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Economic costs and investment challenges of water infrastructure in South Africa

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South Africa is facing significant water infrastructure investment challenges, at the levels of both water resources and services. Principles for water use pricing, charges, tariffs and use are enshrined in South African legislation, but implementation thereof is a major problem. This research paper addresses (*a*) economic costs, (*b*) efficiencies, (*c*) investment challenges and (*d*) the application and maximisation of economic tools. A total of 269 municipalities were sampled, and the research exemplified that South Africa was losing approximately US\$0.617–1.033 billion/annum to various inefficiencies: (*a*) water use underpricing was approximately US\$0.413 billion/annum. Water use charges and/or tariffs closer to cost-recovery levels would provide and ensure financial sustainability. (*b*) Return on capital investment inefficiencies contributed approximately US\$0.926 billion/annum. Revenue far lower than the asset value is illustrative of unsustainable revenue for investments. (*c*) Non-revenue water was 36.8% and approximately US\$0.402 billion/annum. Investments in water infrastructure maintenance projects will minimise distribution losses. (*d*) The multipliers were varied and substantially high – namely, 3–27. This illustrates the extent and seriousness of prioritising the implementation of water conservation and demand-management measures. (*e*) The capital investment gap was estimated at US\$2.258 billion/annum for the next 10 years (2019/2020–2029/2030). Under-capital investments have serious downstream implications for socio-economic development and growth.

Keywords: economics & finance/sustainability/water supply

Introduction

South Africa is facing significant water infrastructure value chain investment (funding and financing) challenges, at the levels of both the resource and provision of water services. Recent studies have estimated that capital investments of US\$55 billion are needed for water infrastructure and water demand in South Africa will exceed supply by 2025 without any supplement of the current water resources, for water security (DWA, 2013; DWAF, 2004; DWS, 2020; McKenzie *et al*., 2012; NT, 2011; Ruiters, 2020; UNEP and WRC, 2008; WB, 2010). Historical trends do not suggest much prospect of increasing allocations to water infrastructure, although South Africa has a public infrastructure investment envelope of US\$68.92 billion that visibly favours infrastructure investment over the current 3-year medium-term expenditure framework (MTEF) (NT, 2019a, 2019b). Furthermore, the sustainability, efficiency and reliability of the water infrastructure value chain is also at risk due to poor maintenance, operation of ill-equipped water infrastructure, underpricing of water use and deteriorating quality of sanitation services in many municipalities.

The value of water is about examining the management of water and the actual cost structure of water use (OECD, 2010a, 2010b; Ruiters, 2013, 2020; Ruiters and Matji, 2015, 2016, 2017; Sadoff *et al*., 2003). Thus, water as an economic good acknowledges that it is a valuable, increasingly scarce resource and that the economic consequences of its use should be understood and weighed, along with sustainability benefits, so that there is an understanding of all the implications of the chosen policy. The need for the ‘user pays’ principle, charging water users for the use of infrastructure, provides the benefit of enabling investments (funding and financing) to be raised, but it also leads to proper market-based pricing signals being employed, which also drives the more efficient utilisation of water infrastructure. Although the principles for water use pricing, charges and/or tariffs for water infrastructure and usage are enshrined and sound in South African legislation, the application and/or implementation thereof is a major problem (Amis *et al*., 2017; DWA, 2013; DWAF, 1997a, 2004, 2007; DWS, 2020; NT, 2011, 2013, 2019c; Republic of South Africa, 1997, 1998; Ruiters, 2013, 2020; Ruiters and Amadi-Echendu, 2019, 2020; Ruiters and Matji, 2015, 2016, 2017; Vawda *et al*., 2011). It helps to identify the social and environmental trade-offs (sustainability challenges) inherent in political decisions and provide objective language and framework within which opportunities can be explored.

The objectives of this research paper were to address the following: (*a*) economic costs, (*b*) efficiencies, (*c*) investment challenges (i.e. funding and financing) and (*d*) the application and maximisation of economic tools for water use (i.e. pricing, charges and tariffs) to generate more productive value than usage for the water infrastructure value chain in South Africa.

Water infrastructure economic costs, efficiencies and challenges: rationale, policy and/or theory

Economic efficiency

The economic efficiencies present in the water infrastructure value chain of South Africa are at both the strategic and operational levels – that is, water-management institutions, water use pricing, operations and maintenance, engineering, investments and so on (Figure 1). Thus, the economic efficiencies of water use pricing, charges and pricing analyses for water infrastructure investments exemplified and include

- the model and/or linkages for water-management institutions, engineering and financial investments needed to bring the water infrastructure development and management into operation (Figure 1)
- the model for the estimates of the investment (capital) and annual costs of project requirements (Figure 1); the potential of the project to satisfy the expected future demands for water and to do this most economically as measured by investment costs, annual costs and cost per unit of water supply (Figure 2)
- the investments, implementation and management of water infrastructure projects, particularly when direct foreign investments are involved – that is, capital financing cost and benefit–cost analysis for a project or a group of projects with multiple purposes (Figures 1 and 2)
- Project finance and management ecosystem for project capital investments, including the sources of funds and financing for each category (Figures 1 and 2)
- the required investments and costs recovery to enable operation to start and meet the cash flow requirements during the early years of operation – namely, (*a*) an effective concessionary agreement between one or more government jurisdictions and one or more commercial partners and (*b*) financial benefits to both water-management institutions and private interests (Figures 1 and 2).

Economic value, costs and pricing of water

The costs and values associated with water infrastructure development, management and supply are distinguished on three levels (Figure 2):

- full supply costs – financial expenditure required to use the resource; the traditional approach to analyse the costs associated with water provision

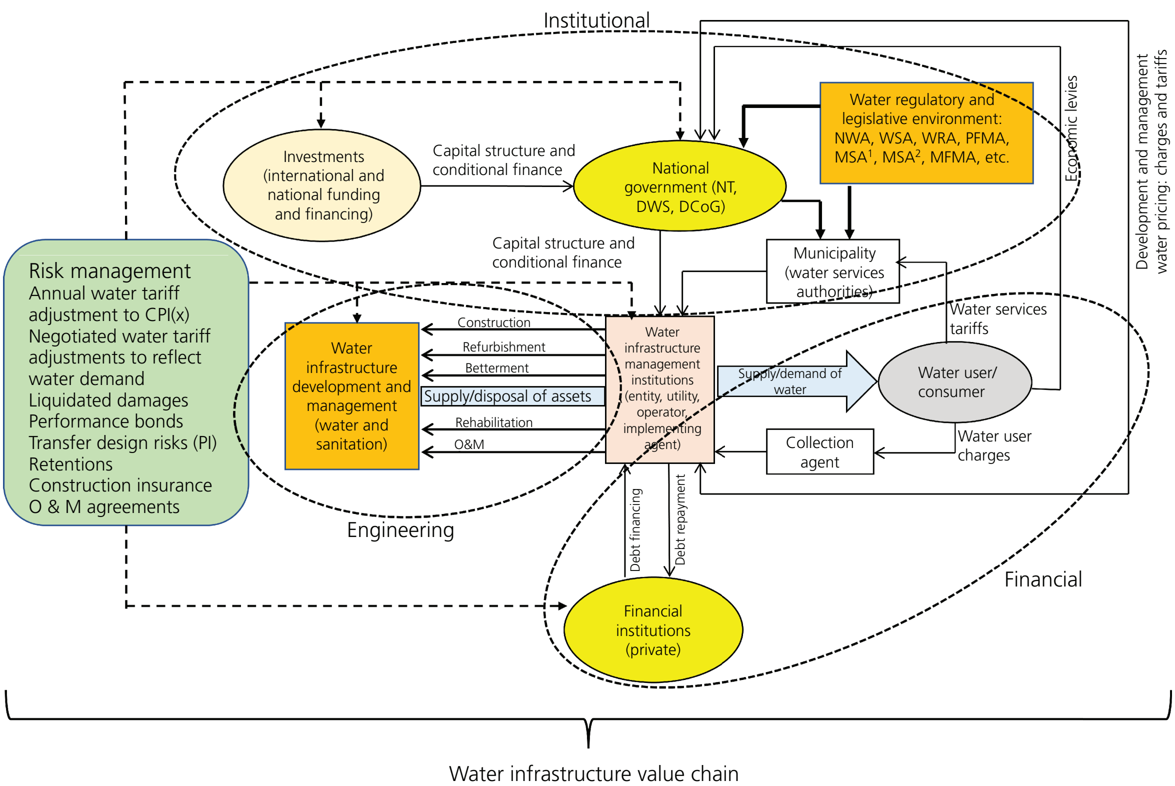


Figure 1. Water infrastructure value chain, engineering and financial interrelationships of water infrastructure development and management – that is, water resources and water services – in South Africa. CPI(x), consumer price index; DCoG, Department of Cooperative Governance; DWS, Department of Water and Sanitation; MFMA, Municipal Finance Management Act (NT, 2003); MSA[1], Municipal Structures Act (DPLG, 1998); MSA[2], Municipal Systems Act (DPLG, 2000); NT, National Treasury; NWA, National Water Act (Republic of South Africa, 1998); O&M, operations and maintenance; PFMA, Public Finance Management Act (NT, 1999); PI, professional indemnity; WRA, Water Research Act (DWA, 1971); WSA, Water Services Act (DWAF, 1997b)

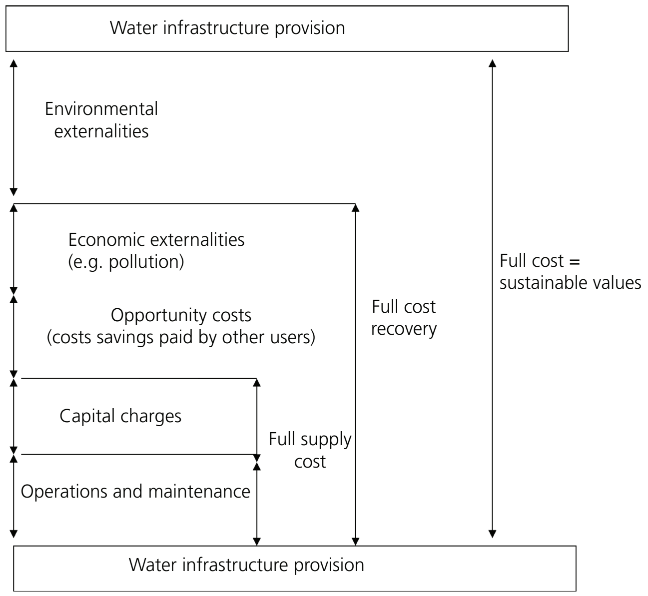


Figure 2. Cost-recovery components of the business for water infrastructure provision, management and supply services in South Africa

- full-cost recovery – use costs plus the opportunity costs and any externalities associated with a pattern of water use
- full costs – full use costs plus the non-use attached to water – that is, the environmental and social impacts and benefits of decisions on water management arising from the multifaceted nature of water as an economic, environmental and social resource.

The incorporation of the aforementioned costs was associated with economic efficiency, which was the utilisation of limited water and financial resources for the provision of water infrastructure and supply for water users, which could exceed the value of the resources themselves – that is, to provide products and services to maintain balance between means (resources) and ends (products) (Figure 3). The conventional economic view is that social welfare is maximised when all costs are reflected in prices – that is, 'full-cost pricing' and/or the 'polluter pays principle' (Figures 2 and 3) (DWAF, 2003, 2007; OECD, 2010a, 2010b; Ruiters and Matji, 2015, 2016, 2017). Only when production and consumption decisions consider all costs to society can appropriate balance between supply and demand be achieved based on pricing. When water use pricing, charges and/or tariffs are artificially low, as the case in South Africa, consumption tends to be excessive. While it is unlikely that water-management institutions will be able to cost fully all externalities into water use charges and/or tariffs, it is important to use pricing to encourage consumers to appreciate the true value of water and effect changes in their patterns of consumption (DWA, 2013; DWAF, 2004, 2007; DWS, 2020). Economically efficient and socially responsible water infrastructure value chain systems

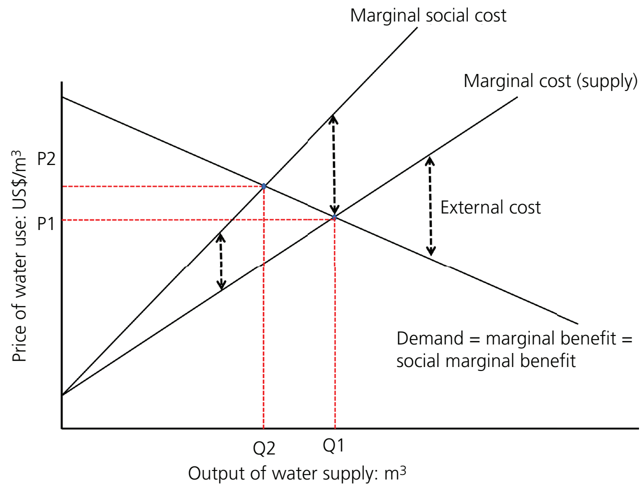


Figure 3. Allocative efficiency, costs (price/m^3) and benefits of production efficiency (output of water supply against costs and revenues) for the water infrastructure value chain in South Africa

also share the added pursuit of avoiding wastage (non-revenue water (NRW) and/or unaccounted for water) and unlawful use (theft) of water, which are prevalent in water-management areas (WMAs) and water use sectors in South Africa (DWA, 2012a; DWS, 2020; McKenzie *et al*., 2012; NT, 2011, 2019c; Stats SA, 2018, 2020). Although the water use pricing, charges and tariffs were deemed economically inefficient because of several factors – that is, the capping of water tariffs, efficient billing, revenue collection and so on – the goals for efficiency should match those of environmental sustainability, financial affordability and the reduction of wastage through the redistribution or reallocation of resources – namely, financial cross-subsidisation, water allocations, water use licences and so on.

Water infrastructure investment challenges

The medium- to long-term consequences and challenges of underinvestments and/or under-expenditure on operations (repairs) and maintenance include

- deteriorating reliability and quality of services
- move to more expensive crisis maintenance, rather than planned maintenance
- increasing the future cost of maintenance and refurbishment
- shortening the useful life of assets and necessitating earlier replacement – that is, high capital costs
- cost influence on charge calculations and models.

These challenges are further compounded by (*a*) many municipalities not managing their water infrastructure assets strategically, (*b*) many municipalities being unaware of what water infrastructure assets they possess, (*c*) many municipalities being unaware of the location of their assets, (*d*) the age and condition of water infrastructure assets and (*e*) investments needed to extend the useful life of these water infrastructure assets. Municipalities generally allocate approximately 5–12% of their annual operating budgets for rehabilitation and maintenance. The overriding principle is always to apply revenue to fund ongoing operational requirements, reduce debt (current and future) and thus minimise future finance costs.

Research methods

Research approach and strategy

This research study followed an inductive, quantitative and qualitative research approach. Thus, it sought to build deeper understanding of the underlying needs and requirements studied through an immersive study of economic costs, efficiencies and water infrastructure investment challenges. The research study did state objectives, data collection and analysis to see what patterns and relationships emerge to link the different variables together (cf. Gray, 2014).

Through problem analysis and theoretical consideration, the objectives were addressed by means of quantitative and qualitative methods – that is, (*a*) questionnaires and checklists, (*b*) interviews, (*c*) documentation review, (*d*) observations, (*e*) specialised focus and/or conference groups, (*f*) work groups and (*g*) case studies (cf. Coldwell and Herbst, 2004; Creswell, 2013). They all had unique designs, contribution and value that addressed the overall research objectives, importance and benefits of the research.

Thus, the quantitative and qualitative research involved two types of data collection methods – that is, primary and secondary data (Creswell, 2013; Tustin *et al*., 2005). An increasingly used method of quantitative and qualitative data collection in research is to carry out a survey of a sample of a population to observe the relationship between a given set of variables (Coldwell and Herbst, 2004; Creswell, 2013). Surveys are most often carried out using questionnaires, and the design of the questionnaire used for quantitative data collection covered the size and scale of the problem to be tackled by the survey (i.e. 'scoping') and the required information.

Data collection

Primary data

A questionnaire was forwarded to participants and stakeholders, including local municipalities and water utilities, requesting information regarding the water use (volume inputs or purchases and distribution losses), funding and financing (investments and expenditure), economic and/or financial indicators and tools and water tariffs (residential, commercial, industrial, mining etc.) for the past 10 years (2008/2009–2018/2019). Personal interviews, face to face, were also conducted with water-management institutions and local government (municipalities). A representative sample size of 269 municipalities was sampled as the study population of the research project. The specific tariff rates for local municipalities were adjusted to comply with predefined blocks – namely, 0–6 kl (m^3), 6–20 kl (m^3), 20–60 kl (m^3) and >60 kl (m^3). Stepped water use tariffs are set in South Africa based on defined blocks of water use.

The sample size included the following:

- a total of 425 individuals interviewed – that is, with national government departments, funding agencies, regulatory agencies and local government representatives
- specialised workshops, discussion focus and/or conference groups – that is, national and provincial workshops, economic and water infrastructure development colloquiums, water infrastructure investment conference groups and so on, consisting of an average of >50 individuals (financial and technical/engineering specialists)
- private business, consulting and construction
- respondent groups and provincial and national organisations
- multilateral funding agencies
- water institutions or regulatory agencies/institutions
- local governments or municipalities (local, district and metropolitan municipalities)
- technical assistance providers
- official development assistance agencies.

Secondary data

Previous or historical reports related to infrastructure needs and funding activities in other countries for the past 20 years were studied (cf. NT, 2019b). The data thus compiled illustrate the historical and current expenditures and revenue patterns of the Department of Water and Sanitation (DWS), the Department of Cooperative Governance, state agencies and utilities, metropolitan municipalities, municipalities (district and local) (NT,) and the private sector for water infrastructure (NT, 2018a, 2018b, 2018c, 2019a, 2019b, 2019c). Revenue streams, local debt, expenditure restrictions and other information related to funding water infrastructure were reviewed. The DWS and the Water Research Commission have undertaken numerous studies that are relevant to this research project, and these were considered.

Statistical analysis

For the quantitative data analysis, (*a*) nominal (categorical) and (*b*) ordinal (ranked) data (scales) types were considered and used, where appropriate (cf. Coldwell and Herbst, 2004; Tustin *et al*., 2005). The statistical analysis for the research topic included the completeness of the survey data and helped identify any information gaps or data inaccuracies. Qualitative data were translated to quantitative data by ranking.

Descriptive statistics were used to summarise data sets into simpler and understandable forms – that is, mean, median and standard error (SE). Inferential statistics were used to determine the level of uncertainty with which the findings should be treated. The non-parametric Spearman's rank correlation, r_s, was used as a significance test statistic to test H_0, the null hypothesis of no association existing between capital funding (total) and the key financial variables (i.e. capital expenditure (water), operational revenue and operational expenditure) employed over the indicated time period. Furthermore, the chi-square (χ^2) test statistic was used to test the null hypotheses (H_0) to determine through contingency tables (cf. Coldwell and Herbst, 2004; Creswell, 2013; Tustin *et al*., 2005) (*a*) whether an association exists between capital funding (total) and the key financial variables (i.e. capital expenditure (water), operational revenue and operational expenditure), (*b*) whether dependency (or contingency) exists between the financial multiplier effects and provinces and (*c*) whether dependency (or contingency) exists between the key financial variables (i.e. return on assets (ROA) (%), gearing ratio (debt/equity), current ratio, asset turnover ratio and weighted average cost of capital (WACC)) and water-management institutions.

For the statistical data transformation, a deterministic mathematical function was applied to each point in the data set so that the data appeared more closely to meet statistical inference assumptions – that is, a replacement that changes the shape of a distribution or relationship (Creswell, 2013; Gioia *et al*., 2012). The research data were $\log_{10}(x + 1)$ and arcsine $x^{1/2}$ transformed before application, where appropriate – that is, each data point z_j was replaced with the transformed value $y_j = f(z_j)$.

Results and discussion

The results address economic costs and efficiencies as alternative of the supply side of funding and financing as broad categories and then economic tools and the challenges of the demand side from water-management institution analysis of investments (funding and financing) for the water infrastructure value chain. Lastly, the results consider reconciliation between the supply and demand of investments for water infrastructure – that is, capital finance gap requirements.

Economic costs and efficiencies

Efficiency of water infrastructure value chain budget execution

Improving the efficiency of capital and operational budget execution could make a further US$0.206 billion/annum available for infrastructure spending each year (Figure 4). If the bottlenecks in capital execution could be resolved, South Africa could on average increase its capital spending by approximately 30% without any increase in current budget allocations. Spearman's rank correlations, r_s, indicate that strong associations exist between capital funding (total) and the key financial variables – that is, r_s = 0.877 for capital expenditure (water), r_s = 0841 for operational revenue and r_s = 0.718 for operational expenditure for the indicated time period (cf. Figure 4). In addition, the H_0 that the capital funding (total) and the financial variables are associated is accepted with $\chi^2 < 43.77$, $\alpha = 0.05$ and $n = 30$ since $\chi^2 = 0.022$ and $p > 0.5$ do not exceed the critical value of χ^2 (cf. Figure 4). Furthermore, water-management institutions allocated approximately US$0.340 billion/annum in water infrastructure expenditure to areas that appear surplus to the basic infrastructure requirements – for example, overemployment, unsustainable water infrastructure projects, policies with regard to overt subsidies for specific water users, free basic water and hidden subsidies – which suggests that public investments can be redirected towards areas of greater impact in the water infrastructure value chain (cf. Table 1 and Figure 4). Only approximately 79% of the capital budget allocated for water infrastructure was executed; approximately US$0.206 billion/annum in public investments was being lost.

Also, the budget formats for South African municipalities draw a clear distinction between operating and capital budgets (Figures 4

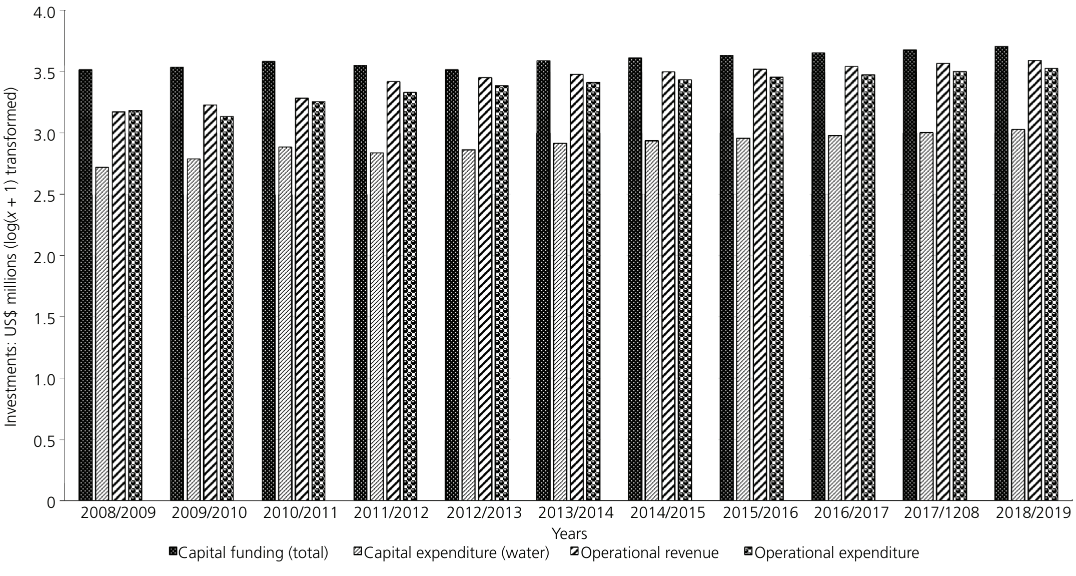


Figure 4. Capital funding, budgeted expenditure (capital and operational) and revenue of water infrastructure at the municipal level (local government) in South Africa

Table 1. Means (±standard deviation) of economic and/or financial indicators for the sampled period (2008/2009–2018/2019) of selected water-management institutions (utilities and entities) in South Africa

Economic parameter	Water-management institutions									
	Amatola Water	Bloem Water	Lepelle North Water	Magalies Water	Mhlathuze Water	Overberg Water	Rand Water	Sedibeng Water	Umgeni Water	DWS WTE
ROA: %	−1.37 ± 3.91	3.40 ± 5.69	6.81 ± 4.83	2.37 ± 1.01	7.35 ± 2.93	2.89 ± 3.92	8.10 ± 2.37	2.48 ± 1.34	11.35 ± 1.73	0.41 ± 2.48
Gearing ratio (debt/equity)	1.26 ± 1.05	0.53 ± 0.16	0.19 ± 0.11	0.73 ± 0.53	0.80 ± 0.46	0.09 ± 0.05	0.23 ± 0.08	0.60 ± 0.29	0.73 ± 0.46	0.33 ± 0.18
Current ratio	1.22 ± 0.26	2.56 ± 0.23	4.61 ± 1.85	3.85 ± 2.91	1.90 ± 0.57	2.49 ± 0.82	1.29 ± 0.34	1.54 ± 0.06	2.27 ± 0.61	1.42 ± 0.71
Asset turnover ratio	−0.69 ± 4.12	4.41 ± 4.89	44.11 ± 11.34	2.37 ± 1.61	7.36 ± 2.93	2.90 ± 3.92	1.50 ± 0.23	2.50 ± 1.59	10.67 ± 1.86	0.33 ± 2.54
WACC: %	14.44 ± 5.65	18.52 ± 2.18	24.49 ± 1.19	17.83 ± 6.24	16.40 ± 4.10	25.83 ± 1.20	10.93 ± 1.40	18.00 ± 2.93	17.06 ± 3.60	26.46 ± 0.38

DWS WTE, Department of Water and Sanitation Water Trading Entity; ROA, return on assets; WACC, weighted average cost of capital

and 5). The water service function is an important municipal function, which comprised 16–20% of the total municipal budgets. There has been constant growth in capital expenditure on water infrastructure and municipalities budgeted to spend US$0.650–1.011 billion for the time period 2019/2020–2021/2022 – that is, the current MTEF (NT, 2019a, 2019b, 2019c). The municipal infrastructure grant (MIG) was by far the largest capital investment for the water infrastructure value chain (NT, 2011, 2013, 2019a, 2019b, 2019c). It has grown strongly over the sampled time period and will continue to grow at approximately 13.5% per annum. However, underspending of capital budgets by approximately US $1.547 billion/annum by water-management institutions, particularly by municipalities, was because of the following: (*a*) weak capacity to budget reliably for water infrastructure expenditure, (*b*) inadequate or poor infrastructure planning, (*c*) inappropriate time horizons for project execution, (*d*) very poor condition of water infrastructure assets and (*e*) smaller rural municipalities having inadequate water infrastructure.

MIG contributed only approximately 28.3% to the capital budgets of metropolitan municipalities, which had been achieved by sufficient revenue (equity) through appropriate and affordable water use tariffs (cf. Figures 4 and 5) (NT, 2011, 2013, 2019a, 2019b, 2019c). However, the MIG contribution to the capital budgets for secondary cities was approximately 75.6% (SE = ±5.3%) for the sampled time period (Figure 5). Thus, these municipalities are MIG dependent with unsustainable water use pricing and tariffs resulting in inadequate cost recovery and revenue. The capital budgets in rural local and district municipalities constituted 100% of MIG.

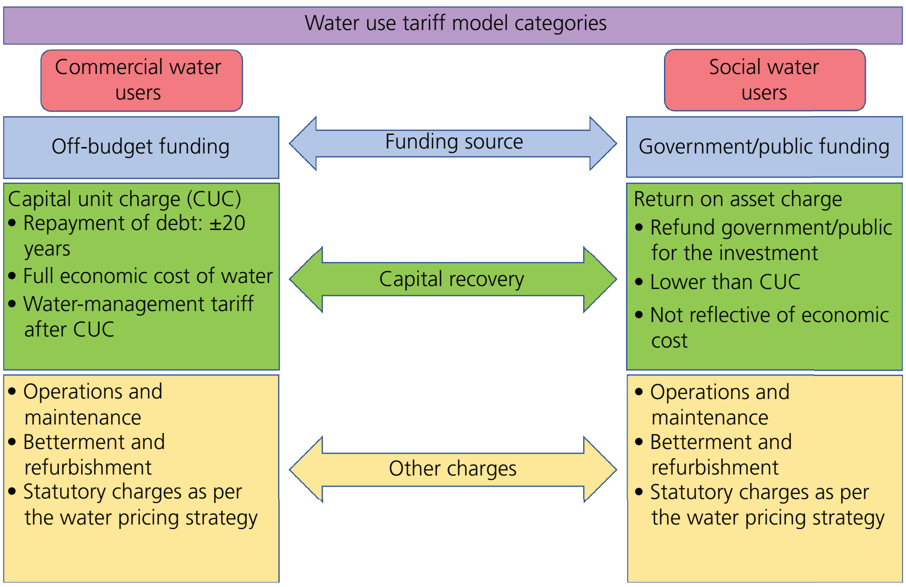


Figure 5. Water tariff model and categories for water infrastructure development and management in South Africa (cf. DWA, 2012a, 2012b, 2012c; DWAF, 2007; DWS, 2020)

Under-maintenance of the water infrastructure value chain

Addressing under-maintenance in the water sector value chain can save approximately US$0.196 billion/annum in rehabilitation, or spending US$1 on maintenance can be a saving of about US$4 to the economy (cf. Goodman and Hastak, 2006; Usace, 1995). On average, 30% of South African water infrastructure assets need rehabilitation and the state of rural water infrastructure is substantially worse than the rest, with 35% of assets in need of rehabilitation, compared with 25% elsewhere (DWA, 2013; DWS, 2020; NT, 2011, 2013, 2019a, 2019b, 2019c; Saice, 2017). Major differences in water infrastructure conditions exist across South Africa, and in the best scenarios >10% of water infrastructure assets need rehabilitation and in the worst-case scenarios >40%.

It is evident from the economic parameters that the investments do not provide for the gap to be closed fully over the coming approximately 10 years, specifically local government and water user associations (WUAs) (Tables 1 and 2). This remaining gap implies that rehabilitation will have to be pushed out into later years. The investment plan provides for a substantial turnaround in the condition of water and sanitation assets as well as provision for new water infrastructure required to remove backlogs in service delivery and provide water demand requirements. The investment plan provides for the maximum possible increase in debt finance raised on the capital market by all institutions. The national backlogs in water infrastructure investment requirements were estimated to be US$2.258 billion/annum, US$0.757 billion/annum for DWS water infrastructure and the remaining for water boards/utilities and local government for the next 10 years (2019/2020–2029/2030) – that is, new capital projects, rehabilitation, maintenance and so on (cf. Table 2) (DWS, 2020; NT, 2019c; Ruiters, 2020; Stats SA, 2018, 2020). The most serious misalignment in municipal budgets involved the underfunding of refurbishments, repairs, betterment and maintenance for the water infrastructure value chain. When water-management institutions, particularly municipalities, experienced any kind of financial stress, invariably the first category of expenditure to be cut was operations (repairs), maintenance and the capital expenditure programme. Thus, given the likelihood of insufficient capital finance (particularly fiscal resources) for the current water infrastructure project portfolio, there would have to be ongoing prioritisation of the capital projects to identify and sequence those projects that offer the best long-term economic returns or address the most critical security of supply concerns.

Distribution losses and NRW

Water-management institutions, particularly municipalities, incur substantial losses on their water distribution networks – that is, due to poor network maintenance, physical leakages, poor network management, illegal connections and various forms of water theft (Figure 6). The South African total water loss or NRW from the water infrastructure distribution and reticulation systems was approximately 1015 million m^3/annum, which is equivalent to approximately 36.8% of the approximately 3190 million m^3/annum of the total water infrastructure system volume input at a particular time (Table 3) (DWA, 2010, 2012a; DWS, 2020; McKenzie *et al*., 2012; NT, 2011, 2013, 2019c; Stats SA, 2020). Using differential production rates, it was possible to estimate the financial value of the NRW, from which it can be derived that the estimated value was on average approximately US$0.402 billion/annum (cf. Figure 6 and Table 3). Municipalities were encouraged to invest in water infrastructure maintenance projects that will minimise water losses, and any resultant loss in water income could be mitigated by reducing volumetric water use charges and/or tariffs and increasing fixed water use charges and/or tariffs.

Economic tools and challenges

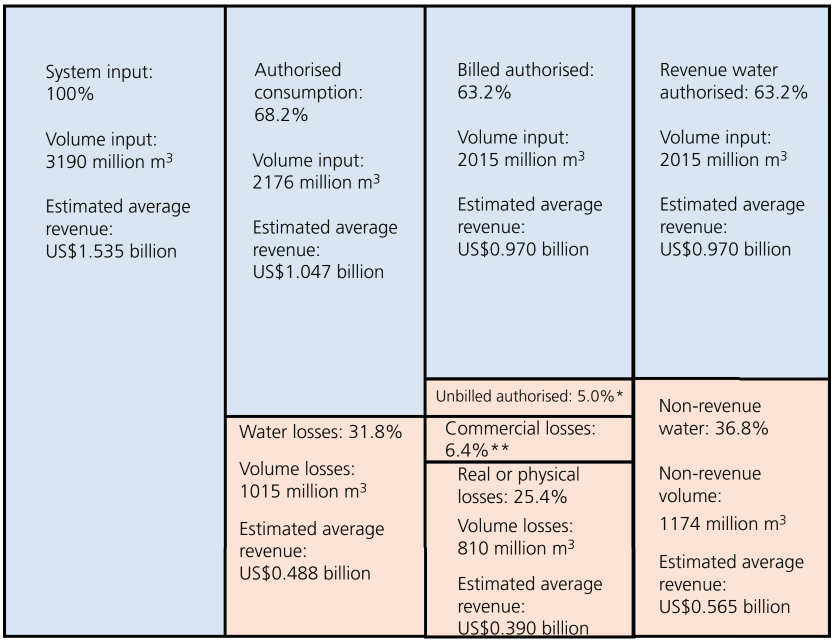
Water use charges, tariff models and multiplier effects

Figure 5 exemplifies the water use charges and/or tariff model for achieving the equitable and efficient allocation of water (economic charge) used in South Africa (Amis *et al*., 2017; DWA,

Table 2. Financial position and contributions by the key water sector role players in water infrastructure in South Africa in 2019

Water institution	Asset book value: US$ billions	Revenue: US$ billions/annum	Operating expenditure: US $ billions/annum	Capital expenditure: US$ billions/annum	Loans (current): US$ billions
Municipal water supply	22.680	2.707	5.600	0.933	0.467
Water boards	3.730	1.867	1.680	0.653	1.120
TCTA	4.387	1.120	0.933	1.028	3.267
DWS: WTE	8.960	0.933	0.840	0.373	2.613
DWS: water supply	—	—	0.187	0.933	—
Total water supply	**39.760**	**6.720**	**8.960**	**3.920**	**7.467**
Municipal sanitation	14.747	1.120	2.520	0.933	0.280
DWS and water Boards sanitation	—	—	0.093	0.280	—
Total sanitation	**14.747**	**1.120**	**2.613**	**1.213**	**0.280**
Total water sector	**54.507**	**7.840**	**11.573**	**5.133**	**7.747**

DWS, Department of Water and Sanitation; TCTA, Trans-Caledon Tunnel Authority; WTE, Water Trading Entity



*Unbilled authorised: 5.0%; volume unbilled authorised; 159.5 million m^3; estimated average revenue; US$76.810 million
**Commercial losses: 6.4%; volume commercial losses: 204 million m^3; estimated average revenue; US$98.237 mllion

Figure 6. National water balance for South Africa according to the International Water Association standards (cf. Lambert, 2003)

Table 3. Estimated value of NRW per municipal category (adopted from McKenzie *et al*. (2012) and National Treasury (NT, 2019c))

Municipal category	Production rate: US $/kl	Estimated cost to supply water: US$ million/annum	Estimated value of NRW: US$ million/annum
A	0.516	953.361	326.979
B1	0.464	317.238	131.126
B2	0.413	134.308	41.003
Urban total		**1404.908**	**499.108**
B3	0.361	83.241	30.760
B4	0.309	31.288	22.686
Rural total		**114.528**	**53.445**
National total		**1519.437**	**552.553**
Extrapolated total		**2044.538**	**743.510**

A, metropolitan municipalities; B1, secondary cities; B2, large towns (municipalities); B3, medium rural towns (municipalities); B4, small rural towns (municipalities)

2013; DWAF, 2003, 2004, 2007; DWS, 2020; Muller, 2018; NT, 2019c; Ruiters, 2013, 2020; Ruiters and Matji, 2015, 2016, 2017; Vawda *et al*., 2011). The administratively determined water use charges and/or tariffs are used in WMAs (catchments or basins) to provide an incentive for water users to increase economic efficiency. These opportunity costs of water as determined by prevailing trading transactions are capped to the level of ROA charge for the relevant water use from the government water scheme or system.

South African water-management institutions were losing approximately US$0.617–1.033 billion/annum to various inefficiencies in water infrastructure operations or expenditure (Amis *et al*., 2017; DWA, 2010; NT, 2011, 2013, 2019c; Ruiters and Matji, 2015, 2017; Stats SA, 2020). In addition, Figure 4 shows the underpricing of water infrastructure value chain, which accounted for approximately US$0.413 billion/annum in lost revenues. If appropriately tackled, these inefficiencies could expand the existing capital resource envelope by 40%, but increasing water use tariffs to unsustainable levels can result in water supply security challenges. In contrast, the raising of water use charges and/or tariffs closer to cost-recovery levels would provide more efficient price signals and help capture lost revenues. However, this is further compounded as a result of inappropriate structuring of water use tariffs and financing of operational services by municipalities (cf. Figures 3 and 5). Therefore, the water use tariff setting needs to ensure financial sustainability and to reflect costs reasonably associated with rendering the service. The use of the inclining block structured water use tariffs demonstrated cross-subsidies between differentiated water use tariff groups explicitly and promoted water conservation and demand management. Two-thirds of South African water-management institutions applied water use tariffs that comfortably cover operating costs, but only one-fifth of the water-management institutions set water use tariffs high enough to recover full capital costs (Figures 2, 3 and 5 and Table 1).

Achieving recovery of only operating costs across all South African water-management institutions would raise a revenue of US$4.125 billion/annum (DWS, 2020; NT, 2013, 2019c; Ruiters, 2013; Ruiters and Matji, 2015; Stats SA, 2020). Revising water use tariffs to make them equal to long-term marginal costs and thereby enabling all South African water-management institutions to recover capital costs would also increase the potential for efficiency gains to approximately US$7.217 billion/annum (cf. Tables 3 and 4 and Figures 2, 3 and 5) (DCoG, 2010; NT, 2013; Stats SA, 2012). However, there are arguments against full-cost recovery through water use pricing, which is not achievable in developing economies (OECD, 2010a, 2010b; Ruiters, 2013, 2020; Ruiters and Matji, 2015, 2016, 2017; WB, 1994, 2010, 2019).

Table 4 and Figure 7 show the multipliers in the water infrastructure value chain sector – that is, average water use tariffs – from raw water to bulk water to municipal retail. The multipliers were varied and substantially high with values between 3 and 27. In general, the multipliers for the 'raw water to municipal water' tariffs were exceptionally high – that is, >6 times. Indeed, high variability in the hydrological cycle, and the central role that water plays in socio-economic development and environmental sustainability, requires robust investment frameworks, planning, risk management and water use pricing to ensure water security and availability. Furthermore, the analysis illustrates the extent and seriousness of the water infrastructure distribution losses, associated water use pricing (charges and/or tariffs), multiplier effects and hence the importance of prioritising the implementation of water conservation and demand-management measures in the water infrastructure value chain of South Africa. In addition, the H_0 that whether dependency (or contingency) exists between the financial multiplier effects and provinces are accepted with $\chi^2 < 79.08$, $\alpha = 0.05$ and $n = 54$ since $\chi^2 = 7.014$ and $p > 0.5$ do not exceed the critical value of χ^2 (cf. Table 4).

Return on capital investment: revenue collection and management

Inefficiencies of various kinds and/or degrees resulting in a total revenue loss of approximately US$0.926 billion/annum are symptomatic of the water infrastructure value chain in South Africa as reflected in the asset value base to revenue, debt equity and current ratios (Tables 1 and 5). In addition, the H_0 that whether dependency (or contingency) exists between the key financial variables (i.e. ROA (%), gearing ratio (debt/equity), current ratio, asset turnover ratio and WACC) and water-management institutions is rejected with $\chi^2 > 55.76$, $\alpha = 0.05$ and $n = 36$ since $\chi^2 = 156.77$ and $p < 0.001$ do exceed the critical value of χ^2 (Table 1). The revenue was comparatively far lower, pro rata, than that for the asset value. This was illustrative of unsustainable revenue collection and management to fund and finance the refurbishment, repairs, maintenance, betterment and rehabilitation of water infrastructure assets and the development of new water infrastructure assets – that is, brownfield and greenfield projects.

The financial plans of water utilities (water boards) contributed to affordable water use charges and/or tariffs, maintaining of optimal debt levels and improved ROA by investing appropriately to enhance their shareholder value (Tables 3 and 5). Expenditure would increase over the medium term – that is, 3 years – at a mean annual rate of 12% – namely, US$0.846–1.186 billion – as result of the combined effect of adjustments for inflation, construction, upgrading and rehabilitation of the water infrastructure value chain. The water utilities made a consolidated net surplus of US$93.114 million for the sampled period (Tables 3 and 5). The impacts on this net surplus were mainly attributed to operational cost escalations in the following: (*a*) raw water cost increases of approximately 9.0%, (*b*) direct labour cost increases of approximately 17.8%, (*c*) chemical and purification cost increases of approximately 20.5% and (*d*) energy cost increases of approximately 34.4%. The revenue collected by water utilities

Table 4. Mean annual water use tariffs (US$/m^3, value-added tax inclusive) and multipliers for the water infrastructure value chain per province in South Africa

Province	Average WRM charges, domestic	Average raw water cost	Average water board tariff	Average municipal tariff (i.e. 20–60 kl)	Average of multiplier: raw to bulk water	Average of multiplier: bulk water to municipal tariffs	Average of multiplier: raw water to municipal tariffs
EC	0.002	0.088	0.488	0.754	5.57	1.54	8.61
FS	0.002	0.032	0.466	0.737	14.52	1.58	22.94
GT	0.002	0.110	0.371	0.674	3.35	1.82	6.11
KZN	0.001	0.034	0.325	0.647	9.63	1.99	19.18
LP	0.002	0.074	0.335	0.760	4.51	2.27	10.23
MP	0.002	0.004	0.366	0.917	10.66	2.51	26.74
NC	0.001	0.075	0.614	1.193	8.21	1.94	15.95
NW	0.002	0.062	0.396	0.752	6.41	1.90	12.17
WC	0.003	0.041	0.504	0.853	12.25	1.69	20.74
National average	0.002	0.076	0.410	0.797	5.39	1.94	10.48

EC, Eastern Cape; FS, Free State; GP, Gauteng; KZN, KwaZulu-Natal; LP, Limpopo; MP, Mpumalanga; NC, Northern Cape; NW, North West; WC, Western Cape; WRM, water resource management

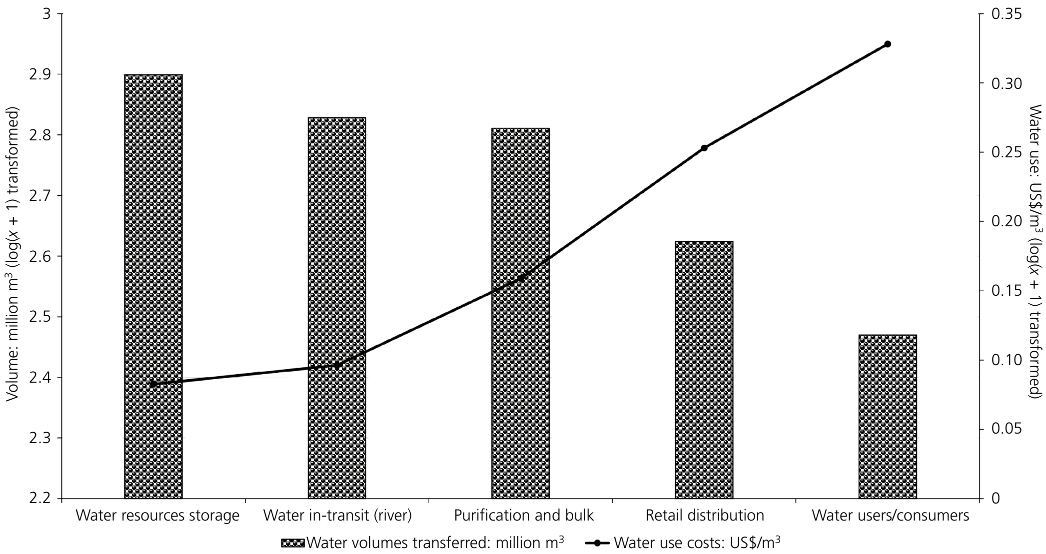


Figure 7. Water losses, inefficiencies and associated estimated water use pricing (log(x + 1) transformed) in a typical water infrastructure value chain in South Africa

Table 5. Summary of the capital finance gap requirements per water-management institution in the investment strategy for water infrastructure development and management in South Africa

Water infrastructure investment requirements	Local government: US$ billions	WUA/private – non-potable: US$ billions	Water boards: US$ billions	National entities: US$ billions	Totals: US$ billions
Capital requirement (per year over the coming 10 years)	4.821	0.731	0.824	2.510	8.872
Current capital available	2.563	0.292	0.399	1.089	4.369
Current gap	2.258	0.438	0.425	1.421	4.502
Proposed interventions (brought in over 5 years)					
Increase in debt finance by national entities				0.664	0.664
Increase in DWA budget				0.757	0.757
Increased own source funding from water boards			0.199		0.199
RBIG grant funding to water boards			0.226		0.226
Increased funding for non-potable distribution systems		0.133			0.133
New funding allocation for local WR infrastructure	0.146				0.146
RBIG funding for regional infrastructure owned by LG	0.173				0.173
Increased ‘own source’ funding from LG	0.239				0.239
Private sector financing through BOT-type contracts	0.266				0.266
Funding of local infrastructure by water boards	0.067				0.067
Increase in MG funding (WS portion)	0.996				0.996
Total increase in funding	**1.886**	**0.133**	**0.425**	**1.421**	**3.865**
Remaining gap	**0.372**	**0.306**	**0.0**		**0.638**

BOT, build–operate–transfer; DWA, Department of Water Affairs; LG, local government; MIG, municipal infrastructure grant; RBIG, regional bulk infrastructure grant; WR, water resources; WS, water services came from the sale of bulk water to municipalities (water service authorities) in their areas of operation (Tables 3 and 5 and Figure 4). Revenue reached US$1.279 billion at a mean annual rate increase of approximately 10.8%. However, for water utilities (water boards), revenue from the consolidated sale of bulk water increased at a mean annual rate of approximately 9.10%, and this increase over the MTEF (3 years) period was mainly due to new approved water use charges and/or tariffs in terms of the water-pricing strategy (DWAF, 2007). They supplied approximately 2.39 billion m^3/annum to approximately 28 million domestic, large commercial and industrial water users. However, water utilities do face many challenges: (*a*) difficulty of concluding long-term bulk water supply agreements with municipalities, (*b*) inability to make long-term infrastructure capital projections, (*c*) municipalities defaulting on payments, (*d*) 'ring fencing' of water services and (*e*) threats to their financial viability and sustainability.

Besides, the results indicated that municipalities' return of capital (revenues) from water use tariffs grew significantly over the research period – that is, approximately 18.6%/annum – and constituted approximately 28% of municipal revenue, and these cross-subsidised other services (Figure 4). In contrast, revenue instability was the most frequently cited obstacle to the adoption of water conservation and demand-management projects, resulting in lower water volumes being sold. However, one way of mitigating this loss of revenue was to shift some charges from a volumetric basis to fixed water use charges and/or tariffs. Free basic water was regarded as revenue water charged at zero rate and was therefore not be included in revenue collection and management. Furthermore, the rapid increases in operational costs have squeezed revenue surpluses and highlighted the need for stricter application of norms and standards relating to surcharges on these municipal services, so that this 'surplus share' that municipalities rely on to subsidise other services could be made transparent and should be protected.

However, the results demonstrated that the total asset book value of water infrastructure was US$54.51 billion, with a total water infrastructure asset replacement value of US$125 billion, only generating 7.84 billion/annum revenue (cf. Tables 1 and 5). The current operating expenditure of US$11.573 billion for the water infrastructure value chain exceeded revenue generation, and loans of US$7.653 billion made up for the shortfall in revenue. This is unsustainable and/or higher grants/subsidies would be needed. Capital expenditure was US$5.133 billion/annum, which translated into under-capital investment in the water infrastructure value chain with serious downstream implications for socio-economic development and growth. These demonstrate the high inefficiencies in the water infrastructure value chain and resultant significant funding gap for water infrastructure capital investments for development and operations and maintenance. The funding gap calls for considering taking more time to attain targets or using lower-cost technologies. Historical trends do not suggest much prospect of increasing allocations from the National Revenue Fund (National Treasury) to water infrastructure, although South Africa has a public infrastructure investment budget (envelope) of US$72.042 billion that visibly favours infrastructure investment of the next MTEF (NT, 2018c, 2019a, 2019b). External finance has not been readily available in recent years after the financial crisis in 2008/2009, South Africa's recent credit downgrades to sub-investment levels and the current Covid-19 economic crisis, and disbursements would likely continue to decline as already committed projects move to the implementation stage. By delaying investment schedules and assuming that efficiency gains are fully utilised, South Africa could not attain the infrastructure targets without increasing its spending envelopes. Targeting a high level of service might not always work in the best interest of the country. Thus, lower-cost technologies can permit broadening the portion of the unserved population with access to some level of basic services for water and sanitation (Amis *et al*., 2017; CSIR, 2007; DWS, 2018a, 2018b, 2018c, 2019).

Conclusions

The results indicate that several reforms and measures are needed in each of the five categories of potential inefficiencies that have been identified and scenarios that could lead to better or improved efficiency in the water infrastructure value chain of South Africa – namely, budget execution, under-maintenance and capital investment challenges, distribution losses and NRW, water use tariff models and affordability and revenue collection and management. These inefficiencies and economic costs are not uniquely South African for water infrastructure investments and operations but an international phenomenon; however, these are more acute in developing economies/countries. In this context, the present opportunities for efficiency gains can be of relevance to sub-Saharan Africa countries, and developing countries/economies in general, which try to develop and manage their water resources for economic development by addressing (*a*) underdevelopment of water infrastructure presenting significant social, economic and political risks; (*b*) variability and unpredictability in hydroclimatic conditions encouraging risk-averse behaviour at all levels of the economy; and (*c*) unreliable water supply, which is also a significant disincentive for investments. In addition, the results exemplified the urgent need to address factors such as demand elasticity, value added of water provision, supply-management scenarios and forecasts, alternative water (provision) delivery modes and robustness on downside water demand – that is, the differentiated 'water mix' for South Africa. However, international benchmarking, trends and comparisons of South African and international financing suggest that South African water infrastructure capital financing is sophisticated by developing or emerging economic norms and standards. The results demonstrated that no mechanisms were found in the international literature that could have made a major difference in the South African capital investment context. Therefore, addressing only the supply side of (water) infrastructure capital financing will not increase investments, but greater attention should be on the demand side, where potential borrowers have the necessary technical and investment (funding and financing) management capacity to plan, finance and execute 'bankable' projects.

Water infrastructure backlogs and economic inefficiencies in the water infrastructure value chain were variable across the country – that is, between and within provinces and water-management institutions. On average, water-management institutions should fully operate revenue collection and management systems, which is a rather significant assumption to meet operations and maintenance requirements. International benchmarking has indicated that Organisation for Economic Co-operation and Development (OECD) and non-OECD countries, such as South Africa, use fixed water use tariffs in conjunction with volumetric components that combine fixed and variable parameters (elements) and/or progressive increase in the weight of fixed water use tariffs. These are normally dependent on the cost of the water supply services or operations and differentiated policy choices. Ultimately, these have led to underpricing and/or low water use tariffs, particularly in non-OECD and developing countries/economies. Thus, it is unlikely that water use charges and/or tariffs will fully reflect the 'full-cost' approach, which would favour the financial sustainability and viability of water-management institutions. However, there were no appropriate 'directionally correct' water use pricing structures designed to encourage water demand management and conservation– namely very high distribution losses and NRW. Thus, water use pricing, charges and tariffs could play a greater role in meeting the capital investments for the water infrastructure value chain in South Africa – that is, return on capital investments – and these imperatives are now greater than ever.

The provision of investments (funding and finance) is an essential ingredient of the overall strategy for the sustainability of the water infrastructure value chain. However, safeguards are required or needed to avoid investments in poorly structured projects and if it is not forth coming several risks, liabilities and challenges could flow forth. The investments available should be used to augment and facilitate in the most economic development, rehabilitation and refurbishment which have the highest economic benefit first and then used for future investment. If the total capacity to obtain finance would not be available, there would be the risk that the water infrastructure value chain could continue to deteriorate from its existing poor condition with consequences of failure of water supply services as well as water quality. However, if water use charges and/or tariffs are not tapered rapidly to a reasonable economic level with explicit subsidies and water pricing as inherent ingredients, water infrastructure investments may continue to decline and stagnate with serious consequences not only to the health but also to the population livelihoods whether they be agricultural, industrial or others.

Finally, closing South Africa's funding gap inevitably requires undertaking of needed reforms and analysis to reduce or eliminate the inefficiencies in the water infrastructure value chain. Only then can the water infrastructure sector become more attractive to a broader array of investors and the country benefit fully from additional investments.

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