Financial sustainability of urban water cycle services in developing countries: a case study in Mozambique

ABSTRACT
A management strategy to achieve financial sustainability of urban water cycle services in developing countries is presented, based on the development of the Long Term Water Supply and Sanitation Services Investment Plan for the Water and Sanitation Infrastructure Administration (Administração de Infra-estruturas de Água e Saneamento (AIAS)) of Mozambique. AIAS is responsible for water supply and sanitation systems of 151 cities and towns (9.38 million inhabitants in 2015, 17.55 million expected in 2040). The needs in this sector are considerable, financial resources are scarce and, as a result, the Millennium Development Goals are still off track to be achieved. An integrated approach was applied to estimate the investments needs, considering differentiated levels of service depending on the urban area characteristics and taking into consideration the household income limitations, in order to achieve an economically sustainable increase in coverage and service level. The work developed resulted in an action plan aligned with the national strategy vision and adaptable to every city and town of Mozambique, including two decision support tools to enable stakeholders’ decision making on potential investments: the Water and Wastewater Database (Base de Informação de Água e Saneamento) and the Dynamic Economic tool to support investments in water supply and sanitation services.

Key words | asset management, decision support tools, developing countries, investment, sustainable cities, urban water cycle services

INTRODUCTION
More than 700 million people still lack ready access to improved sources of drinking water; nearly half are in sub-Saharan Africa. More than one third of the global population, some 2.5 billion people, do not use an improved sanitation facility, and of these 1 billion people still practice open defecation (WHO & UNICEF 2014), a situation with negative impacts on public health, deterioration of the environment and economic development. In particular the inadequate provision of sanitation services in urban areas of developing countries is one of the major challenges of this century (Tayler 2008). This serious situation is rooted in many causes, namely low income and education levels, institutional and political challenges, insecure tenure (Okurut & Charles 2014), the marginalization of urban poor, existing regulations, and a general failure to take the local context into account (Ramôa et al. 2015a).

The Water and Sanitation Infrastructure Administration of Mozambique (Administração de Infra-estruturas de Água e Saneamento (AIAS)) is responsible for the sanitation systems in a total of 151 cities and towns. Except for the Water Supply Investment and Asset Fund (Fundo de Investimento e Património do Abastecimento de Água (FIPAG)) intervention area, which includes 18 cities and three towns, AIAS is also responsible for the water supply systems
of all the remaining 130 cities/towns. In terms of size of the agglomerations, the cities range from about 40,000 to 1.2 million inhabitants, while the towns range from 2,000 to 75,000 inhabitants.

Approximately 42% of the total population of the AIAS area (3.7 million inhabitants in 2013) is served with some type of water supply system: around 6% is served with in-house connections, 17% with yard taps and 19% with public standpipes or boreholes with manual pumps. Regarding sanitation systems, about 37% of the total population of the AIAS area (3.3 million inhabitants in 2013) are served with some type of improved sanitation system, namely 3% with a sewer network, 8% with septic tanks and 26% with improved latrines. There are a few cities with a gravity sewer network, which are mainly stormwater systems that were gradually converted into combined sewer systems. There are only two large Wastewater Treatment Plants in Mozambique which are in regular operation (influence stabilization ponds in Maputo area, the capital of the country, and an upflow-anerobic sludge blanket reactor followed by high rate trickling filters, in Beira). Most of the national expenditure allocated to sanitation comes from donor sources (Cotton et al. 2012).

The needs in this sector are considerable, technical and financial resources are scarce and, as a result, even the Millennium Development Goals in Mozambique are still not on track to be achieved (UNICEF & WHO 2012). According to INE (2010), cities and towns in Mozambique, that are expected to have a total of 9.38 million inhabitants in 2015, will grow to about 17.55 million in 2040. This population increase will aggravate the demand for basic services with scarce resources. To assist decision-making in this context different decision support tools for the water sector have been developed, such as frameworks, checklists, models, toolkits and software programmes (Tornqvist et al. 2008). Another way of modelling decisions in this context is also through the use of decision trees, which present an organized list of guided questions leading the user to a logical solution to a problem as presented by Ramôa et al. (2015b) for the selection of sanitation technologies.

On the other side, service sustainability requires a concerted effort to improve long-term planning, which involves, among other aspects, the need for reinvestments; and the impact of long-term reinvestment policies (Alegre et al. 2014). Different approaches to supporting long-term planning have been proposed over time (e.g. Burn et al. 2003; Kropp & Baur 2005) but dealing with the balance between performance, risk and cost and with the integration of linear (e.g. pipes) and vertical assets (e.g. treatment plants, pumping stations) in a combined and coherent manner is still a major challenge. Besides, the water industry must improve its ability to communicate the reinvestment needs to policy makers and utility CEOs. Whereby, it is essential that simple and understandable approaches and tools are available.

Financial considerations cannot be wished away when seeking effective strategies for achieving development goals (Berga & Mugishab 2010). In this context, a long-term investment plan has been developed for AIAS, in order to have an action plan to achieve an economically sustainable increase in coverage and level of service of water and sanitation systems.

In the development of this plan (ENGIDRO 2013), an integrated approach was applied to select technical solutions and estimate investment needs for the goals established, looking at the urban water cycle as a whole, considering household income constraints, and providing a decision support tool to evaluate the economic viability of the systems.

MATERIAL AND METHODS

The Investment Plan was developed in a very limited period of time of about seven months. To cope with this time constraint, special emphasis was given to the development of user friendly decision support tools, which can easily be updated with future additional data, in order to enable the central government, provincial governments, local authorities and development partners to make decisions on potential investments in AIAS cities and towns, based on collecting and analysing existing information at different sources. Figure 1 illustrates the main inputs and outputs of the Plan.

The Plan included the development of a geographic information system (GIS) environment database, which gathers the main information compiled/produced to support
decision-making – the Water and Wastewater Database (Base de Informação de Água e Saneamento (BIAS)). The main goal of BIAS is demographic, socio-economic and water/wastewater infrastructure characterization, based on the desk review phase and on the field work undertaken, limited to the following ten towns, located in seven different provinces: Palma, Macomia, Chimnonila, Massangulo, Moma, Maganja da Costa, Gorongosa, Macia, Magude and Bela Vista.

According to the National Water Policy, the evolution of the water supply and sanitation services in urban areas should ensure the universality and quality of service; the promotion of the sector’s sustainability; and environmental protection values.

Aligned with this vision, the goals for the water supply sector are to achieve 70% coverage in major urban centres and 36% in secondary urban centres by 2018, and universality in all urban centres by 2025.

In terms of the sanitation sector, the Government goals are to achieve 80% coverage in major urban centres and 32% in secondary urban centres by 2018, and the universality of services in all urban centres by 2025.

In the short term (by 2018) it was assumed that the necessary infrastructures to achieve the Government objectives of the Strategic National Urban Water and Sanitation 2011–2025 Plan established for 2015 regarding water supply and sanitation coverage will be carried out.

In the more densely populated peri-urban areas there is a significant pressure for water solutions with yard taps instead of standpipes which is according with the government orientations to upgrade urban water services and to provide easier access to safe water.

From the public health and environmental protection point of view, collective solutions are probably the most suitable to serve urban and peri-urban densely populated areas, using conventional or simplified sewers systems (small diameter gravity sewers, also called settled sewerage or small-bore sewerage). However, the migratory pressure in the cities and the difficulties in intervening in high density peri-urban areas to implement collective wastewater drainage and treatment solutions, make it expected that over a long period of time the drainage and treatment solutions will be decentralized with individual or collective septic tanks or latrines, and collection of more or less stabilized sludge for further dewatering, treatment and final disposal.

Decentralized approaches have also been proposed to provide practical, alternative options for sustainable urban wastewater management in peri-urban areas (Cheng et al. 2013), although the space available may be critical.

Matching the most appropriate technologies to the specific needs is the key that leads to long-term sustainability (Robbins & Ligon 2014). Given this, in order to meet both financial constraints and social objectives, the Plan proposes
a combination of different levels of service solutions until universality services have been obtained, followed by an improvement in the level of service between 2025 and 2040, with the aim of allowing for a sustainable climbing of the sanitation ladder.

To assess the future water and sanitation infrastructure needs, it was thus necessary to establish a spatial model of the urban evolution of the cities and towns with different water and sanitation levels of service assigned, depending on the settlement density layer and on the average per capita water consumption. This spatial model and levels of service were presented and discussed in a workshop, and established by the AIAS with contributions from the different stakeholders. The different service options include standpipes, yard taps or conventional water pipe networks, and dry (improved latrines) or wet sanitation (septic tanks or sewerage). A division into three structural rings was considered (Figure 2): urban areas with traditional collective water supply and wastewater solutions (e.g. water supply networks, and conventional sewers and treatment plants); dense peri-urban areas with yard taps with septic tanks (50% in 2025, increasing to 75% in 2040) and public standpipes with improved latrines (50% in 2025, decreasing to 25% in 2040); and dispersed peri-urban areas with public standpipes and improved latrines.

A matrix of those structural area percentages was established, considering classes of cities and towns based on their population size (estimated for the years 2015, 2025 and 2040).

RESULTS AND DISCUSSION

The evolutions of the populations planned to be served by the water and sanitation systems are presented in Figure 3, in terms of available level of service.

The unit costs considered for investment needs in water and wastewater were desk-based reviews and the estimations made for the towns carried out by fieldwork. A corrective factor was introduced to take into account the costs of transport of construction materials and equipment in areas with difficult accessibility, using the southern cities of the country as reference.

The estimated total investment needed for the period 2015–2040 is that of 8,605 million USD including 439 million USD for rehabilitation, divided as follows:

- 3,083.26 million USD for water supply infrastructures;
- 5,092 million USD for domestic sanitation (drainage and wastewater treatment);
- 429.26 million USD for urban storm water drainage.

In order to optimize asset investment decisions for urban water and wastewater services, a cyclic and holistic approach to investment provision within the context of strategic asset management is needed (Logan & Janssens 2012).

Under this strategic plan, a tool kit has been developed to assist economic analysis and decision making regarding investment projects for the cities/towns studied. This toolkit provides a financial model linking service levels to the price.

![Figure 2](http://dx.doi.org/10.2166/ws.2016.008)
of the water supply and wastewater collection and disposal, and provides a means of evaluating alternative service levels in an iterative consultation process like the approach proposed by Roche & Obeng (2014). For this purpose, an Excel spreadsheet was developed (Dynamic Economic tool to support investment decisions on water supply and sanitation – DECIS) which allows for the estimating of cash flow for each city/town project over a 25 year period and the simulation of various cost scenarios, due to the higher or lower investment funding rate needed, with the assumption that the rate to be applied to families could not exceed 4% of available household income (household effort rate (HER)).

From the point of view of the financial community, the investment in basic infrastructure for water supply and sanitation is a capital-intensive investment in long-term assets. If undertaken with economic rationality, the market will be available to finance the capital invested since the rates proposed are consistent with capital return and the economic capacity of the population to pay for the service provided.

Table 1 presents a summary of the feasibility analysis of projects at provincial level, for the 130 cities/towns with water supply and sanitation AIAS. In the baseline scenario it is assumed that 100% of the investment is sunk costs non-refundable (100% of investment funding rate) and the number of cities in each province is presented that needs an HER higher than the acceptable maximum (4%). In the project rebalancing scenario is presented the average weight percentage of sunk costs non-refundable needed in each province (investment funding rate) to have an economic sustainability in a scenario in which the payment for the service is 4% of HER.

For example, in the Niassa province, in the north of the country, there is a project in which, even with a 100% funding rate a tariff deficit in operating costs of about 0.1 M USD is obtained, which should be covered by subsidies, assuming
Table 1 | Financial viability at the provincial level for the cities/towns with AIAS water and sanitation

<table>
<thead>
<tr>
<th>Province</th>
<th>No. cities/towns with HER &gt;4%</th>
<th>Investment funding rate</th>
<th>No. underfunded projects*</th>
<th>HER</th>
<th>No. underfunded projects*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niassa</td>
<td>1</td>
<td>100%</td>
<td>5</td>
<td>4%</td>
<td>88%</td>
</tr>
<tr>
<td>D. Delgado</td>
<td>9</td>
<td>100%</td>
<td>2</td>
<td>4%</td>
<td>90%</td>
</tr>
<tr>
<td>Nampula</td>
<td>5</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>82%</td>
</tr>
<tr>
<td>Zambezia</td>
<td>6</td>
<td>100%</td>
<td>1</td>
<td>4%</td>
<td>81%</td>
</tr>
<tr>
<td>Tete</td>
<td>4</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>92%</td>
</tr>
<tr>
<td>Manica</td>
<td>2</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>80%</td>
</tr>
<tr>
<td>Sofala</td>
<td>2</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>78%</td>
</tr>
<tr>
<td>Inhambanje</td>
<td>7</td>
<td>100%</td>
<td>1</td>
<td>4%</td>
<td>84%</td>
</tr>
<tr>
<td>Gaza</td>
<td>6</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>85%</td>
</tr>
<tr>
<td>Maputo</td>
<td>2</td>
<td>100%</td>
<td>0</td>
<td>4%</td>
<td>68%</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100%</td>
<td>9</td>
<td>4%</td>
<td>85%</td>
</tr>
</tbody>
</table>

HER – household effort rate for the water and sanitation services (considering a household income of two average minimum wages).

*Cities/towns that have projects with negative net present value (NPV) assuming 100% funding rate of the necessary investments, meaning that subsidy is required for operation and maintenance costs.

Table 2 | Financial viability for the cities/towns with AIAS sanitation and FIPAG water supply

<table>
<thead>
<tr>
<th>City/town</th>
<th>HER</th>
<th>Investment funding rate</th>
<th>Project balance (USD)*</th>
<th>HER</th>
<th>Investment funding rate</th>
<th>Project balance (USD)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lichinga</td>
<td>3.9%</td>
<td>100%</td>
<td>20,114,750</td>
<td>4%</td>
<td>75%</td>
<td>0</td>
</tr>
<tr>
<td>Cuamba</td>
<td>3.5%</td>
<td>100%</td>
<td>–275,003</td>
<td>4%</td>
<td>92%</td>
<td>0</td>
</tr>
<tr>
<td>Pemba</td>
<td>5.1%</td>
<td>100%</td>
<td>24,233,473</td>
<td>4%</td>
<td>94%</td>
<td>0</td>
</tr>
<tr>
<td>Nampula</td>
<td>5.5%</td>
<td>100%</td>
<td>67,334,927</td>
<td>4%</td>
<td>91%</td>
<td>0</td>
</tr>
<tr>
<td>Nacala</td>
<td>4.7%</td>
<td>100%</td>
<td>18,662,972</td>
<td>4%</td>
<td>51%</td>
<td>0</td>
</tr>
<tr>
<td>Angoche</td>
<td>3.9%</td>
<td>100%</td>
<td>1,883,688</td>
<td>4%</td>
<td>100%</td>
<td>1,315,644</td>
</tr>
<tr>
<td>Quelimane</td>
<td>6.6%</td>
<td>100%</td>
<td>27,014,051</td>
<td>4%</td>
<td>85%</td>
<td>0</td>
</tr>
<tr>
<td>Tete</td>
<td>3.8%</td>
<td>100%</td>
<td>14,852,361</td>
<td>4%</td>
<td>78%</td>
<td>0</td>
</tr>
<tr>
<td>Moatize</td>
<td>3.4%</td>
<td>100%</td>
<td>976,499</td>
<td>4%</td>
<td>87%</td>
<td>0</td>
</tr>
<tr>
<td>Chimoio</td>
<td>3.9%</td>
<td>100%</td>
<td>25,372,924</td>
<td>4%</td>
<td>72%</td>
<td>0</td>
</tr>
<tr>
<td>Manica</td>
<td>3.2%</td>
<td>100%</td>
<td>733,175</td>
<td>4%</td>
<td>80%</td>
<td>0</td>
</tr>
<tr>
<td>Gondola</td>
<td>3.2%</td>
<td>100%</td>
<td>766,826</td>
<td>4%</td>
<td>80%</td>
<td>0</td>
</tr>
<tr>
<td>Inhambane</td>
<td>5.0%</td>
<td>100%</td>
<td>4,167,806</td>
<td>4%</td>
<td>95%</td>
<td>0</td>
</tr>
<tr>
<td>Maxixe</td>
<td>6.6%</td>
<td>100%</td>
<td>12,304,308</td>
<td>4%</td>
<td>97%</td>
<td>0</td>
</tr>
<tr>
<td>Xai</td>
<td>5.7%</td>
<td>100%</td>
<td>6,182,837</td>
<td>4%</td>
<td>100%</td>
<td>974,503</td>
</tr>
<tr>
<td>Chókwè</td>
<td>4.2%</td>
<td>100%</td>
<td>3,355,080</td>
<td>4%</td>
<td>90%</td>
<td>0</td>
</tr>
<tr>
<td>Beira/ Dondo</td>
<td>5.5%</td>
<td>100%</td>
<td>55,306,003</td>
<td>4%</td>
<td>78%</td>
<td>0</td>
</tr>
<tr>
<td>Maputo/ Boane</td>
<td>6.3%</td>
<td>100%</td>
<td>390,064,250</td>
<td>4%</td>
<td>83%</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100%</td>
<td>669,283,548</td>
<td>4%</td>
<td>85%</td>
<td>2,290,147</td>
</tr>
</tbody>
</table>

HER – household effort rate for the water and sanitation services (considering a household income of two average minimum wages).

*Projects with negative NPV assuming 100% funding rate of the necessary investments, meaning that subsidy is required for operation and maintenance costs.
that the rate to be applied to families does not exceed 4% of the available income.

Considering a household income of two average minimum wages, Table 2 shows the HER for water and sanitation services (assuming base rates) and a 100% contribution rate of the investment in grants (baseline scenario), and the funding rates required after rebalancing the project to a HER of 4% (scenario rebalancing the project), for the 21 cities/towns with an FIPAG water supply system and AIAS sanitation system. According to the results presented, there are two cities in which, even with a 100% contribution rate of the investment in grants, subsidization is still required to cope with the tariff deficit in operating expenses.

The feasibility of the projects analysis was also carried out using an alternative approach, by considering the average district household income, based on MAE (2005), in order to take into account the differences in the family income throughout the country. Figure 4 presents the results considering the two approaches.

Given the existing needs, the DECIS tool developed assumes several criteria for prioritizing investments, based on which different rankings can be established, including the investments per capita in each city and town, as presented in Figure 5.

When prioritizing interventions, the following aspects should be taken into account:

- Existing organizational structure for the water supply system and their investment dynamic, such as in the case of cities/towns with FIPAG water services. Where there is an entity strongly boosting water supply, there will be a greater need to cope with wastewater related risks and thus investment in improved sanitation solutions should be a priority.
- Investment profitability of the water and sanitation project in order to serve more people per USD invested; lower per capita investment cities/towns are priorities.
Sustainability of investment projects in order to give priority to projects where there is a greater ability to sustain the project with fewer donated funds.

Expected impact on the improvement of sanitary conditions, giving priority to interventions with a major positive impact in terms of public health.

These criteria and resulting rankings should be seen as data preliminary to decision support. The final result may arise from an analysis involving the stakeholders and should be dynamic in the face of contingencies during the Plan implementation.

**CONCLUSIONS**

The work developed here resulted in an action plan, aligned with the national strategy vision, including decision support tools to enable the stakeholders to make decisions on potential investments in every city and town, allowing for the evaluation of different scenarios in the evolution of levels of coverage and integrating additional data. Compared with other methods or approaches for decision support of investments in the water sector, the DECIS approach, due to its flexibility, seems especially appropriate to Mozambique and other developing countries, with a very dynamic changing environment in terms of urban expansion and economics, and where a great part of the water supply and sanitation infrastructure is yet to be built, financial resources are very limited and household incomes are very low.

As regards the implementation of the Plan the following immediate actions are recommended:

- Fieldwork providing a preliminary diagnosis of existing infrastructures, updating the BIAS.
- Maintaining a database of unit costs for the construction works.
Plan Monitoring and Updating at 2018 (of service and coverage levels and allocated investments).

The success of the Investment Plan depends on a strong connection between the AIAS and other stakeholders, giving special attention to complementary aspects, such as training and capacity building, hygiene and sanitary education, awareness, innovation and regulatory activities, and of course the ability to learn from the experience accumulated in the sector.

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