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Water Systems Asset Management: Overview of practices and tools to build a financial-technical approach for improving water supply services in the global South

Geulweg 16
3356LB Papendrecht
The Netherlands
www.practica.org

Main Authors
Evi Derks (WUR MSc student)
Hasna Afifah (WUR MSc student)
Niels van Damme (WUR MSc student)
Wahdan Achmad S (WUR MSc student)
Wilmer Ligtermoet (WUR MSc student)

Revisors/Editors
Aldo Zamarroni (Practica)
Judith de Bruijne (Practica)
Savvas Papadopoulos (Practica)

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List of Abbreviations

Abbreviation	Definition
ACT	Academic Consultancy Training
ADB	Asian Development Bank
CapManEx	Capital Maintenance Expenditure
EkpDS	Expenditure on direct support
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardization
NGO	Non-Governmental Organisation
NUWS	Northern Umbrella of Water & Sanitation
OPEX	Operating Expenditure
SDG	Sustainable Development Goals
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
US EPA	United States Environmental Protection Agency
TDF	Town Development Fund
VEI	Vitens Evides International
WSAM	Water System Asset Management
WASH	Water, Sanitation, and Hygiene
WASREB	Water Service Regulatory Board
WUC	Water User Committees
WUR	Wageningen University & Research

Key Messages[1]

1. Water Systems Asset Management is not a new topic; though sometimes referred to in other terms, it has gained relevance for addressing water access disparities, optimizing O&M of infrastructure, and promoting sustainable water access in developing countries.

2. Implementing WSAM in the global South faces various challenges, including a lack of policies and regulations, limited funds, technical capacities, and insufficient political will. Despite this, using WSAM tools has proven crucial for data collection, standardized management, and decision-making, thus supporting the development of sustainable water systems in these countries.

3. There are several WSAM (or related) tools in the sector; however, the reasons for organizations to choose specific tools are still not fully known, and the question remains as to whether the tools are being used optimally.

4. Diverse interpretations of WSAM among organizations highlight a need for shared understanding, towards improving collaboration, resource allocation and the development of a shared objective of WSAM in the sector.

5. Organizations (consulted) typically use a mix of paper-based tools, such as self-developed templates, and digital tools like mWater or Commcare. Organizations often prioritize asset inventory, and O&M planning and budgeting. While nearly all organizations incorporate asset inventory in their tools, the financial aspects of O&M are frequently underrepresented. Risk assessment emerges as the least featured.

6. Collaboration and practicality stand out as primary reasons for WSAM tool selection. Simplicity and cost-effectiveness are also universally recognized as driving forces, highlighting the preference for practical tools.

7. Lack of resources (time and money) and lack of knowledge and skills are the main challenges for implementing WSAM practices and tools, challenging the implementation of proper asset management practices, and hindering the use of advanced WSAM tools.

8. A user-friendly web-dashboard, integrating data from various sources, and free access have been mentioned as preferred requirements for a WSAM tool. Furthermore, tools that enable easy data comparison on agreed indicators are user-friendly, and have tailor-made options are expected to best meet the global water sector's needs.

9. Capacity building is considered a fundamental prerequisite for supporting the sustainable introduction of WSAM approaches and tools. Mentoring/tutoring 'side-by-side' is the preferred training option among the consulted organizations.

10. WSAM tools are a 'means to an end,' not the goal as such of WSAM. Thus, the global water sector must converge on the impact to be delivered and the type of results to be shared on WSAM. Flexibility should remain across different countries and organizations in the global South on how to upscale and roll our WSAM—tools. Tools which enable that are probably most effective.

[1] These key messages have been based on statements of staff members from 11 consulted organisations for this study. They might not be fully representative for the water sector in the global South as a whole.

1. Introduction

In the pursuit of Sustainable Development Goal 6 (SDG6)-*universal access to clean water and sanitation*- there is a growing emphasis on evaluating the long-term sustainability of WASH infrastructure in the global South. An evaluation that goes beyond the initial construction phase, emphasizing the efficient use of existing infrastructure over its entire life cycle.

Common challenges related to the sustainability of water systems are multi-faceted. Once water systems have been built, one tends to forget about the continuous flow of resources required for operation and maintenance. A solid plan for (future) costs and resources is essential in the long run to keep systems running. Water Systems Asset Management (WSAM) aims to support the strategic shift in water systems operation: transitioning from a reactive approach of problem-solving to a proactive strategy focused on prevention and mitigation. At the heart of this shift lies the recognition of the pivotal role played by effective WSAM approaches and tools[2].

This report aims to understand better the advantages and disadvantages of various asset management practices and tools. What works best under which circumstances and for what type of organizations? This is with the objective of building sector knowledge towards upscaling Water System Asset Management practices sustainably.

Since 2018, Practica has been leading the way in supporting WSAM as part of the global water development sector agenda. Practica aims to support the overall sustainability of water systems by raising awareness and developing essential skills in long-term maintenance planning and sound

[2] When referring to WSAM tools, the authors refer to Paper-based, Excel-based, online apps and software commonly used for implementing WSAM.

financial management without any commercial objectives. It has developed capacity-building materials and open-source tools (paper-based and online) focused on improving the management and maintenance of small to medium-sized water supply systems in rural and peri-urban areas. A human-centered design process has been adopted to develop these approaches and tools, collaborating with a diverse set of stakeholders, such as water user committees, local governments, NGOs, the private sector, and educational institutes. Practica continuously aims to improve and tailor its capacity-building efforts, and therefore, it commissioned this study on WSAM practices and tools.

This report comprises five chapters. The next chapter delves into the background of asset management, with a specific focus on water systems asset management in the global South. The following chapter outlines the problem definition and methodology employed. Chapter 4 presents the study results, which shed light on various interpretations of WSAM. It proceeds to analyze various types of tools utilized by the interviewed organizations, exploring the key drivers influencing tool selection, examining the challenges associated with adopting specific tools, and emphasizing the role of training, collaboration, and partnerships. The report concludes with recommendations to improve WSAM practices and advocate for enhanced tool utilization.

2. Background

2.1 Asset Management

Asset management has evolved into an essential management practice for many companies. As van der Lei et al. argue, humanity has carried out asset management activities ever since it started using assets such as buildings, transportation methods, water systems, etc. (van der Lei et al., 2012). Assets can be defined as "an item, thing, or entity that has potential or actual value to an organization" (Hastings, 2021). As part of this study, existing literature on (water) asset management and (water) asset management tools have been analyzed and presented below.

Definition of asset management

The first question is ‘What does asset management mean?’. The International Organisation for Standardization (ISO) defines asset management as the "coordinated activity of an organization to realize value from assets" (Hastings, 2021). The United States Department of Transportation defines asset management as "a systematic process for maintaining and operating physical assets cost-effectively through a combination of engineering principles and sound business practices" (Valencia et al., 2011). In this report, we use the definition of ADB and US EPA: “asset management is a strategic approach used to maintain the optimal performance and reliability of specific systems while simultaneously minimizing the costs” (ADB, 2013; US EPA, n.d.; Van Kinderen et al., 2023).

The benefits of asset management

The second question is, 'Why is it necessary?'. Asset management is nowadays recognized as an essential discipline because of the intricate technical nature of modern systems (Hastings, 2021). Systems, such as the drinking water systems in a particular country, have become more and more complex over the last years, including many technicalities as well as many operators. The components and assets in a system increasingly interact with each other, complicating maintenance and increasing necessary resources (Petchrompo & Parlikad, 2019). Therefore, the need arose for comprehensive asset management to maintain the condition of materials and entire systems.

For asset management practices to be implemented correctly, they should yield several benefits, as Hastings (2021) identified. The first benefit is a systematic approach to decision-making so that the needs and benefits of assets are aligned with organizational objectives. Hastings (2021) identifies a second benefit: "appropriate logistic support over the asset life cycle, creating improvements in asset performance." By implementing proper asset management practices with appropriate support, the asset life cycle will be optimized, and its performance will improve. Boulenouar (2014) visualized this as shown in Figure 1. The "expected useful life" will increase under a proper maintenance regime, which can be paraphrased as the "expected useful life" will increase with sound asset management practices. Another benefit Hastings (2021) mentions is that proper asset management practices will result in meeting business and regulatory targets more easily. Lastly, Hastings (2021) argues that asset management practices will lead to benefits in staff development and their expertise.

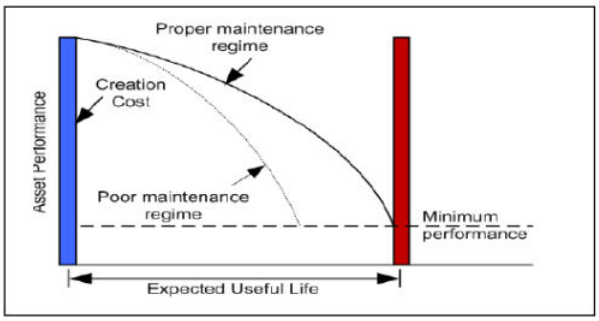

Figure 1. Example impact of maintenance on lifespan of assets. Source: (Boulenouar, 2014)

2.2 Water Systems Asset Management

Why WSAM is relevant for the global South

Water access in the Global South is generally increasing, but there is still a gap and inequality in access between urban and rural areas (Santos et al., 2017). For example, in the SSA region, while 87% of the total urban area is covered with improved water systems, the rural area is still 49% covered (WHO/UNICEF, 2021). This difference in access is sometimes due to spatial inequality/disparity in water source locations in rural areas (Ducrot & Bourblanc, 2017).

Discrepancies in water access between countries are essential to mention, too. In South Asia, most countries still have less than 50% access to safely managed water services, with Nepal having the lowest percentage of just 18% (Sachs et al., 2021; Shrestha et al., 2023). Different reasons can explain the lack of safe water access: 1) high installation costs (Shrestha et al., 2023); 2) affordability for some communities and households; but most importantly, 3) a lack of maintenance of existing infrastructure. This lack of maintenance is most prominent in the Global South, with about 30%-60% of water systems needing to be fixed (Musiimenta et al., 2023; Shrestha et al., 2023).

Because poor maintenance is one of the leading root causes of limited safe water access in the global South, adopting a sound WSAM approach is considered crucial. WSAM can be defined as a manner to support water systems' assets to be maintained optimally for extended periods in a cost-effective manner. This can be achieved by doing joint assessment & service level determination, preparing an asset inventory, establishing robust operations and maintenance planning & budgeting plans, analyzing risks, and conducting financial modeling to ensure the optimal system functioning for its

intended lifespan. Box 1 presents the approach that Practica developed and piloted in different countries such as Nepal, Bangladesh, Uganda, and Mozambique.

Box 1.Water Systems Asset Management Approach developed by Practica.

Practica's approach to WSAM planning and monitoring

Joint assessment & service level determination: an inclusive and participatory approach is vital to make asset management planning and monitoring successful and to ensure transparent decision-making processes. A situation analysis of the water supply system is undertaken in collaboration with key stakeholders. It includes at least the location and history of the scheme, the current quality and quantity of water distributed, its actual capacity, demand quantity, and maintenance history. It is vital to map social and financial aspects such as the balance of expenditures and income over the past years. Defining a (preliminary) envisioned service level with relevant stakeholders is critical as part of this first step. Parameters to be considered are reliability, availability, water quality and quantity, water accessibility, and safety.

Cost and risk-based maintenance planning: implementing a cost and risk-based maintenance strategy involves identifying and assessing potential risks and vulnerabilities connected to the infrastructure and providing water supply services, aligning with the targeted service level. Through the risk evaluation process, one can compile and prioritize all necessary maintenance activities and their associated expenses to uphold the agreed-upon service quality. This assessment helps to comprehend the probability and consequences of different hazards, facilitating the identification of measures to mitigate or prevent these risks efficiently.

Income and Optimization: With a cost and risk-based maintenance plan, you have a grasp of anticipated expenses. These can then be compared against the revenue from water sales and other sources. The potential for optimization can be explored through a financial model that compares income and expenses at different service levels.

Monitoring and Optimization: Monitoring and optimizing a water supply system is an ongoing process that requires continuous attention. Monitoring involves collecting real-time data to make informed management decisions toward adjusting previously modeled scenarios.

WSAM challenges in the global South

Implementing WSAM in the Global South is not without challenges. Katumba (2016) in his study found several challenges, which are a lack of adequate policy on WSAM, limited funds on WSAM, lack of political will, lack of knowledge on WSAM, poor coordination, and planning, poor communication, lack of suitable technical skills to use WSAM tools, lack of information/data on asset conditions and availability, and lack of decision-making and collaboration skills. Below, several examples of literature from different countries are highlighted.

A study from **Uganda** showed that WSAM practices face different demands from different sectors, with political representatives having other demands than departmental head offices, at the same time being confronted with a lack of financial resources and limited social and technical capacities among staff (Musiimenta et al., 2023). For example, the availability of data was an issue in WSAM implementation, making it impossible to perform a risk assessment, make informed decisions on resource allocations, or discover infrastructural deficiencies (Burr et al., 2013; Boulenouar, 2014; Kumasi et al., 2019; Musiimenta et al., 2023).

Although the government in Ghana already kept asset inventories, updating its O&M plan was challenging (Kumasi et al., 2019). The inventory showed that WSAM practices in the districts were

poorly managed, making water systems non-functional and delivering low service levels (Kumasi et al., 2019). The financial side of implementing WSAM became challenging, too, especially since an incentive for district employees to do the monitoring was lacking (Kumasi et al., 2019). This study concluded that estimations on both Operational Expenditures (OpEx) and Capital Expenditures (CapEx) are vital for sound WSAM (Kumasi et al., 2019).

Imonikhe & Moodley (2014) investigated the challenges of WSAM implementation in SSA with **Nigeria** as a study case. Lack of political support for implementing WSAM practices and lack of institutional collaboration inside the Nigerian government were listed as the most hindering factors (Imonikhe & Moodley, 2014). The technical side was problematic, too. They suffered from unreliable data about their assets, leading to poor information management (Imonikhe & Moodley, 2014). On the financial side, the flat water tariff rate did not include O&M costs, which resulted in water systems operating at a loss (Imonikhe & Moodley, 2014). Lastly, the investment gap in new systems of around US$0.6 billion to meet the country's water access targets was mentioned as a significant challenge (Imonikhe & Moodley, 2014).

WSAM tools

Solving the above challenges related to WSAM will require several strategies. Tools can be supportive in this sense but are not ‘a goal as such’. They can only be effective as certain pre-conditions, like political will and institutional embedding, are met. But even if these pre-conditions are not entirely in place yet, tools can support the uptake of WSAM, as they enable the analysis of existing gaps in financial resources, inadequate regulations, and ineffective infrastructure management.

Applying WSAM tools generally facilitates data collection and storage, standardizes data management, enables routine asset checking, and supports data visualization (Fisher et al., 2016). Several tools are on the market today, with mWater being one of the most commonly used. This tool has proven helpful in water management decision-making in Malawi and Afar, Kenya (Miller et al., 2018; Pearce et al., 2021). In Malawi, mWater visualized and mapped water points, which supported decision-making on O&M planning (Miller et al., 2018). In Afar, this tool was used to perform an asset inventory, which helped the operator list maintenance issues (Pearce et al., 2021). It is important to note that mWater has not been designed as a WSAM tool but as a data collection, mapping, storage, analyzing and visualization tool for water systems in the global South. The same counts for some other software tools currently being applied by organizations. They rather have been developed was for financial bookkeeping (e.g., Pegasus) or development sector M&E data collection (e.g., CommCare). These tools generally only support some relevant fields of WSAM and, therefore, often need to be complemented with additional data collection and analysis sources; often resulting in organizations developing supporting templates themselves.

3. Problem Definition and Methodology

3.1 Problem definition

The sector has developed different practices to raise awareness and various tools to plan and monitor WSAM. However, these do not always fit the needs of local authorities, small private entrepreneurs, and water users' committees in managing drinking water systems in rural Africa and Asia. Moreover, the reasons organizations choose specific tools for managing water systems are still unknown, nor is it known whether the tools are being used optimally. Furthermore, organizations in the Global South might require tailor-made asset management tools that genuinely meet local needs and capacities (ADB, 2013).

3.2 Methodology

This research has been conducted as part of the Academic Consultancy Training (ACT) at Wageningen University. Firstly, literature on WSAM and existing tools in the market were studied. Secondly, semi-structured interviews were conducted with a list of stakeholders provided by Practica. These interviews focused on analyzing the barriers, drivers, challenges, features and performance information regarding the WSAM approach they follow and the tools they adopted or developed. Interviews were recorded, transcribed, and coded using *Atlas Ti* software. Each organization has shared its tools, and a comparative analysis has been performed using Practica's developed tool as a baseline for comparison. The guide for the semi-structured interview and the code for analysis can be found in Annex 1 and 2, respectively.

3.3 Overview of Participating Organizations

Three different types of organizations were interviewed: i) business/entrepreneurial, ii) governmental, and iii) non-governmental. The division in these three categories is somewhat arbitrary. For example, most entrepreneurial organizations are registered as NGOs but have been classified as entrepreneurial since they try to work along a business model with the cost recovery from consumers. At the same time, some organizations are classified as governmental or non-governmental, which undertake activities to let (certain) consumers pay and stimulate cost recovery. However, it was felt that a diverse set of organizations with different starting points of their mission and vision contributed to sharpening this exercise outcome. Organizations participating have been separated according to their nature. Practica provided all the contacts for these interviews. A short description of each organization can be found in Annex 3.

Table 1.Overview of organizations that participated in the study.

Name	**Country**[3]	**Management approach**		
		Private	**Governmental**	**Non-governmental**
1001Fontaines	Cambodia, Madagascar, Myanmar, Vietnam	x		
Water Compass	Uganda	X		
WaterStarters/AMREF	Kenia	x		
Northern Umbrella of Water & Sanitation (NUWS)	Uganda		x	
Kakamega County Water and Sanitation Company Limited (KACWASCO)	Kenya		X	
Town Development Fund	Nepal		x	
SNV	Mozambique			x
GOAL/Wells of Life	Uganda			X
IRC/Water for People	Uganda			x

[3] Even though some of these organisations have projects and offices in several countries, the column reflects to the experiences gathered during the interviews specifically for the activities being implemented in the aforementioned country.

4. Results

4.1 Different Interpretations of Water Systems Asset Management

Practica defines Water Systems Asset Management (WSAM) as an approach to support water user committees, water operators, caretakers, and governmental institutions in **optimizing their water systems' technical and financial performance.** It assures the water quantity and quality, and the system's reliability and accessibility match customers' demand, and it supports decisions on infrastructure's design, use, and maintenance[4]. In the view of Practica, WSAM encompasses practices related to:

1. Asset inventory and mapping
2. Risk assessment and risk mitigation measures (mitigate/ prevent asset failure)
3. Maintenance planning and logging
4. Service level monitoring (water quality, quantity, customer satisfaction)
5. Billing and financial management (income and cost tracking)

However, during the interview phase, it was noticed that WSAM is subject to varied interpretations among organizations compared to Practica's definition. This difference in understanding is closely linked to the interviewee's background or

Box 2.Quotations on the different interpretations of WSAM.

Water for People: 'We mainly use Asset Management systems for two purposes. First, to assess the level of service, especially for community-based assets, water points, or public tap stands, but also for the planning purpose to mainly plan for capital replacement or maintenance expenditures.'

IRC: [regarding Asset Management] 'We often focus on helping local authorities work on their planning processes at the district level. These planning processes might be annual plans, or they could be longer-term strategic plans, perhaps five years, maybe even sometimes ten years

[4] https://www.practica.org/our-innovations/asset-management-water-systems/

organizational goal. For instance, Water for People defined WSAM as having two purposes: assessing the service level service and financial planning, while the representative from IRC mainly stated long-term strategic planning and supporting local authorities.

The absence of a shared understanding of WSAM in the sector underscores the diverse interpretations and perspectives of different stakeholders, which may lead to misalignment in strategic priorities and goals among organizations.

4.2 Different tools to implement Water Systems Asset Management

As stated in the problem definition, different WSAM tools exist to support the management of drinking water systems in the global South. Each interviewed organization shared the tools they are using, and a comparative analysis against the tools developed by Practica has been conducted. An overview of the leading practices is shown in Figure 2. The types of tools being used (i.e. Microsoft Excel spreadsheets, custom-made A.M tools, paper-based tools, etc.) have been specified for better comparison.

Defining Practica's approach to WSAM as the point of reference, the tools utilized by the consulted organizations perform varying degrees of asset management. To begin with, themajority of the entities partaking in the study display a satisfying degree of actions related to Asset Inventory & Management. Regarding Risk Assessment & Mitigation, most organizations practice categorizing different risks; however, there is a lack of charting the effects of potential failures and taking measures to mitigate the effects of identified failures.

As for Maintenance Planning & Logging, almost all organizations use an asset management tool with established standards and indicators for smooth, routine operation. Some organizations are also utilizing maintenance logs. The main points lacking are the establishment of emergency operational and maintenance plans and associated issue logs. The option to create purchasing orders for replacement parts was also noted to be missing in most of the cases.

Regarding Service Level & Monitoring, a considerable part of the studied asset management tools provide information on the pumped water quantity and quality. However, the utilization metric of the water source is missing: meaning is not known whether there is under or over withdrawal of the water source. Thus, organizations have no insight into whether they can expand their water system to include more water tap points.

Lastly, the financial data displayed in the WSAM tools have been evaluated. Most of the tools provide information on the capital and operational expenditures (CapEx & OpEx) associated with the water system; however, there are some data gaps regarding other financial indicators, such as the capital maintenance expenditure (CapManEx). Furthermore, water tariffs are considered by most organizations, and, by extension, several of them provide information on projected income.

An overview of the feature matrix can be found in Figure 2. The entire table is also available in the Annex 5 of the report.

A.M Tools Features Matrix			Asset Inventory & Mapping				
Type of Entities	Name of Entities	A.M Tools Utilized	Asset Registry (Parent & Child)	Asset Operational Status (Parent & Child)	Asset Location	Asset Pictures (Parent & Child)	Asset Life Span (Parent & Child)
NGO	Practica	*WASH Alliance*	✓	✓	✓	✓	✓
Private Sector	COMLINK - BOP	*BOP*	✓	✓	✓	✓	✓
NGO	mWater	*Web Dashboard*	✓	✓	✓	✓	✓
		Solstice	✓	✓	✓	✓	✓
		Surveyor	✓	✓	✓	✓	✓
Governmental	Town Development Fund (TDF)	*UNOPS Nepal*	✓	✓	✓	✓	O
		NWASH	✓	✓	✓	✓	O
		I.A.M U.N DESA	✓	✓	✓	X	✓
Governmental	NUWS	*F.R.P*	X	O	X	X	O
		Pegasus	O	X	X	X	X
		Microsoft Excel	O	X	✓	X	X
Governmental	Kakamega	*E.R.P*	X	X	X	X	X
		Blackbooks	✓	X	O	X	X
NGO	Wells of Live	*Microsoft Excel*	✓	O	✓	X	X
NGO	Water For People	*Akvo Flow*	✓	✓	✓	✓	✓
NGO	IRCWash	*Costing Tools*	✓	✓	✓	X	✓
NGO	GOAL	*Microsoft Excel*	✓	✓	✓	✓	✓
NGO	SNV Mozambique	*Microsoft Excel*	X	X	X	X	X
Enterprenurial	WaterStarters	*Custom A.M Tool*	✓	✓	✓	✓	✓
		Upande ERP	?	?	?	?	?
		Design for Good	?	?	?	?	?
Enterprenurial	Water Compass	*Paper/Microsoft Excel*	?	?	?	?	?
Enterprenurial	1001Fontaines	*CommCare*	✓	?	✓	?	?

Figure 2.An overview of the different tools and features per organization (part 1) - other parts can be found in Annex 5.

Legend:
✓ = available
X = not available
O = partly available
? = unknown

Based on the interview's coding, the different WSAM practices are shown in Figure 3. Interestingly, in this diagram, O&M is more mentioned than other practices. This could be because some organizations, like WaterStarters and WaterCompass, talked extensively about O&M thus increasing the overall score of this WSAM practice. However, it is unclear from the interviews whether each organization has O&M planning procedures in place as part of their WSAM plans.

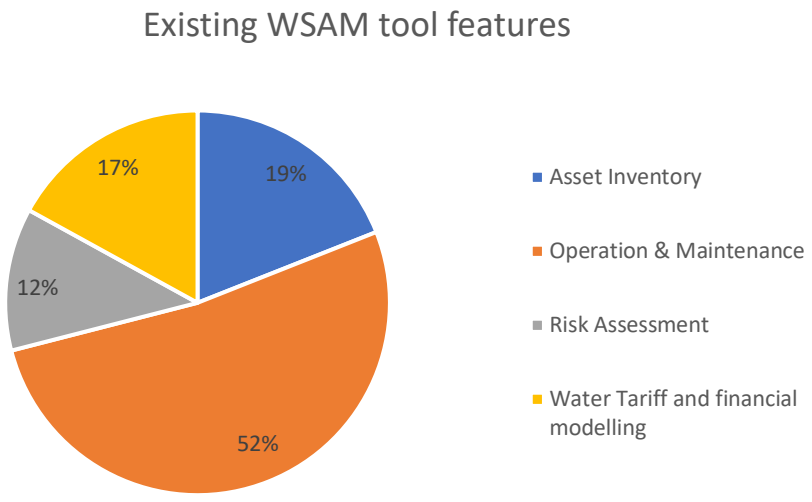

Figure 3.Pie chart of most emphasized WSAM practices in the interviews.

4.3 Comprehensive feature analysis per tool

A comprehensive overview of all the WSAM tools investigated during this research can be found in Annex 5. This matrix provides an overview of the existing features of WSAM tools that are predominantly used by consulted organizations for this research. *A disclaimer regarding this matrix is that not all organizations have shared their WSAM tools. Therefore, the matrix contains question marks for some organizations (i.e. the WaterStarters and GOAL). Also, only five organizations have validated the matrix: Comlink, IRC, WaterCompass, Wells of Life, and NUWS.*

Asset Inventory & Mapping is the practice more commonly featured. Organizations realize the importance of having a clear overview of their assets. The features most organizations are missing are asset pictures and the registration of the assets' life span. In tools that have an Android app format or a web dashboard (e.g., mWater, BOP, WASH alliance tools), pictures can be added easily, since the feature is already built in.

Based on the interviews with IRC and GOAL, geolocation (with exact coordinates), that can be visualized on a map, is considered an essential feature of an asset inventory. This type of map can give insights into where water systems are present (or not) within one region, thus providing valuable information for future water supply systems planning.

Risk mitigation of water system failure is rarely included in the tools reviewed. WASH alliance's tools, along with those used in TDF's pilot projects, are the only ones explicitly performing both risk assessment and mitigation, factors necessary for effectively operating water supply systems. This step could help water managers acknowledge the strengths and weaknesses of specific systems or equipment—for example, the pump efficiency and the probability of pump failure, and how this will affect the water supply or quality. Based on a risk assessment, a mitigation plan for emergencies can be put in place.

Regarding financial aspects, the majority of organizations primarily focus on actual CapEx and OpEx. Nonetheless, organizations like IRC and Water for People have developed methodologies and tools in order to estimate other financial indicators more accurately, such as the CapManEx and the ExpDs. Their method is applied by several countries in the Global South (many of them in Latin America) and is all connected via one web dashboard called siasar.org[5] (Interview IRC, 2023). Also, WASH Alliance's toolbox and COMLINK-BOP's tool accommodate this step.

4.4 Key drivers for selecting Water Systems Asset Management Tools

During the interviews, it appeared the organizations had different reasons for adopting WSAM practices and tools. These have been labeled into six groups:

- **Collaboration/Partnership:** Labeled when a statement is made on tool usage because collaborating partner organizations offered or used a specific WSAM tool.
- **Simplicity/Practicability:** Labeled when a statement is made on the user-friendliness of a WSAM tool, meaning it is easy to use and not complex.
- **Cost for accessing the tools:** Labelled when a statement is made on free accessibility or low cost of the WSAM tool.
- **Adaptability towards Scalability:** Labeled when a statement is made on the tool's ability to adjust its settings for upscaling/ expanding its use within the utility or for a specific service.

[5] https://globalsiasar.org/

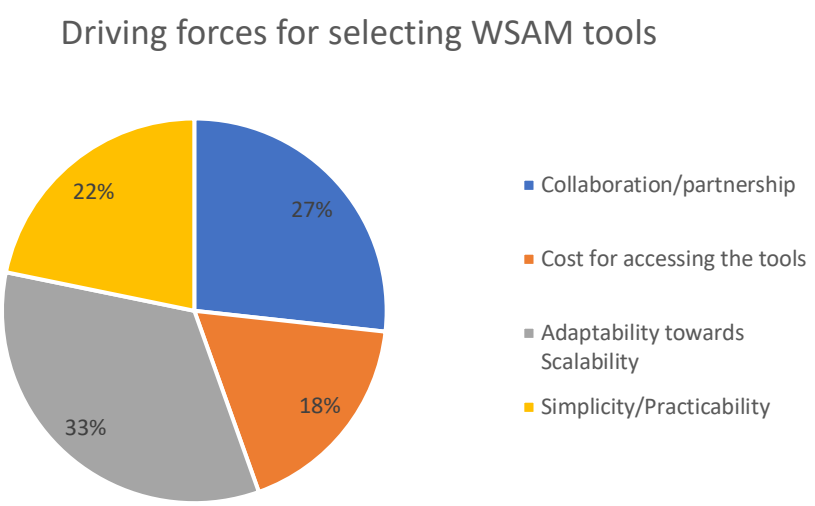

Figure 4.Driving forces for organizations to use WSAM tools.

4.4.1 Collaboration/Partnership

Box 3.Quotations on collaboration/partnership.

Water for People: ''*It's because there was an existing partnership between Water for People and Akvo Flow to measure the progress of the interventions.'*

WaterStarters: *'For the maintenance schedules, as I said, we are also working on a maintenance app together with Design for Good.' They are developing tools with a collaborating partner'.*

Collaboration and partnership are referred to as the most prominent reasons to use a specific type of WSAM tool. Eight organizations stated they use a tool because of an existing collaboration with another organization that had already developed or had access to a specific WSAM tool. Based on the interviews, the collaborations and partnerships are differently structured per organization and have influenced their decision-making differently.

Examples of how collaborative initiatives led to tool development or usage. WaterStarters, for example, actively engages in partnerships with Upande and Design for Good to develop monitoring apps and maintenance tools for water services. Another example is the usage of BOP software in VEI projects. During a visit to software developer Comlink[6], it became clear that BOP software is used in the projects executed by VEI in Africa and Asia.

Another driver within this labeled group is technology adoption due to collaborations. For example, mWater is actively incorporated as a data collection and analysis tool, contributing to sector practices and cooperation with other organizations.

[6] https://comlink.nl/

4.4.2 Simplicity/Practicability

Box 4.Quotations on simplicity/practicability.

WaterStarters: '*So you want simplicity, something that is easy for everyone to use*'
SNV Mozambique: '*If you do have a very complex tool or something that needs people to think a lot, then you end up with a tool that will not be used*'
Water for People: *'But the problem with that one is that we ended up having a lot of data in one Excel, and manipulating them was not really that easy.'*

Simplicity or practicability emerges as another driver for tool selection. This driver is about how straightforward and practical the tool is to be used by all the staff levels within an organization (managerial, technical, field). In other words, how easy it is to implement. The quotations in Box 3 refer to issues experienced by the organizations with existing tools being complex and requiring extensive training, as well as difficulties managing extensive databases in Excel. The wish to automatically transfer (field) data was, therefore, often expressed. On the other hand, it appeared that many of the interviewed organizations still use Excel as their primary data collection tool.

4.4.3 Cost for accessing the tool

Box 5.Quotations on costs for accessing the WSAM tools.

GOAL: *'mWater is free, I think you can more easily share data from mWater than from CommCare'.*
WaterCompass: *'But from everything that we've been looking at, we did reach out to some other asset management tools, but they've been designed for much larger utilities. It just financially, it didn't make sense for us. And so, mWater is also free for the most part.'*
WaterStarters: *'Cost is still a factor to consider. So you have to weigh the balance and see, in as much as maybe you have affordable or even free tools out there. Are they still addressing your purpose? And if you need to develop a new one, what are the cost implications? So it will make you choose one option over the other.'*

A tool's license cost is closely tied to the adoption of certain tools. Generally, a costed license may create barriers for organizations with limited financial resources to enter (field) data, hindering widespread adoption. In the developing sector, where budget constraints are often pronounced, free or low-cost solutions are more appealing and accessible. Many organizations using mWater have opted for this tool due to its free and easily accessible nature, making it a choice that incurs no additional expenses.

4.4.4 Adaptability towards Scalability

Box 6.Quotations adaptability towards scalability.

WaterStarters: ''*So how adaptable, how easy is it to tailor this tool to my evolving needs, to my needs to scale, to the different data that I need to be collecting here.'[….]'How easy is it for this tool to adapt this and take it in as we keep moving'*
WaterCompass: *'What we like about mWater is the ability to design our own forms, and have flexibility to do that'*
TDF: *'So this [the dashboard] needs to be not separated, but it needs to be integrated kind of thing integrated with linked by the unique ID per asset and interoperable across the sector so that as a local government municipality can use all these information for improving the services to the citizens '.*

Adaptability is also mentioned in five interviews as a driver. Adaptability towards scalability refers to the ability to modify the tools to meet the organization's needs (features and processes) and to adapt to the changing needs as the organization grows and upscales its activities.

This adaptability enhances operational efficiency and minimizes the need to migrate to a different tool once the activities of the organization increase. For example, TDF refers to developing an integral and

comprehensive dashboard that can be adapted to different contexts working with various municipalities.

4.5 Challenges to adopt WSAM practices in the field

The main challenges organizations faced while implementing WSAM practices were also investigated. These have been identified as operational, cost-related and organizational. According to the analysis of the interviews, organizational challenges were mentioned the most (46%), followed by operational (42%) and financial (26%), the percentages correspond to the total of interviews.

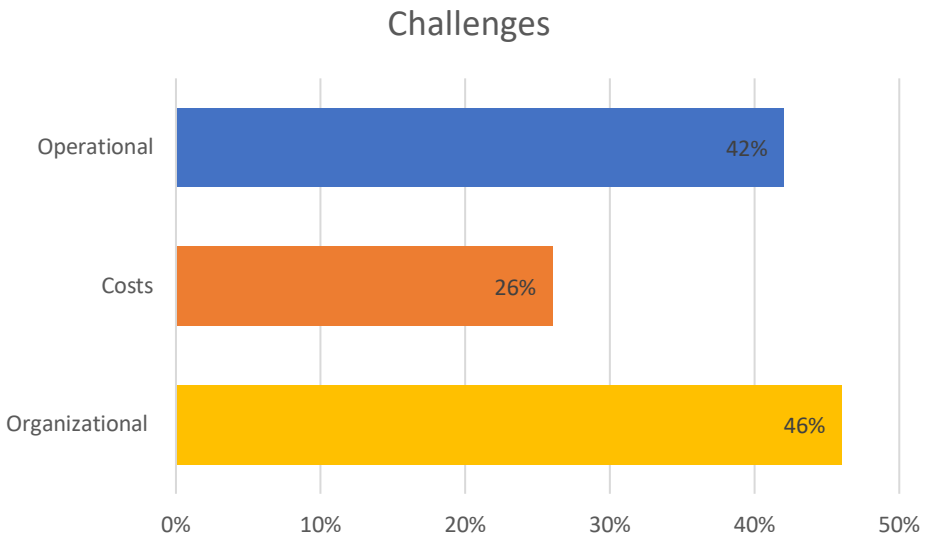

Figure 5.Challenges to implementing WSAM practices.

Although there is no clear relationship between the type of organization (i.e., entrepreneurial operators, government and NGOs) and the challenges they face, it can be inferred that while all organizations mention social challenges, most entrepreneurial operators focus on technical ones. In the following subsections, the challenges will be discussed in terms of technical, financial and transparency, and social, respectively.

4.5.1 Operational

Regarding the technical operational challenges, organizations refer to limited WSAM tool features or cannot find a WSAM tool that fits their needs. Some observe an absence of user-friendly WSAM tools. This is mainly mentioned because they face challenges with operators and communities struggling to put data in. The software interface is often too complex, and entering correct data at the proper place is challenging. They state that training is indispensable to make data entry at the field level successful.

Box 7. Quotations on operational challenges.

WaterCompass: *'The accuracy of the data and the timeliness of the data collection is just something we're always trying to work on.'*
Water For People: *'One of the challenges we are facing is data collection might not be regular. So, I find the information we had the last three years is the same and maybe people are not updating regularly'.*

Streamlining and verifying the data into valuable data representation is incredibly time-consuming, according to Water for People and NUWS. Another constraining factor is that organizations often use paper-based and digital-based tools. The data transition from one to the other is time-consuming, expensive, and prone to human mistakes.

Moreover, in case data has been entered, it can often not be verified whether this data is accurate and of sufficient quality for management. KACWASCO mentions that they face challenges in ensuring

field staff do their jobs adequately. KACWASCO is often unable to track the planned work versus the work completed in the field.

Another operational challenge is large physical distances between water points in combination with poor (internet or mobile) network coverage and quality. Organizations often face large distances between their water assets, which makes it challenging to monitor them. The large distances for maintenance teams traveling between these assets to repair acute failures are time and resources-consuming. Some organizations are using sensors and network-based monitoring systems. However, as rural areas are often involved, it is difficult to guarantee good network coverage. Consequently, this results in more long-lasting water system breakdowns and community drinking water supply failures. This has forced organizations to go back to paper-based templates and/or use Excel-based tools that are more reliable under these conditions.

4.5.2 Costs

Box 8. Quotations on tools and data collection costs.

WaterStarters: '*The other issue is some cost involved, especially the data costs. If I say that, I hope you're able to understand the Internet's cost*'
WaterCompass:*'There are other remote monitoring tools that are available, but they're just too expensive for us to be able to utilize, which is disappointing. '*

The cost of using the tool is frequently cited as a hurdle in adopting certain tools, and this challenge is also associated with data collection costs. When field personnel must visit and support those entering data, water system operation becomes more expensive and complex. Consequently, some organizations may find collecting less data more practical if the information quality aligns with their objectives. While remote monitoring presents an option to reduce staff costs for data collection, its effectiveness still needs to be evaluated.

4.5.3 Organizational

Box 9.Quotations on organizational challenges to uptake WSAM practices and tools.

SNV Mozambique: '*Sometimes the guy that is trained is not the one who is in the field, who is based, who is hosted in the system. So who is reporting is not who is managing the system'.*
TDF: *'These water users associations do not have any in-house technical expertise. Because having technical expertise in place costs money […] So when you talk about asset management in the context of Nepal, the assets are not properly recorded*'**.**

Note: Crosslinks are often found between the organizational and other challenges mentioned above.

Firstly, timely decision-making and implementation processes are mentioned as organizational challenges. It often takes a long time to execute maintenance at the field level. This is, among others, caused by bureaucracy, but the lack of planning, risk assessment, and prioritization plays a role too. Processes, like decision-making about what needs to be done or ordering and delivering spare parts in case of failure, can take several months. Since risk assessments are often not done, no preventive actions are planned for and performed in advance, resulting in long periods of downtime in emergencies.

A second challenge is the skills of water system operators. For example, IRC mentions a limited availability of skilled people within the rural water counties where they operate. The water counties are responsible for local O&M. Due to the aforementioned financial challenges, hiring external technical experts is often impossible.

A related challenge to the two challenges mentioned before is the lack of awareness within organizations and communities regarding the importance of water systems asset management (TDF).

As a result, maintenance is not prioritized or done poorly. As the data obtained is unreliable, invalid, and limited, the monitoring fails, and WSAM cannot be implemented effectively.

4.6 Needs to implement and upscale Water Systems Asset Management

During the interviews, attention was given to understanding organizational needs to accelerate the adoption of WSAM practices.

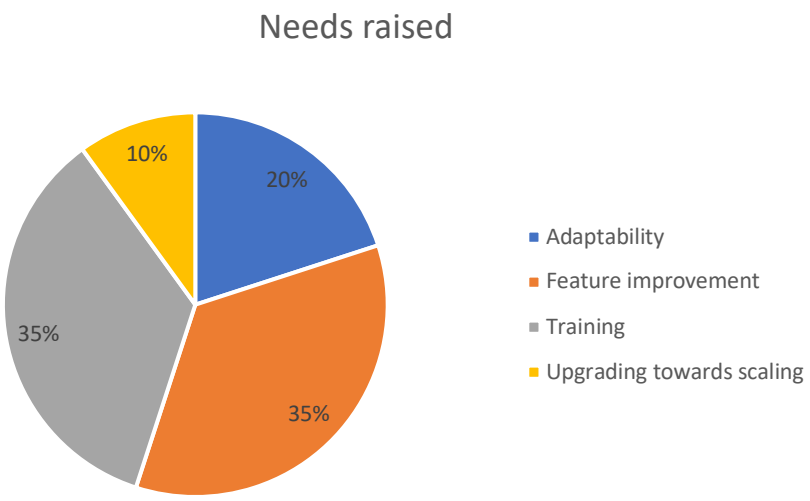

Figure 6.Needs raised by the organizations to implement WSAM practices and tools.

4.6.1 Training

The most recurrent need by all organizations is training. They recognize the importance of building capacities, particularly at the field staff level. Mainly because they refer to their WSAM tools as quite complex. Some Global South operators face technological challenges, as stated by WaterStarters and WaterCompass. Furthermore, TDF noted that training also plays a crucial role in raising awareness of the importance of asset management practices.

Box 10.Quotations on training needs.

WaterStarters: *'We've had systems that are existing. Some of them could be robust, but also very complex […] for it [the tool], to deliver what you want will require much training.*
WaterCompass: *'They've been using paper-based systems for years, and so just getting them used to sort of using a tablet or a smartphone as opposed to paper-based forms just takes a little training and persistence'*
TDF: *'So what is the role of asset management? We need to educate them. Because, at this moment, the asset plan is a practice that is not in place in the water users association'.*

In general, it is common for all organizations to provide at least a short training to support the uptake of the WSAM tool they selected. However, different training methods were mentioned during the interviews. For example, SNV adopts a hands-on approach by actively engaging with the government and operators in practical sessions, exploring all the available tool features. Meanwhile, 1001 fointaines initially employed a classroom training method centered around explaining their overall WSAM approach and why it is necessary. Later in the process, 1001 fointaines, recognized the need to add hands-on training in their implementation processes. This illustrates the diverse approaches organizations take, with some prioritizing direct practical involvement while others begin with instructional tools (PowerPoints, videos) before incorporating practical coaching. Furthermore, most organizations conduct training in collaboration with other institutions. For example,

WaterCompass collaborates with the Uganda Water Project, Water for People with the USAID WASH Project, and TDF with the European Union Project.

TDF and GOAL propose the following training using mentoring or tutoring, or "training side-by-side." This may be more appropriate for capacity building. It highlights the importance of developing tailored and effective training methods that address each group's needs and preferences.

Overall, all organizations see a real need for training, capacity building, and long-term technical support to ensure the uptake of the tools.

Box 11.Quotations on training preferences.

GOAL: '*Our preference would usually be, I think, mentoring, tutoring'.*
TDF: 'The *more simple, simplified, applicable […] we can provide the training side by side, the better'.*

4.6.2 Feature improvement

As all organizations use different WSAM tools, they refer to the need to improve their tools without being specific about which features are lacking. Nevertheless, WaterStarters, KACWASCO, and TDF mentioned the need for an integrated dashboard combining multiple functions. An integrated dashboard should serve technical and field staff, ensuring compatibility across disciplines and sectors. Besides, this integrated tool also needs to be simple and to be interoperable, as mentioned by Water for People. But overall, the highest score for 'feature improvement' corresponds to integrating all the features into a single dashboard.

Box 12.Quotations regarding feature improvement.

KACWASCO: '*So if we had a system [tool] where all this information could be in one place and we can easily access it'.*
Water for People: *'The Excel [tool] we use now is complicated. We are looking for how we can use online software, where people can just do the data entry without manipulating the Excel and changing the formulas or making errors so that when you put it into a web-based well-structured, the tool will give you everything in the same screen'*
WaterStarters: *'We don't really have a standard risk assessment tool...[to some extent] we've been doing it, but you know you do but you're not really*
WaterStarters: *'We wanted a system tailored to our specific needs. So that is what I meant by a responsive system'.*
TDF: *'First and foremost, we need to tailor customize […] it needs to be integrated with linked by the unique ID and interoperable'.*

One concrete feature missed is risk assessment. Since most tools in use have features for asset inventory and O&M practices, WaterStarters stated the need for having a risk assessment feature in place; this will allow them to implement continuous risk management practices.

Though customer satisfaction is not always linked to asset management[7], entrepreneurial operators greatly emphasize the customer side and want this to be included in their tools.

4.6.3 Adaptability

Although the organizations have existing WSAM tools, the suitability of these tools to meet their specific needs often remains unclear. TDF emphasizes that local contexts differ between regions and users (even in the same country, Nepal), making it crucial to have tools tailored to different users' needs. WaterStarters also highlight this, mentioning that meeting specific community needs is essential. These local particular needs can be related to a responsive system for the customers and being able to operate by different sectors. These viewpoints highlight the critical role of adaptability and tailored

[7] In the eyes of Practica, it is vital to link customer satisfaction to asset management. Since customer satisfaction give an indication whether the current service level actually meets customer demands.

solutions in ensuring the effectiveness of asset management tools across diverse operational environments.

4.6.4 Upgrading towards upscaling

Box 13.Quotations regarding upgrading towards upscaling.

WaterStarters: *'As we go towards scaling, we also want a system that can scale with us, a system that can adapt with us as we keep changing, as we keep improving'.*

WaterCompass: *'We're also looking at expanding our assessment of the impact of our water systems to economic level as well'.*

WaterStarters, TDF, and WaterCompass, brought up the need for upscaling. They refer to upgrading the tool's functionality, enabling operations to scale in scope, size, and user base. For instance, WaterStarters wished for a WSAM tool that could expand as they continue to develop as a company. Furthermore, TDF also underscores that once they find suitable WSAM tools, they aim to expand its scope gradually so that it can serve wider communities in their operational region. On the other hand, organizations such as WaterCompass emphasized the need for tools to measure and evaluate economic impacts.

5. Conclusions and Recommendations

5.1 Conclusions

Approach and tools in use

The WSAM practices, methods, and tools used by the interviewed organizations in the WASH sector vary. It starts with the observation that a shared definition of WSAM is lacking. While some have a narrow definition of seeing it as a strategy to record assets and develop a maintenance schedule, others believe it connects all organizational aspects of a water utility, from human resources management to technical life cycle system analysis, consumer service level monitoring, business modeling, and financial management.

Also, the tools to support the planning, implementation, monitoring, and evaluation of WSAM vary between organizations. Organizations often use a combination of different paper-based (e.g., self-developed templates) and digital-based tools (like mWater or AkvoFlow). The interviewed organizations viewed Maintenance Planning & Logging and Asset Inventory & Mapping as the most critical components of their WSAM tools. Almost all organizations use a tool enabling an asset inventory, but forecasting and monitoring financial O&M is often lacking. Risk assessment was the least present tool feature, with only three organizations conducting both risk assessment and mitigation.

Driving forces

According to the interviews, the most prominent reason to use certain types of tools was collaboration/partnership. 8 of the 11 organizations stated that they use a specific tool because of an existing collaboration with another organization, stressing the importance of partnerships in adopting WSAM tools. Also, simplicity/practicability was among the driving forces for choosing specific tools, resonating across all interviews. The organizations emphasized the importance of straightforward and practical tools that operators can easily understand. Cost considerations also proved to be a significant driving force for selecting specific WSAM tools, favoring the free tools. To illustrate, most organizations use the mWater tool as this tool is freely accessible, whereas, for example, Commcare is considered expensive by some organizations.

Challenges

All interviewed organizations encountered particular challenges in implementing WSAM practices. In contrast, the organizational difficulties were referred to as the biggest ones, followed by operational and financial challenges. First, time-consuming decision-making and implementation processes were often mentioned. Water systems' maintenance usually takes a long time, caused, among others, by bureaucracy but also by a lack of planning, risk assessment, and prioritization. Secondly, a lack of knowledge and skills was often referred to, challenging the implementation of proper asset management practices and hindering the use of more advanced WSAM tools.

Organizations experienced technical/operational challenges as well. They mentioned the lack of certain features and the inability to find a WSAM tool that meets all their needs. For example, several organizations indicated they lack a user-friendly web dashboard that integrates data from various sources. Currently, operators struggle to put data into a mix of multiple templates and software. Finally, license costs of the tools were sometimes mentioned as constraints.

Needs

The 11 organizations interviewed experienced various needs regarding introducing WSAM as an approach, specifically to roll out the tools. The most prominent need was adequate capacity-building. All organizations recognize the importance of training, especially at the field level, since most WSAM tools are considered complex, and operators in the field face several technical challenges. Most organizations find training operators at the field level the most challenging. Some organizations, such as TDF and GOAL, emphasize mentoring/tutoring ‘side-by-side’ to build capacity rather than giving formal classroom training, which operators might quickly forget.

The organizations also indicated they would like some *feature improvements*. An integrated web dashboard was mentioned most. Besides, some organizations would like specific risk assessments or customer satisfaction features.

Overall conclusion

While the diversity of interpretations, approaches, and tools can be explained by varying contexts, challenges, and needs organizations encounter, it may lead to misalignment in strategic priorities and goals in the wider water sector. Without a shared understanding, various stakeholders approach WSAM with varied objectives, potentially hindering collaborative efforts and the efficient allocation of resources. Furthermore, the absence of a common ground impedes the development of shared vision tools (paper-based and online) that can be universally adopted, disables data comparison, and prevents consistent and impact-driven approaches across the sector.

However, applying tools and implementing WSAM are embedded in the context of challenges, driving forces, and needs. In the end, tools are a ‘means to an end’, not the goal of WSAM. Thus, the global water sector must especially converge on the impact to be delivered and the type of results to be shared on WSAM. Flexibility should remain across countries and organizations in the global South on how to upscale and roll our WSAM. Tools that enable easy data comparison on agreed indicators, are open-source, user-friendly, have tailor-made options, and can easily be integrated with other

dashboards will probably be crucial for enabling this. This is with the ultimate goal of improving the sustainability and accessibility of water systems in the global South.

5.2 Recommendations

Practica have formulated the following tentative recommendations based on the interviews and literature research conducted by the ACT team.

1. The absence of a shared definition in the rural water sector of WSAM could be tackled by more frequent sharing and aligning of approaches, practices, and methods in use. Sector organizations, like Rural Water Supply Network (RWSN) and Global Water Operating Partnerships Alliance (GWOPA), could play a role in facilitating more exchanges and documentation on methods and tools in use and best practices. Dedicated research initiatives, like REACH and REAL programs, or think-thanks and capacity-building organizations, like Global Water Centre (GWC) or IRC WASH, could support the development of common guidelines on WSAM, especially for the rural water sector in the global South.
2. Connected to this, it is unsurprising that all interviewed organizations indicated the need for more capacity building on WSAM. Most interviewees agree that the knowledge and skill gap is the largest at the field level. Still, the study was too brief to give insights into the exact curriculum or informal learning network required to overcome this gap. It is therefore also recommended to investigate the training needs further and whether it makes sense to collectively build capacity among different organizations or develop tailor-made knowledge and skill programs.
3. This study and its established tool comparison matrix are the first steps in comparing different methods and tools in use but are not fully encompassing. There is a clear need to dive deeper and understand better among the organizations interviewed how they operationalize WSAM. In most cases, only one staff member has been consulted, while it is evident that different staff members within an organization bring various perspectives. At the same, it is worthwhile to consult an additional number of organizations applying other methods and tools (e.g., WaMaSys), which have not yet been analyzed in this investigation. Doing more consultations will likely provide a more accurate picture of what type of tool features are commonly used and which ones still lack. It hopefully will also result in more insights into the user-friendliness of each tool for specific target groups.
4. The question ‘What works for whom, when, and where?’ is also not answered yet. The study gave an impression in which circumstances and challenges arise. Still, it did not analyze in which socio-economic, institutional, and legal context what approach and tool was being deployed and where it worked best. It is likely that varying local conditions, governmental regulations, and capacities require different approaches and tools. It is therefore advised to collect more best practices on ‘what works for whom, when, and where?’.
5. Simultaneously, the water sector does not operate in a vacuum. New trends and innovations are continuously emerging. It is also vital to track these and make this part of knowledge-sharing and continuous capacity-building efforts.
6. Finally, as the conclusion emphasizes, ‘tools are a means to an end’. Understanding better the ‘joint end in mind,’ which means aligning with institutional and political agendas (e.g., national-level governmental policies), establishing partnership visions, and streamlining organizational objectives and goals, will be vital to getting the correct data on the table and the motivation among stakeholders to do so. It is thus recommended to create a better overview of what ‘the end in mind is’ when it comes to WSAM across the rural water sector in different countries and regions.

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Annexes

Annex 1. Semi-structure Interview Script

Semi-Structured Interview Script: Water Asset Management Tools

Introduction (Introduce yourself to stakeholders. Tell them shortly about FLoW and the project, etc.):

We as the Future Leaders on Water (FLoW) academic consultancy team of Wageningen University and Research (WUR) have been asked by Practica to develop an overview of the different asset management tools used by the different stakeholders and the driving forces involved, by conducting interviews. By these tools we mean both paper and digital-based structures for logging maintenance (technical) and finance (financial) of the water systems you are in charge of. Think about aspects like asset inventory, operation and management (O&M), risk assessment, water tariff, modelling. We are a group of 5 highly motivated graduate students each having our own cultural background and field of expertise. The focus of this interview is on water asset management tools. We will cover the following topics respectively: (1) what the type of WAMT is, (2) what the driving forces are behind this choice, (3) whether the needs are fulfilled and (4) what challenges are faced.

1st Topic: Type of Water Asset Management Tools (WAMT)

Phase 1:

1. What water asset management tools are currently used within your organization (paper-based, app, etc.)? Can you **describe** your current AM practices (billing, O&M, water tariff, etc) and their importance to your organization/project?
2. Is this tool **developed** within your organization or developed by other organizations?

Phase 2 (Feature)

1. What are the **key features** of the WAMTs your organization uses? And what type of data is collected? What key data is collected under each feature? And why?
2. **What** is the process of data collection (input/outputs)? **Who** is collecting what data? Who is analyzing it? And who and how are the results used?

2nd Topic: Driving forces behind the usage of WAMT

1. What **factors** influenced the **decision** to choose the current water asset management tools?
a. Follow up: What are any **distinctive features** that stand out compared to other tools in the market?

3rd Topic: Need of organizations/local communities regarding WAMT & Challenge in applying WAMT

1. How do you ensure that your staff (or the outsourcing staffs) is effectively trained in utilizing Asset Management approach and tools?
2. In what ways do these tools **contribute** to meeting the organizational goals or community needs?
a. Follow up: What features do you **miss**?
3. What are the **challenges (socio-technical)** regarding the implementation of the WAMTs?
a. Follow-up: **Why** is this a challenge? Could you **elaborate** on the challenge?
4. How does your organization plan to **overcome** this/these challenge(s)?

Closing

Thank you so much for your time and answers. We really appreciate your attendance in this meeting. For now, we have had enough information. We will continue working on this information and structure it. Practica will keep you updated regarding our output and the webinar. Thank you all and have a nice day!

Reminder(!): Ask the organization

Annex 2. Coding Structure

The coding has been done in a deductive way. As during the data analysis new code groups might appear, also some inductive coding is involved in the process of the research. The different themes and the subtopics presented below are briefly explained. The themes are:

1. Type of WAMT:
    - Code:
        - Digital-Based:
        - Paper-Based:
        - Self-Made:
        - Feature:
        - Operator:
2. Driving force behind the choice of WAMT:
    - Code:
        - Finance:
        - Simplicity/Practicability:
        - Flexibility:
        - Upscaling:
        - People Influence:
        - Integration:
3. Challenge in applying WAMT:
    - Code:
        - Technical:
        - Social:
        - Economical:
        - Solution Plan:
4. Need of community regarding WAMT:
    - Code:
        - AM Tools:
        - Feature:
        - Training:
        - Upscaling:

Annex 3. Overview of organizations that participated in the study

Private/entrepreneurial operators

1. 1001Fontaines

   1001Fontaines[1] is an entrepreneurial organization focusing on providing safe drinking water for everyone. 1001Fontaines wants to improve the health of vulnerable communities by providing access to safe drinking water every day. The organization originates from France and is now implementing programs in 4 countries: Cambodia, Madagascar, Myanmar and Vietnam. 1001Fontaines uses a specific model, consisting of 4 major points. The first step is setting up water kiosks, which are small enterprises producing and delivering affordable safe drinking water. Secondly, they recruit and train local workers to empower the local population. Thirdly, they want to combine philanthropy and social entrepreneurship to ensure safe access to drinking water. Lastly, 1001Fontaines also distributes free drinking water in schools.

2. WaterCompass Uganda

   The WaterCompass[2] project provides reliable access to clean water in underserved areas in three water-stressed districts of Uganda: Gomba, Sembabule, and Bukomansimbi. In those three locations, they worked in WASH sectors including water supply, improve sanitation, and hygiene promotion. They built, operated, and maintained solar-powered water supply systems with community involvement as the foundation. Their primary partner is a local agent who sells water credit and monitors the systems. Their solar-powered water supply systems have a 99.8% operational uptime and will earn $2,542 in income by 2021[3]. This revenue is used to maintain the system and reinvest in expanding existing systems or building new ones, hence increasing access to clean water indefinitely[2].

3. WaterStarters / AMREF Kenya

   WaterStarters[4] functions as a social enterprise operating within Kenyan communities through a collaborative approach. Regarding water asset management, WaterStarters aim to support the water supply systems in both rural and peri-urban areas, providing water for domestic use, livestock, irrigation, and wildlife. Moreover, they facilitate the growth of rural businesses by ensuring water availability. On the financial front, WaterStarters employs a franchise model wherein communities and entrepreneurs participate in co-investment, fostering ownership and enabling payback. Additionally, they implement a financial model incorporating prepaid water meters. From a technical standpoint, WaterStarters employs groundwater scans to guarantee the sustainable extraction of water. The groundwater pumps are powered by solar panels and a monitoring dashboard is in place tracking key indicators, ensuring efficient and effective water asset management[4].

Governmental

1. Northern Umbrella of Water & Sanitation (NUWS) - Government of Uganda. The Northern Umbrella of Water & Sanitation (NUWS)[8] is part of the Umbrella Authorities (UA) of the Uganda's government and established in 2011[9]. Their vision is to become the leading water and sanitation utility in the North of Uganda[10]. They are responsible for the technical and financial operations of piped water schemes in the North of Uganda. It is not exactly known how many people are served by this water system, but according to estimations this is around 17% of the Northern population. The system consists of 814 km of mains length and has an average age of 12 years. For the financial part an online billing and payment system is in use, called Pegasus[11].

2. KACWASCO - Kakamega county - Government of Kenya
   Kakamega County Water and Sanitation Company Limited (KACWASCO) is an owned agency of the County Government of Kakamega established in 2021 to provide water within areas of service according to the regulations of the Water Services Regulatory Authority (WASREB)[12]. Currently, around 78% of the Kakamega county is provided by clean, safe and quality water, estimated to be 432 284 people. The area of coverage is divided into 5 region each having their own area and scheme mangers. The vision of the organization is to connect the entire population to improved water and sanitation services.

3. Town Development Fund (TDF) - Government of Nepal
   Town Development Fund (TDF)[13] is an independent finance institution formed by the Government of Nepal (GoN) in 1989 to offer loan and grant money for Nepal's sustainable urban infrastructure. Their primary client in Nepal is local government, particularly municipalities. According to the annual report, the water supply and sanitation sector is TDF's largest investment portfolio, accounting for 52.5% of overall investment. They have an Asset Management Action Plan (AMAP) for all of these projects, and they collaborate with UN-DESA, UNCDF, and UNOPS. The practical use of the AMAP for critical asset management has begun in 65 municipalities by reviewing and accounting for the existing property management practices of pilot municipalities using the Diagnostic tool. This AMAP is meant to increase municipalities' capabilities as well as their financial status for future investment.

NGOs

1. SNV (for Gov of Mozambique)
   SNV is a global development organization working in several sectors, founded in 1965. They work in the agri-food, energy and water sector. SNV sees the water crisis as not only an

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81 https://www.1001fontaines.com/en/

2 https://www.watercompass.org/

3 https://uploads-ssl.webflow.com/5f7f1394cd380bb70111d0b6/635a39343f3edc8a53933697_2021%20Annual%20Report-2.pdf

4 https://www.waterstarters.org/home

5 https://www.mwe.go.ug/content/umbrella-north

6 http://uo-uganda.weebly.com/north.html

7 https://www.mwe.go.ug/sites/default/files/NUWS.pdf

8 https://www.mwe.go.ug/content/umbrella-north

99 http://uo-uganda.weebly.com/north.html

1010 https://www.mwe.go.ug/sites/default/files/NUWS.pdf

11 https://www.ldpg.or.ug/wp-content/uploads/2021/06/Umbrella-Authorities-2020-rev-210607.pdf

12 https://kakamegawater.co.ke/about-us/

13 https://tdf.org.np/

ecological and economic crisis, but rather as an equity and governance crisis. For the water sector, SNV is committed to "increasing the reliability and availability of water and sanitation at an acceptable quantity and quality"[14]. The company consists of over 1600 colleagues, working in more than 20 countries in Africa and Asia while their main office is located in the Hague. SNV puts the emphasis on the performance of institutions, stating that strong institutions are essential for data-provision, resulting in more informed decision-making[14].

2. GOAL Uganda
   Founded in 1977, GOAL[15] works on solving major humanity crises and vulnerable communities. They have 5 programs to achieve their goals: people survive crises, people have resilient health, people have food and nutrition security, people pursue a sustainable, resilient, and inclusive world, and other programmed priorities. Regarding our project, we will be involved in the People Have Resilient Health program.

3. IRC The International Water and Sanitation Centre (IRC)[16] is a foundation that focuses on the WASH sector in developing countries. The members of IRC are mostly citizens from these countries: Burkina Faso, Ethiopia, Ghana, Honduras, India, Mali, Nigeria, and Uganda. They engage in the facilitation of collaborative efforts involving many stakeholders, including governmental bodies, water utilities, private enterprises, non-governmental organizations (NGOs), citizen groups, and entrepreneurs.

4. Water for People Uganda[17]: Started working in Uganda in 2008 by learning about the population's water and sanitation needs and building relationships with local government and the private sector. It now supports water services in Kamwenge and Luuka Districts and sanitation services in five additional services

Annex 4. Limitations and Ethical Concerns

It is essential to be aware of the risks associated with data collected through semi-structured interviews. Staff from organizations can purposely withhold information during interviews, thereby affecting the whole outcome of the research. Interviewees can also be biased towards their WSAM tools. Another critical aspect of the study is factual accuracy. To verify the insights gained from the interviews, a thorough literature research in the field of WSAM has been conducted. The positionality of the researcher should also be considered. As students of Wageningen University, it has been acknowledged that there is a vast cultural gap between the researchers and the operators and staff members of the drinking water systems in rural areas in the global South. Which might affect the interpretation of the data collected and, thus, the overall result of the research.

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[14] https://www.snv.org/about-us

[15] https://www.goalglobal.org/countries/uganda/

[16] https://www.ircwash.org/tools/irc-costing-and-budgeting-tools

[17] https://www.waterforpeople.org/uganda/

Annex 5. Matrix of Water Systems Asset Management Tools

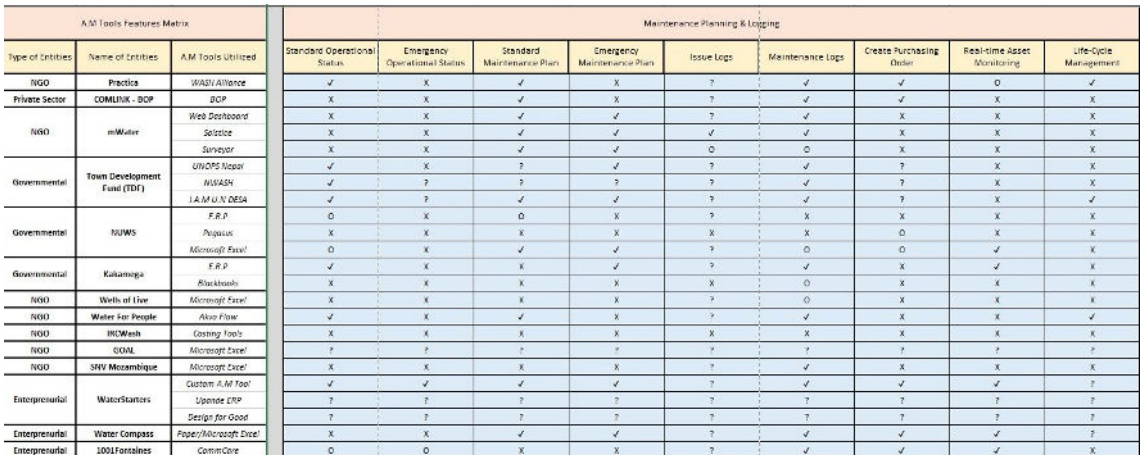
Features of WAMT

A.M Tools Features Matrix			Asset Inventory & Mapping				
Type of Entities	Name of Entities	A.M Tools Utilized	Asset Registry (Parent & Child)	Asset Operational Status (Parent & Child)	Asset Location	Asset Pictures (Parent & Child)	Asset Life Span (Parent & Child)
NGO	Practica	*WASH Alliance*	✓	✓	✓	✓	✓
Private Sector	COMLINK - BOP	*BOP*	✓	✓	✓	✓	✓
NGO	mWater	*Web Dashboard*	✓	✓	✓	✓	✓
		Solstice	✓	✓	✓	✓	✓
		Surveyor	✓	✓	✓	✓	✓
Governmental	Town Development Fund (TDF)	*UNOPS Nepal*	✓	✓	✓	✓	O
		NWASH	✓	✓	✓	✓	O
		I.A.M U.N DESA	✓	✓	✓	X	✓
Governmental	NUWS	*F.R.P*	X	O	X	X	O
		Pegasus	O	X	X	X	X
		Microsoft Excel	O	X	✓	X	X
Governmental	Kakamega	*E.R.P*	X	X	X	X	X
		Blackbooks	✓	X	O	X	X
NGO	Wells of Live	*Microsoft Excel*	✓	O	✓	X	X
NGO	Water For People	*Akvo Flow*	✓	✓	✓	✓	✓
NGO	IRCWash	*Costing Tools*	✓	✓	✓	X	✓
NGO	GOAL	*Microsoft Excel*	✓	✓	✓	✓	✓
NGO	SNV Mozambique	*Microsoft Excel*	X	X	X	X	X
Enterprenurial	WaterStarters	*Custom A.M Tool*	✓	✓	✓	✓	✓
		Upande ERP	?	?	?	?	?
		Design for Good	?	?	?	?	?
Enterprenurial	Water Compass	*Paper/Microsoft Excel*	?	?	?	?	?
Enterprenurial	1001Fontaines	*CommCare*	✓	?	✓	?	?

Figure 5.A: Asset Inventory & Mapping

A.M Tools Features Matrix			Risk Assessment & Risk Mitigation				
Type of Entities	Name of Entities	A.M Tools Utilized	Asset Registry (Child)	Description of potential failures	Failure Impact & Probability	Risk Category	Risk Mitigation
NGO	Practica	*WASH Alliance*	✓	✓	✓	✓	✓
Private Sector	COMLINK - BOP	*BOP*	✓	X	X	X	?
NGO	mWater	*Web Dashboard*	✓	✓	O	O	O
		Solstice	✓	X	X	X	X
		Surveyor	✓	X	X	X	X
Governmental	Town Development Fund (TDF)	*UNOPS Nepal*	✓	X	X	✓	X
		NWASH	✓	?	?	✓	?
		I.A.M U.N DESA	✓	✓	X	✓	✓
Governmental	NUWS	*F.R.P*	X	O	X	X	X
		Pegasus	X	X	X	✓	X
		Microsoft Excel	✓	X	X	O	X
Governmental	Kakamega	*E.R.P*	X	X	X	X	X
		Blackbooks	X	X	X	X	X
NGO	Wells of Live	*Microsoft Excel*	X	X	X	X	X
NGO	Water For People	*Akvo Flow*	✓	X	X	✓	X
NGO	IRCWash	*Costing Tools*	X	X	X	X	X
NGO	GOAL	*Microsoft Excel*	?	?	?	?	?
NGO	SNV Mozambique	*Microsoft Excel*	X	X	X	X	X
Enterprenurial	WaterStarters	*Custom A.M Tool*	X	X	X	X	X
		Upande ERP	X	X	X	X	X
		Design for Good	X	X	X	X	X
Enterprenurial	Water Compass	*Paper/Microsoft Excel*	✓	✓	X	X	X
Enterprenurial	1001Fontaines	*CommCare*	✓	X	X	X	X

Figure 5.B: Risk Assessment & Risk Mitigation

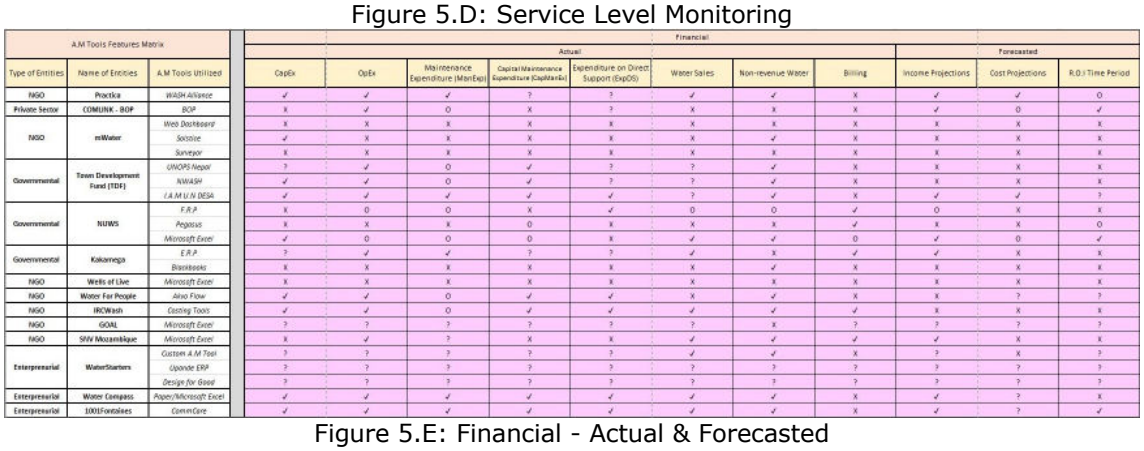


A.M Tools Features Matrix			Maintenance Planning & Logging								
Type of Entities	Name of Entities	A.M Tools Utilized	Standard Operational Status	Emergency Operational Status	Standard Maintenance Plan	Emergency Maintenance Plan	Issue Logs	Maintenance Logs	Create Purchasing Order	Real-time Asset Monitoring	Life-Cycle Management
NGO	Practica	WASH Alliance	✓	X	✓	X	?	✓	✓	O	✓
Private Sector	COMLINK - BOP	BOP	X	X	✓	X	?	✓	✓	X	X
NGO	mWater	Web Dashboard	X	X	✓	✓	?	✓	X	X	X
		Solstice	X	X	✓	✓	✓	✓	X	X	X
		Surveyor	X	X	✓	✓	O	O	X	X	X
Governmental	Town Development Fund (TDF)	UNOPS Nepal	✓	X	?	✓	?	✓	?	X	X
		NWASH	✓	?	?	?	?	✓	?	X	X
		I.A.M U.N DESA	✓	?	✓	✓	?	✓	?	X	✓
Governmental	NUWS	F.R.P	O	X	O	X	?	X	X	X	X
		Pegasus	X	X	X	X	X	X	O	X	X
		Microsoft Excel	O	X	✓	✓	?	O	O	✓	X
Governmental	Kakamega	E.R.P	✓	X	X	✓	?	✓	X	✓	X
		Blackbooks	X	X	X	X	X	O	X	X	X
NGO	Wells of Live	Microsoft Excel	X	X	X	X	?	O	X	X	X
NGO	Water For People	Akvo Flow	✓	X	✓	X	?	✓	X	X	✓
NGO	IRCWash	Costing Tools	X	X	X	X	X	X	X	X	X
NGO	GOAL	Microsoft Excel	?	?	?	?	?	?	?	?	?
NGO	SNV Mozambique	Microsoft Excel	X	X	X	X	?	✓	X	X	X
Enterprenurial	WaterStarters	Custom A.M Tool	✓	✓	✓	✓	?	✓	✓	✓	?
		Upande ERP	?	?	?	?	?	?	?	?	?
		Design for Good	?	?	?	?	?	?	?	?	?
Enterprenurial	Water Compass	Paper/Microsoft Excel	X	X	✓	✓	?	✓	✓	✓	?
Enterprenurial	1001Fontaines	CommCare	O	O	X	X	?	✓	✓	✓	X

Figure 5.C: Maintenance Planning & Logging

A.M Tools Features Matrix			Service Level Monitoring				
Type of Entities	Name of Entities	A.M Tools Utilized	Water Quality	Water Quantity	Water System Utilization	Consumption Projection	Customer Satisfaction Indicators
NGO	Practica	WASH Alliance	✓	✓	O	?	?
Private Sector	COMLINK - BOP	BOP	X	X	✓	X	?
NGO	mWater	Web Dashboard	✓	X	X	X	?
		Solstice	X	✓	X	X	?
		Surveyor	✓	X	X	X	?
Governmental	Town Development Fund (TDF)	UNOPS Nepal	X	✓	X	X	?
		NWASH	✓	✓	X	X	?
		I.A.M U.N DESA	✓	✓	✓	X	?
Governmental	NUWS	F.R.P	X	O	X	O	?
		Pegasus	O	X	O	X	?
		Microsoft Excel	X	✓	X	O	?
Governmental	Kakamega	E.R.P	X	X	✓	X	?
		Blackbooks	✓	✓	X	X	?
NGO	Wells of Live	Microsoft Excel	O	X	X	X	?
NGO	Water For People	Akvo Flow	X	✓	X	X	?
NGO	IRCWash	Costing Tools	✓	✓	X	✓	?
NGO	GOAL	Microsoft Excel	?	?	?	?	?
NGO	SNV Mozambique	Microsoft Excel	✓	✓	✓	✓	?
Enterprenurial	WaterStarters	Custom A.M Tool	✓	✓	?	?	?
		Upande ERP	?	?	?	?	?
		Design for Good	?	?	?	?	?
Enterprenurial	Water Compass	Paper/Microsoft Excel	✓	✓	✓	✓	?
Enterprenurial	1001Fontaines	CommCare	X	✓	O	O	?

Figure 5.D: Service Level Monitoring



A.M Tools Features Matrix			Financial									
			Actual							Forecasted		
Type of Entities	Name of Entities	A.M Tools Utilized	CapEx	OpEx	Maintenance Expenditure (MainExpi)	Capital Maintenance Expenditure (CapMainExi)	Expenditure on Direct Support (ExpDS)	Water Sales	Non-revenue Water	Billing	Income Projections	Cost Projections	R.O.I Time Period
NGO	Practica	WASH Alliance	✓	✓	✓	?	?	✓	✓	X	✓	✓	O
Private Sector	COMLINK - BOP	BOP	X	✓	O	X	?	X	X	X	✓	O	✓
NGO	mWater	Web Dashboard	X	X	X	X	X	X	X	X	X	X	X
		Solstice	✓	X	X	X	X	X	✓	X	X	X	X
		Surveyor	X	X	X	X	X	X	X	X	X	X	X
Governmental	Town Development Fund (TDF)	UNOPS Nepal	?	✓	O	✓	?	?	✓	X	X	X	X
		NWASH	✓	✓	O	✓	?	?	✓	X	X	X	X
		I.A.M U.N DESA	✓	✓	✓	✓	✓	?	✓	X	✓	✓	?
Governmental	NUWS	F.R.P	X	O	O	X	✓	O	O	✓	O	X	X
		Pegasus	X	X	X	O	X	X	X	✓	X	X	O
		Microsoft Excel	✓	O	O	O	X	✓	✓	O	✓	O	✓
Governmental	Kakamega	E.R.P	?	✓	✓	?	?	✓	X	✓	✓	X	X
		Blackbooks	X	X	X	X	X	X	✓	X	X	X	X
NGO	Wells of Live	Microsoft Excel	X	X	X	X	X	X	X	X	X	X	X
NGO	Water For People	Akvo Flow	✓	✓	O	✓	✓	X	✓	X	X	?	?
NGO	IRCWash	Costing Tools	✓	✓	O	✓	✓	✓	✓	✓	X	X	X
NGO	GOAL	Microsoft Excel	?	?	?	?	?	?	X	?	?	?	?
NGO	SNV Mozambique	Microsoft Excel	X	✓	?	X	X	✓	✓	✓	✓	X	X
Enterprenurial	WaterStarters	Custom A.M Tool	?	?	?	?	?	✓	✓	X	?	X	?
		Upande ERP	?	?	?	?	?	?	?	?	?	?	?
		Design for Good	?	?	?	?	?	?	?	?	?	?	?
Enterprenurial	Water Compass	Paper/Microsoft Excel	✓	✓	✓	✓	✓	✓	✓	X	✓	?	X
Enterprenurial	1001Fontaines	CommCare	✓	✓	✓	✓	✓	✓	✓	X	✓	?	✓

Figure 5.E: Financial - Actual & Forecasted

Asset Inventory		
Asset Registry (Parent & Child)	:	Name and/or custom ID number of the parent and/or child assets
Asset Operational Status (Parent & Child)	:	Fully-Active, Partially-Active, Inactive, Malfunctioning, etc.
Asset Location (Map/Geo-location)	:	Exact location of the asset, e.g. coordinate location/district/province/etc.
Asset Pictures (Parent & Child)	:	Are pictures of the parent/child assets used in the A.M tool?
Asset Life Span (Parent & Child)	:	Expected life-used of the parent/child assets
Risk Managament & Risk Mitigation		
Asset Registry (Child)	:	Is it possible to individually register the child assets?
Desription of potential failures	:	Are the major/most common failures that threaten the system classified in the A.M tool?
Failure Impact & Probability	:	Is the impact of the failure's to the system explained? How possible is for the failure to occur?
Risk Category	:	Can the levels of risk due to failure be classified in the A.M tool?
Risk Mitigation	:	Is the plan to overcome the risk that might happen due to the failure explained in the A.M tool?
Management Planning & Logging		
Status Operational Condition	:	Is the operating procedure in standard conditions explained? (i.e. indicators related to the pumped water and expected revenue that tell that the system is working properly)
Emergency Operational Status	:	Is the operating procedure in emergencies explained? (i.e. an indicator below a certain acceptable deviation translates into reduced capability of the system to perform its function)
Standard Maintenance Plan (Preventive Maintenance)	:	Is it explained what tools/skills are necessary for proper maintenance and who is responsible to perfom it)
Emergency Maintenance Plan (Reactive Maintenance)	:	Is it explained what is the plan in case of emergy maintenance need? (i.e. what is the direct response after the problem has been confirmed?)
Issuing Logs	:	Is there the option to upload issue logs after a problem has been identified?
Maintenance Logs	:	Is there the option to upload maintrenance logs after the issue has been resolved? (i.e. how it was solved, resources spent, etc.)
Create Purchasing Order	:	Is it possible to automatically order replacement parts to perform the required maintenance?
Reail-time Asset Monitoring	:	Is it possible to automatically capture data from the machines/equipment and feed it to the A.M. tool?
Life-Cycle Management	:	Is the option to classify the life-cycle management of the system from acquisition to decommisioning available in the A.M. tool?
Service Level Monitoring	:	
Water Quality	:	Is there the option to upload data on the quality of water? (i.e. chemical sampling tests, purity indicators, etc.)
Water Quantity	:	Is there the option to set how much water the system pumps in a set period of time?
Water System Utilization	:	How much of the water available in the source is being utilized by the water system?
Consumer Projection	:	Estimation of the need and willingness of additional points to connect to the system
Customer Satisfaction Indicators	:	Includes factors such as affordability, accessibility, safety, and reliability that are associated with the water system
Financial		
- Actual		
CapEx	:	Initial investment in the development of water system
OpEx	:	Regular expenses for operation and maintenance
Maintenance Expenditure (ManExp)	:	Smaller maintenance costs associated with the smooth operation of the water system
Capital Maintenance Expenditure (CapManEx)	:	Expenses for major maintenance or tools replacement (like new replacement parts for the water system)
Expenditure on Direct Support	:	Expenditure on both pre- and post-construction support activities directed to local-level stakeholders, users or user groups
Water Sales	:	Prepare and distribute the bill for the water customers
Non-revenue Water	:	Quantitice indication of water consumption
Billing	:	The bills of water selling being collected and registered
- Forecasted		
Income Projections	:	Is the information available about the water tariffs, projections about the water prices, and information on governmential subsidies or donor support?
Cost Projections	:	
R.O.I Time Period	:	Estimation year of the return value for investment
Legend		
✓	:	Avalaible
X	:	Not Available
O	:	Partly Available
?	:	Unkown
Parent & Child Assets	:	Designation coined to describe the main assets and those that comprise them. For example, a water pump is a parent asset and its main valve is one of the cgild assets

Figure 5.F: Matrix Explanation

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