion that water supply should be a service (i.e. with no end date) rather than simply the provision of physical infrastructure with a limited design life. Regardless of the term used, it is clear that physical infrastructure must be supported by monitoring, management, and financing arrangements which continue to enable the delivery of water over time.

Second, there is a fundamental difference in the time dimension of the two concepts, functionality and sustainability. Functionality is a snapshot taken on a particular date (or a set of dates within a limited period). It is essentially set in the present tense (or, of course, past tense, once reported). Sustainability on the other hand is about services over time, in particular the future continuous. It concerns the likelihood that services will continue to function over time, and so it is about assessing risks and probabilities into the future. Functionality may act as a crude indicator of sustainability, but perhaps nothing better.

Third, sustainability is multi-dimensional, as the continued functioning of a service depends on water resources (the environmental dimension); consumer behaviour (the social and cultural dimensions); policies, organizations and management (the institutional and governance dimensions); technical aspects; and the financial dimension. In contrast, functionality is one-dimensional, even binary in its simplest form.

If we are to persist with the notion of functionality, the concept needs to be developed and refined in order to give better insights into sustainability. The following sections suggest some ways in which this might be done.

Unpacking functionality

Categories of functionality

Assuming a WHP functions for at least some of the time, then it has three main attributes: its (short-term) water quantity or yield, water quality, and seasonality. Regarding yield and water quality, in general either the users find these properties reasonably acceptable, as evidenced by their year-round use of the source, or they do not. Serious dissatisfaction with either attribute usually leads to abandonment in favour of what is perceived to be a preferable source. A seasonal source is defined here as one which completely dries up or in which the yield falls significantly for several months of the year. Seasonality in this sense is a relatively long-term failure (typically lasting months rather than days), and it reflects on the water resource which the well or borehole is tapping, rather than the mechanical device (the handpump) that lifts water (although too shallow a vertical positioning of the pump cylinder can lead to the WHP 'drying up' as the seasonal water level drops below the intake). Seasonal water points may nevertheless contribute usefully to domestic water supply, especially if they are more conveniently located than more distant perennial sources.

Mechanical performance, yield, water quality and seasonality (four variables) could in principle combine to create a large number of functionality and non-functionality categories. Such a number would be cumbersome to work with, so we propose a smaller number of categories of functionality: three reflecting water points that are found to be working on the day of monitoring and five for water points that are not (eight in total). The list is shown in Table 1. Although yield and perceived water quality are two quite separate matters, either of which could lead to the abandonment of a water point, we combine them here in order to reduce the total number of categories for discussion.

F1, F2 and F3 comprise those WHPs found to be functional on the day of monitoring. NF1, NF2, NF3 and NF4 comprise the non-functional WHPs on the date of the survey. NF5 is unknown at the time of monitoring and would not be visited, therefore contributing to the unknown but likely over-estimate of functionality.

The important thing about F1 water points is that failure (most likely mechanical breakdown, but possibly long-term water table decline) *will occur*. Exactly when this will occur is unpredictable, but breakdown is a challenge that those responsible for managing the water point will inevitably have to face. No mechanical device is immune from breakdown. F1 water points are those that have not broken down *yet*. F2 water points are interesting because they can reveal useful insights into the ways in which users, managers, and their supporting organizations respond to breakdown, and also how long repairs normally take – an important aspect, discussed later. F3 water points may usefully contribute to water supply, but only for part of the year.

The number of water points in category NF1 is not known with precision, but these clearly form a very different category to F1 and F2. Reducing downtimes must be a high priority for sustainability-focused interventions, as is shown through modelling discussed later. NF2 water points, like those in category F3, cannot be acceptable as a sole source, but alongside other (perhaps more distant) perennial sources, they may make a useful contribution to water services. Regarding identified abandoned water points (NF3 and NF4), the most interesting questions are about how soon they broke down, and whether in truth they should never have been commissioned in the first place. Drilling contracts which put the onus on the contractor to drill successful wells, and in which supervision by the client is non-existent, create perverse incentives that may well result in significant numbers of low-yielding or poor-quality water points coming into service – and then being abandoned quickly. The forgotten water points in category NF5 are by definition difficult to quantify; approaches to doing this are discussed further later.

Water points in sub-categories NF3, NF4 and NF5 will only be of interest in certain types of analysis, which is why it is important to establish the scope of data collection. An inventory approach will only be interested in serviceable water points, whereas a historical approach will want to consider all water points.

Table 1 is a thought piece rather than a proposal for a monitoring approach. It should be emphasized that, despite the sub-categorization, the table still captures

Table 1 Sub-categories of functionality

		Mechanical	*Yield/quality*	*Seasonality*
F1	Functional, and has never yet been non-functional. Yield and quality acceptable. Not seasonal			
F2	Functional at the time of monitoring, but has experienced mechanical failure in the past. Yield and quality acceptable. Not seasonal			
F3	Functional at the time of monitoring, but dries up at certain times of year. Yield acceptable when working, water quality acceptable, but seasonal			
NF1	Non-functional due to mechanical failure at the time of monitoring, but will be repaired. Yield and water quality acceptable. Not seasonal			
NF2	Non-functional due to water resource limitations at the time of monitoring. Yield acceptable when working, water quality acceptable, but seasonal			
NF3	Non-functional and abandoned. Reasons may include unacceptability of water quality or yield, or repeated mechanical failures		could be any	
NF4	Abandoned and decommissioned. Water point considered to be irreparable		could be any	
NF5	Abandoned and forgotten		could be any	

Note: no shading indicates no problem; light shading indicates a past or present problem which does not necessarily render the water point non-functional at the time of monitoring; and dark shading indicates a problem that renders the water point non-functional at the time of monitoring.

a binary idea of functionality in the overall categories of F and NF. It is acknowledged that defining ‘functional’ is not straightforward, for example if conditions are attached to the yield, the water quality or the likely sanitary risk upon inspection, as raised earlier in the discussion on partial functionality. Future efforts to harmonize and standardize the monitoring of functionality – if this is to be the approach taken – must address this challenge.

In focusing on the different categories of functional and non-functional water points, rather than tackling the bigger issue of service level and performance, we acknowledge that we are addressing only one prerequisite for a reliable and sustained service. Furthermore, our intention here is not to unpack the underlying causes of poor functionality, which include inadequate financing and management, conflict, political interference, and corruption. These matters are addressed in part by Foster (2013) and Walters and Javernick-Will (2015). They are also the subject of the ongoing Hidden Crisis project (UPGro, n.d. a, b).

Modelling functionality

Modelling, especially in circumstances of limited data, can give important insights into how systems work and what information we need in order to gain even greater understanding. A model is a simplification of reality – and therefore should be used with caution – but it is a way of representing a system which is useful when our minds cannot readily grasp how the different parts of that system perform in combination. We set out here one very simple model, in the form of an equation, and we apply that model with some plausible but fictional data. The insights so produced can assist our understanding. To our knowledge, there is no primary data including these exact variables.

The overall functionality of a sample of water points (for example by district, or by year of construction) is given by the following equation:

$$F = (1 - a) - (1 - a)\frac{nd}{365}$$

where: F is the overall functionality of the population or sample (fraction, but usually expressed as a percentage); a is the fraction of the overall frame of water points that are permanently out of service and abandoned, i.e. the proportion of the total number falling into categories NF3 and NF4 (dimensionless). Note that water points in the NF5 sub-category are not included in a, since the number of NF5 water points is unknown. The equation calculates functionality within a sample of water points, but NF5 water points cannot be sampled, by definition. Depending on the aims of the exercise, the number of NF5 water points could be estimated from secondary data; n is the average number of breakdowns per water point per year (dimensionless); d is the average duration of a breakdown (days).

The first term in brackets $(1 - a)$ represents the proportion of water points remaining after the abandoned NF3 and NF4 water points have been excluded. The second term, $(1 - a) \times nd/365$, represents the average number of days per year that non-abandoned water points are out of action. Specifically, the product nd is the average downtime (days) per serviceable water point per year.

So, for example, if the average number of breakdowns per year is 2, the average duration of a breakdown is 21 days, and the proportion abandoned is 0.18 (18 per cent of the total number), the overall functionality is 72.6 per cent.

The use of this equation may be defensible if we are reporting functionality by year of construction. However, one would expect the values of n, d and a to be age-dependent. The use of the equation of course depends on having realistic values for the three variables. Obtaining such estimates is an important part of the attempt to really understand functionality and service performance.

The functionality of a sample of water points is determined by the values of the parameters a and nd. If we are modelling functionality of a mixed-age sample, then we need to take into account the age-dependence of a, n and d and the number of water points, N, constructed in each year (going back as far as necessary over time).

Table 2 contains fictional but plausible values of the model parameters, constructed with the India Mark II handpump in mind, but without the benefit of

Table 2 (Fictional) model parameter values and calculated functionality

Age (years) y	*Mean no. of breakdowns per year per water point n*	*Mean duration of breakdown, days d*	*Mean proportion abandoned a*	*Calculated functionality % Fn*
0–1	0.50	5	0.150	84.4
1–2	0.75	8	0.175	81.1
2–3	1.50	10	0.200	76.7
3–4	2.00	12	0.225	72.4
4–5	2.25	15	0.250	68.1
5–6	2.50	18	0.275	63.6
6–7	2.75	18	0.300	60.5
7–8	3.00	19	0.325	57.0
8–9	3.25	20	0.338	54.5
9–10	3.50	20	0.350	52.5
			Mean	67.1

Note: the values of *n*, *d* and *a* constitute inputs to the model. The calculated mean functionality assumes that the same number of water points were constructed every year.

real data for that model. To our knowledge there are no hard data for handpumps regarding number of breakdowns, time to repair and rates of abandonment as a function of age. Such data are badly needed. It may be that continuous time-series data from water-level loggers, handpump handle sensors or flow meters will become more widely available in future. If so, such data can be brought into the analysis of functionality and service reliability. RWSN (2015) lists a number of examples of such initiatives.

The number of breakdowns per year, *n*, would be expected to increase fairly steadily, with the seriousness and hence duration, *d*, of breakdown increasing correspondingly. The number abandoned year by year might be expected to gradually rise from the already relatively high levels in the first year as the performance of the service deteriorates. In this table we assume that the same number of water points were constructed each year, although this of course could be varied if one had real data. The final column of the table gives the calculated value of functionality for that year's cohort, and these figures are plotted in Figure 1.

Figure 1 shows in graphical form the way in which the model behaves. It is apparent that the abandoned water points bring the maximum possible functionality score for the sample down to 85 per cent in this case (*a* is assumed to be 15 per cent by the end of year 1). Thereafter, functionality falls because of the effect of downtime (the product of *n* and *d*) and further abandonment of water points. It makes no difference to the calculated functionality if the average downtime is made up from two breakdowns of 10 days' duration or one breakdown of 20 days' duration. Both factors are important, and if both are large, functionality of the sample can fall to very low values. It is not clear what the relative effects of breakdown frequency and downtime are on human behaviour, especially the decision to abandon a water point.

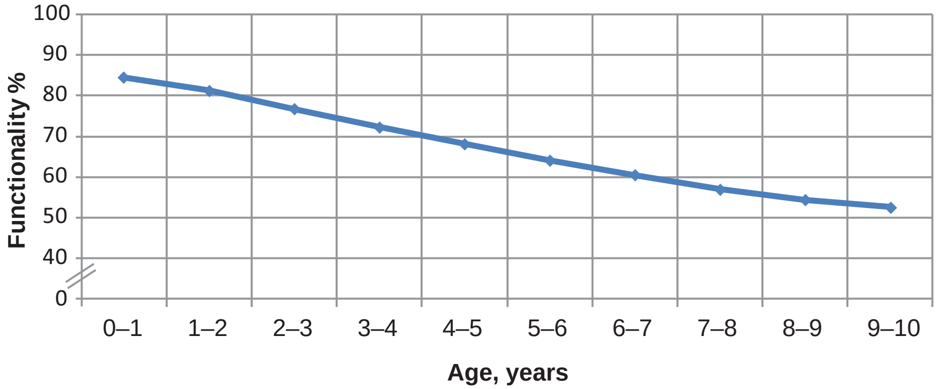

Figure 1 Modelled age–functionality relationship from Equation 1 and Table 2
Note: Assuming a = 0.15 in year 1 rising to 0.35 in year 10, average downtime rising from 2.5 days in year 1 to 70 days in year 10

The purpose of presenting the fictional data in Table 2, and the implications in terms of functionality, is to highlight two things. First, by undertaking careful sensitivity analysis of the model parameters and their relationships to functionality, we can obtain insights into the relative effects of the three parameters. If we wish to improve functionality, is it more effective to reduce the average number of breakdowns per water point per year, to reduce the duration of downtime, or address the issue of abandonment?

The model output in Figure 1 bears considerable similarity to recent analyses of water-point mapping data from four countries in Africa, as shown in Figure 2. The data come from a forthcoming regional assessment of the operational sustainability of rural WASH services in Sub-Saharan Africa, as part of the VFM-WASH research project funded by the UK Department for International Development. These data are fully discussed, including the implications of the number of observations for the denominator problem, in Tincani et al. (forthcoming). The steep drop in year 1 is considered to reflect inadequacies in siting (especially in the case of wells and boreholes) and poor design and construction, exacerbated by inadequate construction supervision. The loss of perhaps one-quarter of all commissioned water points in the first year after construction is simply unacceptable.

Impact of improvements

The two key model parameters are a, and the product of n and d. The effect of reducing a, the proportion of abandoned water points, is clear: the entire curve is shifted upwards. By reducing nd, the annual downtime, the effect is to flatten the curve. Figure 3 shows the graph which results from reducing all values of both a and nd by 15 per cent. The overall functionality of the multi-year sample is improved from 67.1 per cent to 71.6 per cent.

The question arises as to what are achievable and realistic targets for a and nd. If a best-case scenario is imagined in which the number of abandoned water points does

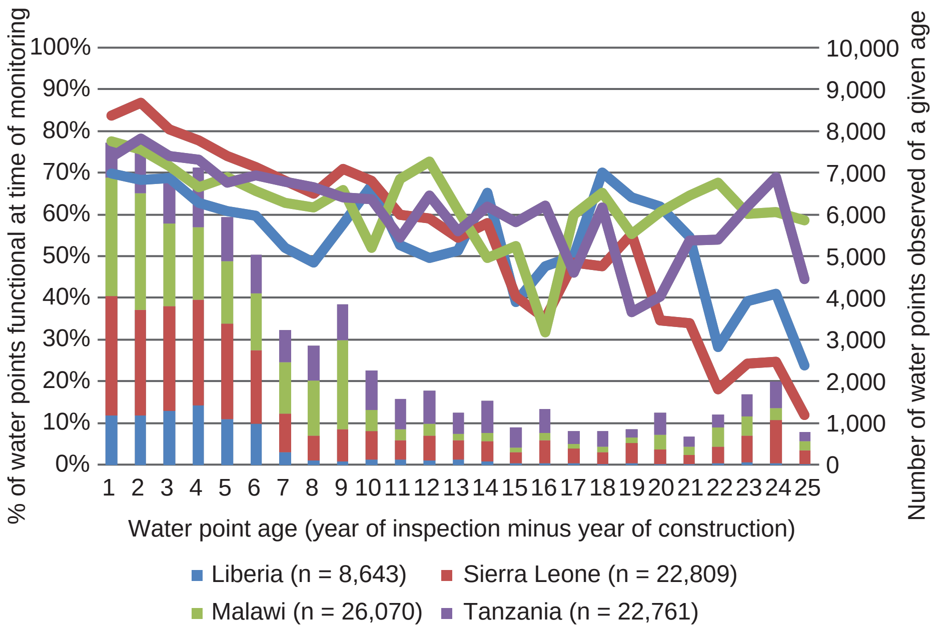

Figure 2 Functionality of water points by age in four African countries
Note: lines represent functionality of water points (of various types, not only WHPs) by age; stacked bars indicate the number of observations by age
Source: analysis by OPM, data from RWSN WPM group, cited in Tincani et al., forthcoming

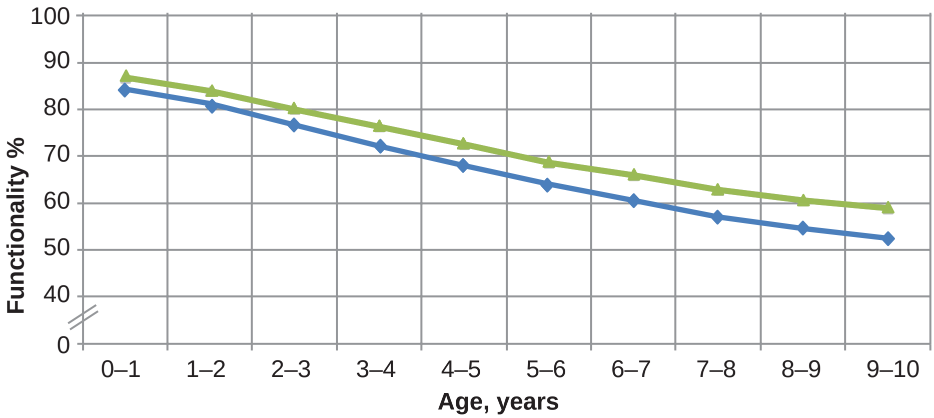

Figure 3 Functionality of a multi-age hypothetical sample by year of construction
Note: the lower line is as per Figure 1, while the upper line is the result of reducing *a* and *nd* by 15 percentage points for all years

not exceed 10 per cent in one-year-old WHPs, and 20 per cent for 10-year old WHPs; no more than one breakdown occurs per year; and the mean repair time is five days; then the overall functionality of this multi-age sample would be 86.7 per cent. Therefore, a target of approximately 85 per cent may be an achievable benchmark. For comparison, Adank et al. (2014) suggested a total downtime not exceeding 18 days while Carter et al. (1996) suggested as a goal a total downtime not exceeding seven days per year.

All this suggests two things:

- reducing rates of abandonment (*a*) – especially early abandonment for avoidable reasons – and reducing total downtimes (*nd*), are key to improving functionality and service to water users;
- realistic targets should be set for the various failure parameters, with corresponding expectations regarding overall functionality; an expectation of overall mean functionality (across the multi-age sample) nearer to 85 per cent than 100 per cent may be more realistic.

Better data

The second purpose of this kind of modelling and thought experimentation is to highlight the type of data which would be of real value in understanding and addressing sustainability challenges. The model above does not attempt to overcome all the flaws in functionality identified at the beginning of this paper. However, if monitoring visits and water-point mapping rounds asked the following questions, we would start to build up some real understanding of the performance of water services and have a stronger basis for determining the relative merits of different technologies and management and financing arrangements.

In the case of functioning water points:

- When did the water point last fall out of service?
- How long did it take to repair?
- What challenges were faced and overcome in carrying out the repair?

In the case of non-functioning water points:

- How long ago did it break down?
- What efforts are being made to repair it?
- What challenges are faced in undertaking repair?
- What are the consumer attitudes to this water point, especially concerning satisfaction with discharge and water quality?

In the case of abandoned water points:

- How soon after construction was it abandoned?
- Why was it abandoned?
- Is it repairable?

Modelling the denominator problem

As discussed above, the ‘denominator problem’ is the fact that monitoring data often fails (deliberately or otherwise, depending on its objective) to pick up water points that have been abandoned. In order to try to model the effect of the ‘full denominator’, let us consider a district in a developing country which is trying to improve sector performance. The local government wants to map all public water points constructed in the past 10 years and look at their functionality. The scope is all public water points (meaning publicly available), whether in or out of use, with no specification on whether they were constructed by an NGO, government or communities.

District officials travel to every sub-district and map a total of x water points, of which y were functioning (falling into sub-categories F1, F2 or F3 in Table 1). In addition they found z which were serviceable but non-functioning (NF1 and NF2), and p which were abandoned (NF3 and NF4). Therefore $x = y + z + p$.

However, they could not map an additional q water points which had been constructed and then abandoned in the past 10 years, but for which no physical evidence remained (NF5). If their objective is to know N (all public water points constructed in the past 10 years), then $N = x + q$.

There are many possible definitions of a functionality indicator, F^*, for all public water points constructed in the past 10 years.

$F_a = y/x$	% of *observable* water points which were functional
$F_b = y/(y+z)$	% of *serviceable* water points which were functional (i.e. excluding abandoned water points)
$F_c = y/N$	% of all water points constructed which were functional (i.e. including all categories in Table 1)

It is intuitive that $F_a > F_b > F_c$. From their data, the government can calculate F_a and F_b, but not F_c, unless they estimate q. Several methods are possible for this estimation:

1. *Assumptions/records of water points constructed per year.* If they assume that 50 water points were constructed per year for the past 10 years (N = 500) but x = 450, they can calculate that q = 50.
2. *Records of investment.* If they estimate that 10 years ago the annual investment in rural water supply in their district was $80,000 and it is now $150,000, and they know the average price of water points and the inflation rate, they can work out N and then q.
3. *Estimates of coverage.* If they have population surveys or reliable coverage estimates, they can estimate the number of people served in a given year. Using government policy assumptions (e.g. 250 people per water point, with all the problems that entails) to estimate the number of water points likely to have been in service in a given year, they can therefore estimate N and then q.

Each of these methods comes with its own problems. This example serves to illustrate the denominator problem and to urge caution in using functionality data without understanding the scope of the original data collection. It also provides lessons and warnings for future efforts to harmonize functionality monitoring. Tincani et al. (forthcoming) use variants on the above methods to estimate the 'true denominator' in some of the countries in Figure 3. They show that, if the denominator reflected the full population of water points that ever existed within the timeframe of interest, then overall functionality would be far lower than it seems, and the curves in that figure would be steeper and would become asymptotic to the x-axis even more quickly.

Conclusions

Functionality as commonly mapped and monitored is a relatively poor indicator of rural water service performance or sustainability. The first part of the paper demonstrates the complexities of improving functionality as an indicator. Table 1 is informative, but not necessarily to be recommended as an approach to the problem of monitoring service performance. Functionality, even in a nuanced form, is a blunt instrument.

What are reasonable expectations regarding functionality? Is the oft-quoted 60–65 per cent unacceptably low or surprisingly high, considering the management and post-construction financing models that have been prevalent in the last three decades and longer? Should the target be 100 per cent or something lower? One conclusion of this paper is that 85 per cent would be an ambitious but potentially realizable target.

If we are trying to understand how non-functionality actually impacts on services and people, then standard measures such as mean time between failures (modified in this paper as mean number of breakdowns per year, n) and downtimes (mean duration of breakdown, d) are far more useful. Furthermore, knowledge of the proportion of water points of any given age which are abandoned, and the relation of this parameter to age, is crucial. Were we to have data on these three parameters, we would have a much better quantitative understanding of functionality and ultimately of service performance.

To complement such quantitative data, we need better narratives, histories of water-point breakdown, of struggles to raise funds, and of successes and failures in regard to water-point repair and maintenance. Just as a doctor takes a medical history, so we need water-point histories.

Understanding the quantitative interactions of model parameters can help to give some insights into the priorities for action to improve services. Should we focus on reducing the number of breakdowns per year, average downtimes per breakdown, or the proportion of water points abandoned? Modelling can help here, but it is not the whole story. Numerical models tell us nothing about human behavioural psychology – for example, how many breakdowns per year (however minor) cause the users to lose patience and abandon the water point? Is there a critical downtime per breakdown, beyond which consumers are more likely to give up on the water point?

The most important conclusion of this paper is that we should move beyond measuring and reporting functionality to the use of more informative indicators of the way services are implemented and managed. Quantitative data relating number and duration of breakdowns and abandonment to age, for different technologies, and management and financing arrangements, offer a much more informative set of indicators. Combined with qualitative information, we could develop better measures of the health of WHPs and water points in general, so producing much more useful indicators of service performance and sustainability.

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