THE STATE OF WATER PROVISION EFFICIENCY

Report to the

Water Research Commission

by

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Executive Summary

The EFFICIENCY benchmarking initiatives in the South African water sector are significant and commendable. However, there is a need to develop one comprehensive benchmarking framework that makes use of robust econometric/statistical techniques, to allow valid interpretation of performance as opposed to descriptive analysis. The current benchmarking frameworks have some key performance area (KPA) and key performance indicator (KPI) duplication which may increase the burden on water utilities – the water service authorities (WSA) and water service providers (WSP). It is essential to develop a single, comprehensive and uniform framework (which makes use of the same KPAs and KPIs) that enables performance analysis and comparison of South African WSAs, as well as allowing for international comparison with similar water utilities.

All benchmarking frameworks consist of a set of KPAs and the related KPIs, selected based on a regulatory body's goals. KPAs are areas of performance explicitly or implicitly reflected in the vision of an organisation. In the case of a country, KPAs reflect the goal envisioned for a sector. KPIs are quantifiable measurements that reflect the efficiency of an organisation in each KPA. Each KPA has a KPI or set of KPIs that differ depending on the vision, mission and goals of the organisation being evaluated.

This report presents a systematic application of efficiency analysis carried out on the South African water sector to assess the relative efficiency of WSAs. The technique assigns efficiency ratings ($E \sim 1$), to all WSAs being evaluated, that are conditional on the dataset under study. That is, the assessment of a WSA as relatively inefficient implies the existence in the dataset of WSAs (or combinations of WSAs) displaying greater efficiency. Similarly, the assessment of a WSA as relatively efficient implies that the dataset does not contain any WSA (or combinations of WSAs) performing more efficiently. Consequently, in the case of relative inefficiency it can be shown that the performance of the WSA in question can be improved, whereas relative efficiency does not preclude the existence of more efficient WSAs outside the selected dataset.

Based on existing literature, analysis of existing international and local benchmarking initiatives and the mandate of the Department of Water and Sanitation (DWS), THE STUDY

proposes the following KPAs for benchmarking the efficiency of water service provision: *asset maintenance; operational efficiency; service quality; access to and affordability of water services; financial sustainability*; and *water quality*. The study also proposes the following KPIs: asset maintenance – *apparent losses* and *real losses*; operational efficiency – *labour per connection, labour per population served, labour costs* and *vacant employee posts*; service quality – w*ater availability, water pressure* and *response time of complaints*; access and affordability of water services – *water coverage, cost of new connection, waiting time for new connection, households served by pipe connections, households per connection* and *average tariff cost*; financial sustainability – *cost recovery, collection period, metered water sold, bad debts, average revenue, average operating cost* and *level of capital expenditure*; and water quality – *water quality compliance*.

This study was based on a panel dataset, from 2010 to 2017, consisting of 147 WSAs. Considering that the model adopted for this study was primarily an input-output model, the key variables in the dataset were input and output variables, which are proxies for KPAs and KPIs. Operating cost, number of employees and network length are the inputs used in this study. Water quality (%) is selected as an output variable, together with the total volume of water distributed (kl/year). Three explanatory variables are evaluated: non-revenue water (kl), customer density and location (urban or rural).

Missing data resulted in obtaining efficiency scores for only 77 WSAs for the years 2009-2012 and 2014. The study used the Data Envelopment Analysis (DEA) double bootstrap model with a truncated regression to compute the efficiency scores for South African WSAs. This model allows for the estimation of bias-corrected efficiency scores and the identification of the drivers of efficiency. The results are:

Table of scores

Top 5 most efficient urban WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
CPT	City of Cape Town	2010	1.01	2
TSH	City of Tshwane	2010	1.01	3
WC024	Stellenbosch	2010	1.02	4
EKU	City of Ekurhuleni	2010	1.02	5
JHB	City of Johannesburg	2010	1.02	9
TSH	City of Tshwane	2011	1.01	1
EKU	City of Ekurhuleni	2011	1.02	14
CPT	City of Cape Town	2011	1.02	15
MP313	Steve Tshwete	2011	1.02	20
JHB	City of Johannesburg	2011	1.02	25
WC043	Mossel Bay	2012	1.02	7
EKU	City of Ekurhuleni	2012	1.02	8
WC032	Overstrand	2012	1.02	10
WC024	Stellenbosch	2012	1.02	11
WC023	Drakenstein	2012	1.02	13
CPT	City of Cape Town	2014	1.02	6
JHB	City of Johannesburg	2014	1.02	12
EKU	City of Ekurhuleni	2014	1.02	24
FS192	Dihlabeng	2014	1.03	37
TSH	City of Tshwane	2014	1.03	38

Top 5 most efficient rural WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
NC061	Richtersveld	2010	1.01	2
FS196	Mantsopa	2010	1.02	4
NC077	Siyathemba	2010	1.02	5
NC067	Khâi-Ma	2010	1.03	12
NC453	Gamagara	2010	1.04	18
NC077	Siyathemba	2011	1.02	3
NC067	Khâi-Ma	2011	1.03	10
FS205	Mafube	2011	1.03	14
NC453	Gamagara	2011	1.03	15
FS191	Setsoto	2011	1.04	21
NC066	Karoo Hoogland	2012	1.01	1
NC077	Siyathemba	2012	1.02	7
FS183	Tswelopele	2012	1.02	9
NC061	Richtersveld	2012	1.03	11
FS196	Mantsopa	2012	1.03	13
NC077	Siyathemba	2014	1.02	6
FS191	Setsoto	2014	1.03	8
FS196	Mantsopa	2014	1.03	16
LIM362	Lephalale	2014	1.04	17
NC453	Gamagara	2014	1.04	19

Top 5 least efficient urban WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
GT484	Merafong City	2010	1.11	137
WC043	Mossel Bay	2010	1.11	135
NW373	Rustenburg	2010	1.10	132
GT485	Rand West City	2010	1.10	131
KZN225	Msunduzi	2010	1.10	126
GT484	Merafong City	2011	1.11	138
GT485	Rand West City	2011	1.11	134
NW373	Rustenburg	2011	1.10	122
KZN282	uMhlathuze	2011	1.10	119
KZN252	Newcastle	2011	1.10	116
GT484	Merafong City	2012	1.11	136
NW373	Rustenburg	2012	1.10	130
GT485	Rand West City	2012	1.10	128
LIM354	Polokwane	2012	1.10	121
GT422	Midvaal	2012	1.10	111
GT484	Merafong City	2014	1.13	140
GT485	Rand West City	2014	1.12	139
NW373	Rustenburg	2014	1.10	133
WC043	Mossel Bay	2014	1.10	129
WC044	George	2014	1.10	127

5 least efficient rural WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
DC12	Amathole District Municipality	2010	1.34	167
FS162	Kopanong	2010	1.31	163
NC062	Nama Khoi	2010	1.25	159
WC034	Swellendam	2010	1.22	153
WC033	Cape Agulhas	2010	1.22	146
DC12	Amathole District Municipality	2011	1.34	166
FS162	Kopanong	2011	1.31	164
NC062	Nama Khoi	2011	1.26	161
DC14	Joe Gqabi District Municipality	2011	1.22	151
FS161	Letsemeng	2011	1.22	150
FS162	Kopanong	2012	1.38	168
DC29	iLembe District Municipality	2012	1.24	157
FS161	Letsemeng	2012	1.23	156
NC062	Nama Khoi	2012	1.22	155
EC109	Kou-Kamma	2012	1.22	148
FS162	Kopanong	2014	1.32	165
NC062	Nama Khoi	2014	1.29	162
FS161	Letsemeng	2014	1.26	160
DC29	iLembe District Municipality	2014	1.25	158
EC105	Ndlambe	2014	1.22	154

These efficiency scores highlight some important findings for the urban and rural water sectors of South Africa:

1. Of the urban WSAs, four out of the eight metropolitan WSAs are among the most efficient and none of the eight are among the least efficient WSAs in any of the years under review. This may potentially indicate economies of scale in the urban sector.
2. However, the rural efficiency scores are indicative of a possible different conclusion. The district WSAs are not among the most efficient WSAs for any of the years under review, but three district WSAs are among the least efficiently performing WSAs. This may indicate the absence of economies of scale in the rural water sector.
3. The determinants of efficiency differ between urban and rural water sectors.

Impact of water investment and provision on economic growth

The results of this component of the study show that water investment and provision are fundamentals – basics that can be employed as a growth engine in the economy.

These findings are highlighted by the results presented in the table below:

Impact of water investment and provision on economic growth

GVA	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
Expenditure	(6.23e-07)	(1.27e-07)	4.91	(0.000)	3.66e-07	8.81e-07
Water quality	(1.706)	(0.327)	5.2	(0.000)	0.492	0.833
Water distributed	(0.0002)	(0.00007)	3.25	(0.002)	0.00009	0.0004
Consuming units	(0.082)	(0.033)	2.49	(0.018)	0.015	0.149
Water operating expenditure	(6.44e-06)	(6.95e-07)	9.27	(0.000)	5.03e-06	7.85e-06
Constant	(6743.024)	(6274.885)	1.07	(0.290)	-5971.1	19457.15
Overall R^2	(0.989)					
Sigma_u	(17459.492)					
Sigma_e	(2515.587)					
Rho	(0.98)	(fraction of variance due to u_i)				

These results show that total investment (measured by total expenditure) made by a municipality has a positive and significant contribution to economic growth. An increase in expenditure of R1 million will result in an additional increase in Gross Value Added (GVA) of R0.623 million. And investing R1 million in water supply has the potential to increase GVA by R6.4 million. These results are comparable to those of several similar studies in the 2016 UNESCO report that also find a correlation between water-related investment and economic growth – such that it was found that investment in small-scale projects in Africa providing access to safe water and basic sanitation could offer an estimated economic return of about US$28.4 billion a year, or nearly 5% of the Gross Domestic Product (GDP) of the continent.

Impact of water supply efficiency on economic growth

GVA	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
Population	(0.194)	(0.012)	16.09	(0.000)	0.17	0.219
Expenditure	(6.42e-07)	(1.24e-07)	5.17	(0.000)	3.91e-07	8.94e-07
Efficiency	(81.364)	(9.886)	8.23	(0.000)	9.665	20.81
Constant	(-89102.79)	(10345.5)	-8.61	(0.000)	-110028.5	-68177.04
Overall R^2	(0.9854)					
Sigma_u	(156099.39)					
Sigma_e	(2475.098)					
Rho	(0.99974865)	(fraction of variance due to u_i)				

Water efficiency was found to be positive and a driver of municipality GVA, with an increase of 0.1 in water efficiency score[1] leading to an increase of R81 million in GVA. This could be because an increase in efficiency translates to increases in several indicators, such as more revenue collection, more water distribution and therefore more jobs being created.

The general consensus is that capital investment in the water sector promotes economic growth. Water security is low in South Africa; therefore, it is plausible that investment and the subsequent enhanced water supply efficiency and productivity in water-related assets will enhance economic growth. Without such investment, continued inefficiencies in the sector will exert drag on economic growth and may create a low-level equilibrium. The efficiency of water provision and management has featured in policy orientation in most economics and development agendas. The empirical results in this study have found evidence to support efficiency of water provision and management for economic growth.

[1] Efficiency score ranges between 0 and 1.

Impact of water supply efficiency on employment

Employment	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
GVA	(6.725)	(0.653)	10.29	(0.000)	0.301	0.444
Expenditure	(9.09e-03)	(8.56e-04)	7.78	(0.000)	9.71e-04	1.81e-03
Population	(2.301)	(0.072)	31.26	(0.000)	0.215	0.245
Efficiency	(0.681)	(1.735)	3.9	(0.069)	-2.833	4.194
Constant	(63805.49)	(3641.05)	17.52	(0.000)	56434.57	71176.41
Overall R^2	(0.986)					
Sigma_u	(144688.99)					
Sigma_e	(545.698)					
Rho	(0.99999)	(fraction of variance due to u_i)				

These results show that an increase in GVA of R1 million will increase employment by seven jobs. A water efficiency improvement of 10 per cent will create six employment opportunities. Investing in water quality, water distribution and efficiency of water provision will have a statistically significant impact on creating jobs in South Africa. The impact on employment could be more if the informal sector was considered. In conclusion, other findings imply strong ties between water provision efficiency and economic growth.

Main findings

1. Over the past years there has been increasing interest in the efficiency and impact of water supply in the economy.
2. In part this interest has manifested itself in the increased use of numerous econometric/statistical techniques to determine the efficiency of the water sector.
3. From a methodological point of view, it can be argued that appropriate efficiency analysis helps to better estimate unbiased efficiencies, and in determining the different factors that can affect the efficiency of water utilities.
4. First of all, there are economies of scale in the water sector; but there is also evidence that at some point, these diminish.
5. Typically, larger WSAs reach the highest level of efficiency; but when inefficiency of utilities enters the analysis, geographical location has a stronger significant effect on efficiency.

6. Both geographical characteristics and economies of scale seem to be important aspects to take into consideration, particularly when evaluating them simultaneously.
7. The results show a negative and significant impact of non-revenue water and proportion of connected meters on water-supply efficiency of urban WSAs.
8. Population density has no significant impact on the efficiency of water supply in urban WSAs.
9. By contrast, population density matters in rural WSAs – it is positive and significant.
10. Moreover, in rural water utilities the proportion of connected meters is also positive and significant, while non-revenue water does not have any impact.
11. WSAs provide important building blocks for economic development, with both direct and indirect impacts on economic growth and job creation.
12. As water becomes scarcer, the associated economic rents will claim an ever larger proportion of GDP and employment, and this could strain economic performance.

Recommendations

1. Any benchmarking initiatives should account for the geographic location of the water utility.
2. As geographic location affects the efficiency and productivity of a water utility, policymakers should rethink their funding models.
3. Smaller WSAs may benefit from merging, since larger water utilities are more efficient.
4. It is possible that corporatisation of WSA operations could bring about many of the performance gains that come with privatisation.
5. Non-revenue water has a negative impact on efficiency; this should promote discussion as to which legal framework would foster the improvement and modernisation of existing ageing infrastructure.
6. The water sector is one in which monopoly conditions are common; therefore improvements in performance can only be brought about with economic regulation.
7. There is a need for regulatory incentives as a way to promote performance improvement.
8. The potential for worsening water scarcity could constrain economic growth and employment; thus there is a need for substitution, and this can only be accelerated by introducing economic incentives for conservation.
9. Improved water efficiency has the potential to alleviate the worst effects of water scarcity.

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Abbreviations

CRS	Constant returns to scale
CSD	Commission of Sustainable Development
DEA	Data Envelopment Analysis
DMU	Decision-Making Unit
DWS	Department of Water and Sanitation
EBC	European Benchmarking Co-Operative
GVA	Gross Value Added
IBNET	International Benchmarking Network for Water and Sanitation Utilities
IMESA	Institution of Municipal Engineering of Southern Africa
KPAs	Key Performance Areas
KPIs	Key Performance Indicators
MAINS	Length of water mains
MBI	Municipal Benchmark Initiative
MDG	Millennium Development Goal
NGP	New Growth Path
NWRS	National Water Resource Strategy
RDP	Reconstruction and Development Programme
SALGA	South African Local Government Association
SFA	Stochastic Frontier Analysis
SIWI	Stockholm International Water Institute
VRS	Variable Returns to Scale
WRC	Water Research Commission
WSAs	Water Service Authorities
WSPs	Water Service Providers

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Chapter 1: Rationale

1.1. Background

Availability of water is a crucial factor in human well-being – both the level of it, and the distribution. Water resources are finite; and in some parts of the world, such as sub-Saharan Africa, water is becoming increasingly scarce. This scarcity, combined with the many competing uses for water, creates complex choices for how water resources should be allocated. According to Opschoor (2006), views on the supply of water to users fall into two opposing categories: (a) water as a purely private economic good, best provided through markets; and (b) water as a public good, the access to which is to be guaranteed as a human right.

Pure public goods have two defining features, namely 'non-rivalry' and 'non-excludability'. The former means that one individual's consumption of water does not diminish the ability of other people to consume water. The latter implies that people cannot be prevented from consuming the good. In a market economy, the allocation of scarce natural resources is normally determined by trade in markets. However, water resources have several unique characteristics which suggest that the traditional market mechanism can lead to inefficient and inequitable allocation. This leads to the fundamental question of whether water should be considered a public or a private good.

Access to safe drinking water and sanitation was declared a human right by the United Nations in 2010. Therefore, water should not be treated the same as other marketable goods. Its provision should not result in the exclusion of anyone, because the transfer of water to one group of users may be morally unacceptable if it deprives other users. However, after basic water needs have been satisfied in line with the spirit of human rights, any additional water use is no longer a basic human right (White, 2015). In the context of South Africa, 25 litres per person per day or 6 000 litres per household per month is the legislated human right of every citizen. As such, when water use exceeds this threshold it becomes a private good; and so, like other private goods, is best allocated through markets. It is for this reason that we conclude that water has a dual aspect, namely as a human right and as a private good. Views on water matter, as they influence one's ideology and emotion, which can ultimately influence whether water provision should be supplied by the public or the private sector.

According to Biswas (2013), the private-versus-public argument over the provision of water has been going on for at least the past two decades, with no sign of any consensus emerging between opponents and proponents of privatisation. He argues that this is because the debate has basically been dogmatic, biased, and more of a reflection of personal preferences than anything else. He argues that conceptually, there is no reason the public sector cannot provide better services than the private sector. Braadbaart (2002) conducted an extensive review of the water-industry evidence regarding ownership effects, and found that they are neither independent nor overwhelming. Private water utilities are no more efficient than their public counterparts. Water utility privatisation sometimes produces efficiency gains, but not always.

In most countries around the world, water provision is carried out by a government authority using public infrastructure. In some cases, this system is successful in reaching most households; but in others, corruption prevails, and infrastructure deteriorates as funding to this sector diminishes. Where public provision is judged inadequate, water providers often turn to private sector participation, which can take two main forms: full privatisation, and public-private partnerships. The latter can be further split into three different varieties, and is the most common form of privatization today. However, the debate between these options for provision of water remains so heated that certain countries have even passed laws banning privatisation (including countries both in the developing world, such as Nicaragua and Uruguay, and in developed countries, such as the Netherlands). Fortunately, the choice between supplying water publicly or privately need not be definite; instead, it may be subject to change depending on circumstances, and often occurs in cycles of privatisation and de-privatisation over long periods of time (Saner, Yiu and Khusainova, 2014).

For policymakers, especially in developing countries, the tentative conclusion to be drawn from this is that a change from public to private management will not necessarily result in efficiency gains. Therefore, water utility benchmarking is critical for improving public water sector performance. Water managers in this sector can only manage what they measure; access to data on productivity patterns and relative performance allows water utility managers to direct attention to shortfalls. Similarly, policymakers require quantitative analyses to identify utilities with strong and weak performance. Effective benchmarking requires identifying and choosing indicators that are unambiguous and verifiable, consistent with long-term incentives for good performance, and easy for the public to understand. The basis for an effective performance reporting system is having the right indicators.

Benchmarking should not be done in isolation; there should be links to environmental and economic considerations. The water sector is at the core of sustainable development, especially in developing countries, and has economic importance. Thus water managers and policymakers need to assess the entire range of government interventions to understand fully the economic, social and environmental impacts on a given sector, region or group of people. Given the important role of the water sector in the South African economy, this study will also link the performance of Water Service Authorities (WSAs) – water utilities, and their implications for economic development.

1.2. Contextualisation

Firstly, benchmarking empowers a broad section of civil society to ask fundamental questions: why one WSA has achieved demonstrably better performance than another, for example, or why some WSAs choose to ignore some important key performance indicator such as water quality. Mobilising water consumers in this way is likely to lead to demands on the regulated water utilities – whether private or public – to improve performance. Performance benchmarking has become standard practice in regulated water utilities in developed countries such as England and Canada, with considerable success.

Secondly, the basis of an effective and sound performance reporting system is good data, the right indicators, clear presentation, and credible public debate. Indicators must be measurable and meaningful indicators of performance, and should capture obvious features of the water service provided. This enables water users to understand variations in service performance between different water providers, and over time. Indicators may focus on quality, for example, or efficiency, affordability, or comparative performance. Some may be expressed as indexes adjusted for different operating conditions. Given the lack of consensus in the South African water sector on the most suitable performance indicators, this discussion is important for shedding light on the possibilities of finding the most appropriate performance indicators to resonate with the water sector.

Thirdly, economic policymakers tend to confront policy issues one at a time, starting by stating policy objectives in single-dimensional terms. This approach presents challenges, since a policy intended to achieve only a single objective usually has unintended and unrecognised consequences. For this reason, water managers and policymakers need to determine the entire range of government interventions to understand fully the economic, social and environmental impacts on a given sector, region or group of people. Improving water resource management requires recognising how the overall water sector is linked to the national and local economy. For too long, many water managers in water service authorities have failed to recognise the connection between macroeconomic policies and their impact; for example, water-intensive companies may relocate or choose to locate their business activities elsewhere if effective water governance is not in place.

1.3 Benefits of efficiency analysis

The benefits of conducting efficiency benchmarking in this analysis are:

a) The ability to identify and review the most appropriate key performance indicators that resonate with the South African water sector. The performance indicators identified are those that draw on data that is reliable, can be verified, and is not susceptible to multiple interpretations. They reflect conditions over which the service providers have control. We acknowledge that indicators that offer an indisputable basis for judgment are not easy to find, and that even the process of measuring some indicators can lead to disputes.

b) Information management is crucial for improving water sector performance. Thus, data collection and quality of data influence the integrity of results.

c) Structural variables (such as population density) and the quality thereof are identified as essential for undertaking efficiency analysis. Nonetheless, there is still room for methodological improvements and the use of richer datasets. Because conventional Data Envelopment Analysis (DEA) input/output data may contain random errors, efficiency frontiers resulting from DEA may be distorted by statistical noise. Bias-corrected bootstrapping DEA came into being due to this criticism of the conventional DEA approach. This study joins a growing number of studies using bootstrapping DEA to correct efficiency scores. A WSA panel-data approach to efficiency is used.

d) The determinants that significantly affect Water Service Providers (WSPs) are identified. The aim is to identify and measure the level of factors affecting the performance efficiency of WSPs, as this enables improvement efforts to target the right areas.

e) The process of identifying the best practices and metrics that can be used by water providers to support the attributes of effectively managed water utilities; developing and documenting a framework and methodology for utilities to evaluate these attributes; and in the case of this study, creating an *Excel-based tool* that can be used to conduct a self-assessment for internal performance benchmarking.

f) Quantifying the impact of improved water services directly on local economic growth. Such findings allow policymakers to address and improve on the growth-enhancing aspects of water service delivery.

1.4. Research project aims

- Identify and present an overview of key performance indicators;

- Develop a comprehensive panel dataset covering at least five years of municipal water provision for the country's water service providers;

- Track municipal performance in the efficiency of water provision over the last few years, using the stochastic frontier analysis, data envelopment analysis or free disposable hull methods;

- Assess the factors that impact on the efficiency of water provision, particularly on efficiency gains;

- Develop a benchmarking Excel tool for conducting self-assessment;

- Quantify the direct impacts of efficiency of water provision (through municipal operating and capital expenditure) on local economic growth.

Chapter 2: Key Performance Indicators

2.1. What is benchmarking?

Benchmarking is a process that allows the past or current performance of a firm or utility to be compared to a relevant reference performance. The reference performance may be artificially determined, or it can be based on the best-performing firm in the group under investigation. Benchmarking allows a group of firms to be ranked from best- to worst-performing, based on specific areas determined to be vital to the efficient operation of the firm. On its own, benchmarking cannot be classified a regulatory method (De Witte and Marques, 2009).

Often, regulators in countries determine desirable levels of performance in specific areas, and use benchmarking to determine the firms that are complying or not complying. The results of the exercise are used in a regulatory manner when firms face consequences related to their benchmarking results (De Witte and Marques, 2009). Benchmarking allows firms or utilities to learn from best practice, and encourages sustainable service delivery (Molinos-Senante, Donoso, Sala-Garrido and Villegas, 2018).

2.2. Evolution of benchmarking

Benchmarking was first implemented in the private sector in the 1950s but only gained momentum in the 1970s, when the American Xerox company implemented it to increase their competitiveness against the rising Japanese technology firms. The merits of benchmarking – which include the ability to learn from another firm's best practice, and encouraging competition and innovation – resulted in the widespread use of the technique in the public sector. By the mid-1990s, four out of five firms in South-East Asia, Europe and North America used benchmarking techniques (McDonald, 2016). The enthusiasm for benchmarking spread to the public sector in the late 1980s, and was first implemented in the water sector in the 1990s. The water sector had been under considerable pressure, due to factors including climate change, economic and population growth, and urbanisation (DeWitte and Marques, 2009).

Economic growth, population growth and increased urbanisation meant water utilities needed to expand their service delivery to accommodate the new demand. This highlighted the need for the sector to become more efficient. Then climate change brought about the need for sustainability as a goal, as many regions in the world started experiencing lower levels of rainfall. Benchmarking was brought to the sector by regulators to achieve both efficiency and sustainability goals. Water utilities learnt from each other's best practice, thus achieving the efficiency objective; and in many countries, sustainability became one of the key areas included when benchmarking (DeWitte and Marques, 2009; Murungi and Blokland, 2016).

In many developing countries, the water sector has been enabled to assess their resource allocation and consequently their performance and production efficiency, or lack thereof. This encouraged the redistribution of resources based on the best practices of similar-sized utilities with comparable operational and cost structures, resulting in increased overall efficiency (Laine and Vinnar, 2014). DeWitte and Marques (2009) argue that in the Netherlands, Portugal and Australia, benchmarking of water utilities resulted in significant improvements in their performance.

2.3. Key performance areas (KPAs) and key performance indicators (KPIs)

All benchmarking frameworks consist of a set of key performance areas (KPAs) and the related key performance indicators (KPIs), selected based on an organisation's or regulatory body's interests or goals. KPAs are the areas of performance explicitly or implicitly reflected in the vision and/or strategies of an organisation. In the case of a country, KPAs reflect the goal envisioned for a sector. In the water sector, examples include water quality and service delivery. KPIs are the quantifiable measurements that reflect the performance of a firm under each KPA. Each KPA has a KPI or set of KPIs that differ depending on the vision, mission and goals of the firm being evaluated.

The choice of performance indicators is paramount in the benchmarking process, as this determines what constitutes efficiency and inefficiency. The definition of a successful and efficient water service utility is largely dependent on the observer's bias. On one hand, a water utility provides access to water, a public good, which has been deemed a basic human right; and thus, utilities operate as natural monopolists. On the other hand, water remains a product; and its provider must have a sound business model in place to serve public welfare. The provision of water to all at affordable prices can be seen to conflict with the need to control the quality and quantity of water available. This highlights the importance of performance indicators, as they steer attention towards what constitutes efficiency (Danilenko, Van den Berg, Macheve and Moffit, 2014).

Performance evaluation frameworks are increasingly being used to shape policy, practice and funding arrangements in the public sector, particularly in developed countries such as Finland and the Netherlands. This is due to the resulting efficiency gains, as well as the public's need for increased transparency and accountability of water utilities. This has led to increased efforts to "export performance evaluation frameworks from Europe and North America to countries in Asia, Africa and Latin America" (McDonald, 2016).

The indicators selected for a developed country's evaluation framework may not all be relevant in a developing country's water utility context, due to the vast differences in end users, culture, politics and environmental conditions. Benchmarking requires that utilities in different places be compared based on specific indicators. The process of selecting indicators must be stringent, or it will not capture the unique characteristics of each water utility and what may constitute its individual efficiency based on its circumstances and resources. In extreme cases where a framework is imposed without modification for local circumstances, benchmarking may result in a shift of attention from locally relevant problems to external procedural norms that may be inappropriate for a specific utility (McDonald, 2016).

Utilities are responsible for the provision and collection of relevant data needed to correctly quantify the chosen indicators. In developing countries, most water utilities – many of which are small – operate in under-funded or poor jurisdictions with significant service backlogs. Benchmarking often imposes stringent reporting requirements which may serve to exacerbate the inefficiencies experienced by the water utilities, particularly when reporting is done for different entities in different forms (Laine and Vinnari, 2014). In addition, data collection has been found to be difficult for wellresourced utilities operating in developed countries. In low-income countries, the collection of basic statistical information presents significant challenges, and thus the collection of comprehensive data needed for certain indicators may not occur (McDonald, 2016). The unavailability of data needed for benchmarking compromises the usefulness of performance evaluation.

Performance evaluation rates utilities against other similar entities; this information may be publicly available, enabling the citizenry to compare their water provider with those in another jurisdiction. This has resulted in the public being able to participate actively in the decision-making process in an informed manner. A goal of benchmarking in the water sector is to encourage competition in an otherwise non-competitive sphere. This results in the utilities focusing their resources to enhance their performance in alignment with the indicators that are measured (McDonald, 2016); which implies that what is measured is most likely to experience improved efficiency and performance. When the choice of indicators for the performance framework is not relevant to the circumstances of a utility, this may result in the misappropriation of resources towards 'keeping up with the Joneses' instead of addressing the inherent issues affecting that particular jurisdiction and its end users.

2.4. International benchmarking frameworks

Global players such as the World Bank have made noteworthy strides in creating benchmarking frameworks that can be used to perform international comparisons. In 1996 the World Bank established the International Benchmarking Network for Water and Sanitation Utilities (IBNET), which aims to provide a universal benchmarking standard to enable all utilities and policymakers worldwide to measure and compare their performance (Danilenko et al, 2014). It makes use of IBNET Apgar scoring, which assesses a utility's health based on five indicators for each KPA (or six, if the utility also provides sewerage services). The Apgar criteria cover the following KPAs:

- Water supply coverage
- Sewerage coverage
- Non-revenue water
- Collection period

- Operating cost coverage ratio
- Affordability of water and wastewater services

The European Benchmarking Co-Operative (EBC) is another framework that allows global comparison of water utilities. It uses five KPAs:

- Water quality
- Reliability
- Service quality
- Sustainability
- Finance and efficiency

The Aqua Rating allows international comparisons using eight rating areas:

- Service quality
- Operating efficiency
- Financial sustainability
- Corporate governance
- Investment planning and implementation efficiency
- Business management efficiency
- Access to service
- Environmental sustainability

These benchmarking frameworks use different key areas to assess efficiency, and thus cannot be reliably compared; they may give different results for the same water utilities. The frameworks are mainly suited to measuring efficiency and service provision to existing customers serviced by a pipe connection – that is, modern techniques of water provision. In many developing countries, a significant percentage of the population does not have access to piped water, due to a lack of infrastructure and investment. Though without modern piped water, the people are serviced via non-piped water and on-site sanitation, particularly the urban poor (Murungi and Blokland, 2016).

The benchmarking techniques available do not facilitate the assessment of these pro-poor services, instead disqualifying any pre-modern techniques of water management and evaluation. There is a need to develop frameworks that are cognizant of the pro-poor initiatives being employed by utilities in less developed countries.

2.5. South African benchmarking initiatives

In South Africa, the importance of benchmarking in the water sector has been realised both by government and by organisations including the South African Local Government Association (SALGA) and the WRC. There are a few benchmarking initiatives currently being used to benchmark the performance of Water Service Authorities or Water Service Providers. These include the Blue Drop, which is an incentive-based regulation mainly concerned with the quality of drinking water and water-safety planning; the Green Drop, which is another incentive-based regulation primarily concerned with wastewater quality; the No Drop criteria, used to assess water conservation and demand management; and the Municipal Benchmark Initiative (MBI), a voluntary benchmarking initiative (DWA, 2014; DWA, 2015; MBI, 2015).

The Blue Drop system determines the performance of a municipality based on the following six KPAs, each with a set of Key Performance Indicators:

- Water safety planning (five KPIs)
- Process management and control (three KPIs)
- Drinking water quality verification (three KPIs)
- Management, accountability and local regulation (four KPIs)
- Asset management (six KPIs)
- Water-use efficiency and water-loss management (three KPIs)

In total, the Blue Drop has 24 KPIs. The Blue Drop includes the No Drop performance area, which assesses water-use efficiency and water-loss management (DWA, 2014).

The Green Drop system measures the performance of a municipality based on the following KPAs:

- Process control, maintenance and management skill
- Wastewater monitoring
- Submission of wastewater quality results
- Effluent quality compliance
- Wastewater quality risk management
- Bylaws (local regulations)
- Wastewater treatment capacity
- Wastewater asset management

The Blue Drop and Green Drop results are published annually and are publicly available, and this has increased accountability and transparency in the water sector (DWA, 2015).

The MBI is a SALGA-led initiative supported by the WRC in association with the Institution of Municipal Engineering of Southern Africa (IMESA). There are six performance areas, each with KPIs, used to benchmark municipality performance:

- Water conservation and demand management (six KPIs)
- Human resources and skills development (six KPIs)
- Service delivery and backlogs (eight KPIs)
- Operations and maintenance (three KPIs)
- Product quality (three KPIs)
- Financial management (11 KPIs)

MBI has a total of 31 KPIs, termed the ‘shopping list’. The municipalities have the option to select KPIs and collect relevant data associated with the KPIs they have chosen. This data is used to develop a municipal-specific scorecard. The advantage of not requiring municipalities to report on all the KPIs is that it enables participation to begin at a basic level, and grow to more advanced reporting as officials realise the benefits of benchmarking. The municipalities with smaller capacity (and thus less ability to report on complex KPIs) are not excluded from participation, and can benefit from benchmarking efforts (MBI, 2015).

Despite the effort to be inclusive, the full benefits of metric (performance) benchmarking are compromised. Metric benchmarking requires the statistical comparison of water utility performance based on common KPIs. The very ability of municipalities to select indicators gives rise to the likelihood that each municipality will have different indicators to determine its scorecard, and thus cannot be accurately compared to similar municipalities. If municipalities cannot make an equal comparison on the performance areas determined for MBI, the benefits of learning from best practice will also not be fully realised.

The benchmarking initiatives in the South African water sector are significant, and commendable. However, there is a need for the development of one comprehensive benchmarking framework that makes use of robust econometric and statistical techniques to allow valid interpretation of performance, as opposed to descriptive analysis of results. The current benchmarking frameworks have some KPA and KPI duplication, which may increase the burden on municipalities and water-service authorities and providers. It is essential that a single, comprehensive and uniform framework (i.e. one that would make use of the same KPAs and KPIs) be developed that will enable performance analysis and comparison for South African water service authorities as a whole, as well as allowing comparison with similar water utilities internationally.

2.6. Theoretical framework of benchmarking initiative

This study aims to develop a comprehensive benchmarking framework to evaluate the performance of South African WSAs, in order to encourage efficient and sustainable performance goals.

There are various considerations made when constructing a benchmarking framework. Firstly, it is essential that the indicators selected are simple and easy to understand. This is because ideally, a large number of WSAs will be required to report on the chosen indicators; consequently, the complexity of the indicators may result in measurement errors and misreporting of data. Secondly, the framework should allow for comparability between utilities with similar characteristics. This allows utilities to learn from the best practice of the most efficient, and promotes efficiency and sustainability goals. Thirdly, the selected indicators should quantitatively measure inputs used by the WSA or outputs produced by the WSA. Indicators that measure the outcomes should never be included. This is because outcomes may be partly influenced by the level and quality of services provided by WSAs, but are not directly under the control of the utility. Only factors that are endogenous to the utility should be included in a benchmarking framework that assesses efficiency of performance.

Kaplan and Norton (2007) proposed four key perspectives to be included in any benchmarking exercise: a financial perspective, a customer perspective, an integral business perspective and an innovation and learning perspective. Two additional perspectives have been determined to be essential: the social and environmental perspectives. These six perspectives give a broad summary of how to select and develop KPAs for each sector. Tynan and Kingdom (2002) determined that developing countries should assess their water utilities under four broad categories: efficiency of investment, efficiency of operations and maintenance, financial sustainability, and responsiveness to customers. The KPIs chosen for each KPA should meet the SMART criteria: they must be Specific, Measurable, Achievable, Relevant and Time-bound.

As discussed above, choice of KPAs is largely motivated by the goals and objectives a firm, organisation or sector is interested in achieving. In South Africa, the water sector is regulated by the Department of Water and Sanitation (DWS). The DWS is responsible for the promotion of the provision of sustainable water resources and services to the people of South Africa. It has four main performance areas: service quality, financial viability, institutional effectiveness, and technical efficiency. Service quality mainly identifies factors that affect customer satisfaction, including continuity of water services and the affordability of those services. Financial viability assesses the tariffs charged by WSAs, to determine whether they are cost-reflective and affordable. Institutional effectiveness provides an overview of a utility's business performance; staff skill levels, revenue collection and maintenance of assets are evaluated in this KPA. Technical efficiency deals with the standards of the services offered. This includes factors such as water quality and the level of non-revenue water (DWA, 2015).

2.7 KPAs and KPIs for assessing South African WSAs

Based on the existing literature, analysis of existing international and local benchmarking initiatives, and the mandate of the DWS, the following KPAs and KPIs have been selected for the comprehensive South African benchmarking framework proposed by this study:

2.7.1. Asset Maintenance

This KPA concerns the care and maintenance of existing WSA assets. These assets include water infrastructure such as water pipes and meters. It is vital for a WSA to dedicate expenditure to maintaining its assets, as neglect will result in apparent and real water losses, as well as revenue loss. The indicators for this KPA are:

- Apparent losses
- Real losses

Apparent losses and real losses make up the total amount of unaccounted-for-water. Apparent losses include water loss due to inefficient billing systems and illegal connections. Real losses involve the physical loss of water due to factors including leakages. High volumes of both indicators signal that a WSA has poor system management, less than efficient commercial practices, and inadequate pipeline maintenance.

2.7.2 Operational efficiency

A WSA is more efficient than another if it uses fewer inputs or less of the same inputs than the other WSA to produce the same level of output. This KPA is concerned with evaluating how efficiently a utility uses its inputs when producing output. Labour is one of the most important inputs; thus, Human Resource considerations are included in this KPA. The KPIs are:

- Labour per connection
- Labour per population served
- Labour costs
- Vacant employee posts

High ratios of labour per connection, labour per population served and labour costs signal inefficient use of staff (inputs) in the production process. Vacant employee posts are included particularly to address the structural employment facing local government in South Africa. Large numbers of vacant posts are likely to cause inefficiency, as this indicates there are no skilled personnel to fulfil the objectives of the utility.

2.7.3 Service quality

This KPA aims to evaluate the level of satisfaction or dissatisfaction experienced by customers as it relates to the level and quality of water services received. The following KPIs are used to evaluate satisfaction:

- Water availability
- Water pressure
- Response time for complaints

Water-service interruptions and low water pressure result in customer dissatisfaction and low levels of service quality. Customer complaints should be addressed promptly. Long response times are associated with lower levels of service quality.

2.7.4. Access and affordability of water services

Access to water is considered a basic human right, protected by and stipulated in the South African constitution. It is vital for WSAs to continue to address service delivery backlogs and expand water services to the existing excluded population. The water services should be affordable, as no-one should be prevented from enjoying this basic human right because of high costs and tariffs. The following KPIs are used to evaluate this KPA:

- Water coverage
- Cost of new connection
- Waiting time for new connection
- Households served by pipe connections
- Households per connection
- Average tariff cost

A WSA should aim for 100% water coverage of the population in its jurisdiction. The high cost of new connections means low demand for these connections, resulting in the exclusion of the less fortunate from accessing piped water. Utilities should aim to expand the number of households that access water via piped connections. This aids the sanitation goals of the water sector as well as allowing more efficient revenue collection by the utilities. High tariff costs result in either the exclusion of some groups of people from accessing water services, or significantly high levels of bad debt accruing to the WSA, as people cannot afford the high tariffs.

2.7.5. Financial sustainability

This KPA evaluates whether a WSA is achieving at least the break-even point enabling the utility to cover all operating expenditure. In the long run, failure to cover costs will result in underinvestment in assets, declining service quality, and an inability to expand water services. The KPIs are:

- Cost recovery
- Collection period
- Metered water sold
- Bad debts
- Average revenue
- Average operating cost
- Level of capital expenditure

A cost recovery indicator that is greater than 1 shows that a WSA is failing to cover operating costs, and an indicator less than 1 shows that the WSA is generating enough revenue to meet operating expenditure and some capital costs. The collection period of an efficient WSA should be short, as this means that customers are paying on time. High levels of bad debt signal that the utility is not financially sustainable, as bad debts represent revenue lost to the utility.

2.7.6. Water quality

This KPA is generally thought of as the most important, as people require clean and safe drinking water. WSAs must closely monitor the quality of water distributed, as infected water can have dire consequences, potentially leading to the spread of diseases such as cholera. The KPI for water quality is:

- Water quality compliance

The WSAs' compliance with the national regulatory standards is assessed.

2.7.7. Benchmarking framework for South Africa

Table 1 below shows a summary of the KPAs and KPIs selected specifically for the South African context.

Table 1: List of KPAs and KPIs for assessing WSAs in South Africa

Key Performance Area	Key Performance Indicator	Measurement
Asset Maintenance	1. Apparent losses	% of system input volume
	2. Real losses	% of system input volume
Operational Efficiency	1. Labour per connection	Labour/1000 connections
	2. Labour per population served	Labour/1000 people served
	3. Labour costs	Labour costs/Total operating costs
	4. Vacant employee posts	Vacant posts/total number of posts
Service Quality	1. Water availability	Hours of service/day
	2. Water pressure	Average water pressure
	3. Response time for complaints	No of days to address complaint
Access and Affordability of Water Services	1. Water coverage	% of population receiving water services
	2. Cost of new connection	% of per capita GDP
	3. Waiting time for new connection	Days
	4. Households served by pipe connections	Number of Households served by pipe connections/Total number of households
	5. Households per connection	Number of households/connections
	6. Average tariff cost	Average tariff cost/kl sold

Key Performance Area	Key Performance Indicator	Measurement
Financial Sustainability	1. Cost recovery	Total annual operation expenses/Total annual pre-tax collections
	2. Collection period	Days
	3. Metered water sold	% of metered water sold/total water delivered
	4. Bad debts	% of collections
	5. Average revenue	Average revenue/kl sold
	6. Average operating cost	Average operating cost/kl sold
	7. Level of capital expenditure	Capital expenditure/Total expenditure
Water Quality	1. Water quality compliance	% of quality tests in compliance with national regulatory standards

2.8 Conclusions

The importance of benchmarking in the water sector has been recognised since the 1990s. Developed countries have developed frameworks that are relevant for their specific cases, and have seen great improvements in water-utility performance over the years, including increased competitiveness and increased efficiency. Utility managers have learnt from the best practices of similarly-endowed firms to improve overall efficiency and promote sustainability in the sector.

Developing countries have also made use of benchmarking techniques in the last few decades. However, often the benchmarking frameworks selected to evaluate the efficiency of the water sector are taken from the 'developed countries' context and experiences, and imposed on developing countries. Developing-country water utilities are generally less advanced than and at times significantly different to developing countries; thus, some indicators may not apply, or may be measured differently to the proposed indicators. This compromises the findings of the benchmarking efforts. This realisation has led regulators and governments to advocate for benchmarking frameworks that are relevant to the developing-country context. This study provides such a benchmark for the South African water service authorities.

Chapter 3: Development of a panel dataset of the country's Water Service Providers

3.1. Background

This project focuses on providing more policy relevance than just efficiency benchmarking. In meeting this objective, the project provides an overview; identifies the key performance indicators; develops a comprehensive panel dataset covering at least five years of municipal water provision by the country's water service providers; and tracks municipal performance in efficiency of water provision over the last few years.

Moreover, we assess the factors that impact on the efficiency of water provision, particularly on efficiency gains. We also assess the development of the Excel benchmarking tool for conducting self-assessment, and quantify the direct impacts of efficiency of water provision (through municipal operating and capital expenditure) on local economic growth. The aim here is to present a panel and sub-water utility data in water benchmarking that will enable us to do efficiency analysis.

3.2 Methodology

We adopt a quantitative approach; a combination of efficiency and econometric methods will be used. This is done using two widely accepted methods of efficiency analysis, namely the parametric SFA and the non-parametric DEA. Farrell (1957) defines technical efficiency as the ability of a decision-making unit (DMU) to produce maximum outputs from a minimum set of inputs. Therefore, a DMU that is technically inefficient is either producing fewer outputs from a given set of inputs (output-oriented efficiency) or using too many inputs for a given set of outputs (input-oriented efficiency). The level of inefficiency is determined by the calculation of a production set, which is a combination of a set of inputs to produce a set of outputs. This is given as:

$$\Psi=\{(x,y) \mid x \in R_+^p, y \in R_+^q, (x,y) \text{ is feasible}\} \quad \textbf{(1)}$$

where Ψ = the production set

x = a vector of inputs

y = a vector of outputs

With $p > 0$ and $q > 0$, $y_1 \ldots y_q$ outputs is feasible with $x_1 \ldots x_p$ inputs. The production set can be estimated using the SFA or DEA methods. The boundary of the production set is essentially the production possibility frontier of the production process, i.e. the boundary where production is maximised. Any DMU that deviates from this maximum attainable output is considered inefficient in its production process. Estimating the production set using one of the three methods mentioned will thus estimate inefficiency in terms of the deviation of the DMU's production from the production possibility frontier. The SFA method is a parametric technique used to estimate the production possibility frontier, while DEA is a non-parametric approach. Unlike most studies, which use a standard DEA, we have used an Advanced DEA model.

We have used the double-bootstrap DEA model with a truncated regression, which is a non-parametric approach. This model allows for the estimation of bias-corrected efficiency scores and the identification of the drivers of efficiency in the water sector. The double-bootstrap DEA model is a modified version of the conventional DEA model. The DEA model uses linear programming to compute the efficiency frontier used to compare firms against each other to determine efficiency scores (see Simar and Wilson, 2007).

The double-bootstrap DEA allows for the estimation of bias-corrected efficiency scores in the first bootstrap stage; and this allows statistical inferences to be made and hypothesis testing to be conducted. The second bootstrap, or the double-bootstrap stage, identifies the determinants of the efficiency scores found in the first stage by applying statistical tests to the efficiency scores obtained in the first stage to determine whether there are significant differences between the efficiency scores of units, clustered according to factors that may affect efficiency (Molinos-Senante et al., 2018). As in previous studies, Algorithm 2 of the double-bootstrap DEA model proposed by Simar and Wilson (2007) was used in this study. This model is highly preferable to Tobit; it has the capacity to truncate the DEA score differently to the Tobit model (which censors the DEA score), thus giving more accurate results.

The analysis described is followed by an investigation into the determinants that significantly affect water service providers (i.e. the efficiencies and inefficiencies discussed above). The aim is to identify and measure the level of each factor affecting the performance efficiency of water service providers, as this enables improvement efforts to be targeted to the right areas. The last aspect of the study is to analyse the impact of efficiency on economic growth, which involves the impact on industrial development and the impact on employment. This analysis will follow the fixed-effect analysis. To make this analysis, we need a set of data, which we have constructed. The data is presented in the sections that follow below.

3.3 Data description

Local government in South Africa is made up of municipalities of various types. In the main these may be divided into two categories, namely the largest metropolitan municipalities, and the district municipalities. The former are characterised by the largest metropolitan areas, which are governed by metropolitan municipalities. The latter consist of several local municipalities. As far as service delivery is concerned, municipalities are divided into the following categories:

Table 2: South African municipal categories

Classification	Description	Characteristics	Water Utilities
A	Metropolitan	Large urban cities	8
B1	Local	Large secondary cities	19
B2	Local	Large towns	27
B3	Local	Small towns	108
B4	Local	Mainly rural towns	72
C1	District	Not authorised to provide water services	23
C2	District	Authorised to provide water services	21

Source: StatsSA, 2016

This study divides the municipalities into two clusters, namely urban and rural, guided by the categories in Table 2 above. Urban municipalities are those classified as A, B1 and B2, whereas rural municipalities are those classified as B3, B4 and C2. There are 147 municipalities authorised to provide water services, making them Water Service Authorities (WSAs), and 136 municipalities not authorised to provide water services; C1 falls under the latter category. As the model we have adopted for this study is primarily an input-output model, the key variables in our dataset are input and output variables, which are proxies for key performance areas and key performance indicators. These key parameters are presented in Table 3 below:

Table 3: List of variables for efficiency analysis to be used in the Data Envelopment Analysis

Variable	Model Specification
Total water-provision cost (R000)	Input
Number of water-consumer units	Output
Number of employees	Input
Units receiving free basic water	Output
Total water-related income (R000)	Output
Employee-related costs (R000)	Input
Water quantity (million m3)	Output
Bulk water tariff (R000)	Input
Capital price (R000)	Input
Bulk water cost (R000)	Input
Sales of water (R000)	Output
Network Length(km)	Input
Water quality (%)	Output

The selection of inputs, outputs and explanatory variables included in this study was guided by the existing literature on efficiency analysis. The most widely used inputs in the literature include operating costs, length of mains, labour costs, number of employees, and capital expenditure (Brettenny and Sharp, 2016; García-Valiñas and Muñiz, 2007; Ananda, 2014). Operating costs, number of employees and network length are the inputs used in this study. Total expenditure less employee-related costs gives the operating costs (in R/year) of the water utilities. Number of full-time workers is used as a proxy for labour-related costs in the model. Length of mains (in km) is used as a proxy for total capital expenditure. Guided by the literature, widely used outputs in efficiency analysis include total volume of water distributed/delivered (see Molinos-Senante et al., 2018), output quality (see Ananda, 2013) and level of properties (see García-Valiñas and Muñiz, 2007). WSAs should not only be able to meet consumer demand; the water delivered should also be of good quality. Failing to provide good-quality water is an indication of inefficiency. Therefore, water quality (%) is selected as an output variable in this study, together with the total volume of water distributed (in kl/year).

Three explanatory variables are evaluated in this study: non-revenue water (in kl), customer density/number of consuming units, and location (urban or rural). Non-revenue water in this study is defined as apparent losses (which includes unauthorised consumption) plus real losses (which includes leakages). It is an endogenous variable to a large extent, as a WSA can implement measures to reduce unauthorised consumption, as well as leakages resulting from ill-maintained infrastructure. The *a priori* assumption is that non-revenue water will have a negative effect on efficiency, as high water losses increase the cost and amount of inputs used to produce the demanded output.

Customer density and location are exogenous variables. Customer density is chosen as an explanatory variable to investigate whether South African WSAs benefit from economies of scale in water-service provision. If economies of scale exist, customer density should have a positive effect on efficiency. Location is included in order to investigate whether efficiency is affected by being in an urban or rural area. If location in urban areas has a positive impact on efficiency scores, it will be vital for efficiency analysis to be conducted in urban and rural clusters. A rural WSA has no control over its location. Efficiency scores should not penalise municipalities for exogenous factors, particularly if such scores are used to set tariffs or determine grant amounts from the government.

In addition to the main variables, the study investigates whether human capacity constraints, corruption, poor management, a lack of funding or municipal policies (all under the ambit of 'control variables') are resulting in inefficient and ineffective water-service provision. The results thereof will ensure policymakers know exactly where to target their interventions to improve municipal performance in water provision. The results will also help in estimating the impact of water-related grants and/or water revenue on efficiency, and give policymakers a sense of whether the current financing mechanisms are appropriately supporting efficient service delivery.

The data to measure these variables is sourced from a variety of secondary sources, including Statistics South Africa (municipal vacancies, from the Non-Financial Census of Municipalities), the Auditor General (audit opinions) and the National Treasury (grants allocated to municipalities). Considering we are also interested in knowing the drivers behind efficiency, we go beyond merely generating scores by also assessing the determinants of the efficiencies or inefficiencies. The second stage of our analysis entails running models to assess these drivers; hence our dataset should also include the explanatory variables, which may explain the scores we generate.

Table 4: Independent variables for efficiency analysis

Variable	**Expected Sign**	**Unit of Measurement**
Non-revenue water	-	Measured in ZAR
Customer density	-	Proportion of population
Location	+	Dummy variable 1= urban
Human capacity constraint	-	Number of employees required
Corruption	-	Dummy variable
Poor management	-	Dummy variable from audit document
Lack of funding	-	Measured in ZAR
Water related grants	+	Dummy variable from grant allocation

We are quantifying the direct impact of improved water services on local economic growth. Such findings will allow policymakers to address and improve on the growth-enhancing aspects of water service delivery; see Table 5 below for variables to be used in the investigation of the relationship between water service provider efficiency and macroeconomic indicators, in other words its impact on growth and employment.

Table 5: List of variables for growth and employment

Gross value added in municipality	+	Measured in ZAR
Operating and capital expenditure	+	Measured in ZAR
Gross value added of a water-intensive industry	+	Measured in ZAR
Total employment in municipality	+	Measured in ZAR
Total employment in a water-intensive industry	+	Measured in ZAR

Structural variables (such as population density) and quality have been identified as essential for objective efficiency analysis, and these are included in the models as control variables. The following control variables are included in the dataset, and are considered during the modelling phase:

Race proportions: The Community Survey indicated how many people of each race resided in each municipality. These amounts were divided by the total population size to get a proportion for each race group in each municipality.

Proportion of total income from Intragovernmental Grants ≥ 50% dummy: the total municipal income acquired through intragovernmental grants is presented in the Financial Census for Municipalities; this was divided by the total income for each municipality, to calculate the proportion of income that was received through intragovernmental grants. If this proportion was more than or equal to 0.5, the dummy variable would have a value of 1.

Proportion of households that are of a certain size: this was sourced from the Community Survey, which presented it as the number of households in each municipality that had the specific number of people living in that household. These amounts were divided by the total number of households to calculate a proportion for each municipality.

Provincial dummies: these are simply dummy variables indicating which province a municipality is in, and the data was sourced from the Community Survey.

The proportion of households that are in urban areas: this data was also sourced from the Community Survey, and included the number of households that were urban, farms, or traditional land. These absolute figures were then divided by the total number of households to calculate a proportion for each.

Proportion of highest education level: The Community Survey presented the number of people in each municipality who had obtained a specific level of education. Very specific information was provided here, with education level broken down into grades and specific post-school qualifications. These were combined to fit into six categories: no schooling, some primary education (grade 6 and below), complete primary education (grade 7), some secondary education (grade 8-11, as well as incomplete school-level equivalent qualifications), complete secondary education (grade 12 and complete school-level equivalent qualifications), and tertiary education (all post-school qualifications). Each of these categories was divided by the total population size to calculate a proportion.

Unemployed people: this data was sourced from the Quantec Regional Indicators, and comprised the number of people who were unemployed as well as the percentage of the population these people represent. This percentage is simply the number of unemployed people divided by the total population size and multiplied by 100, and is not the same as the unemployment rate.

Employed people: this was sourced from the Quantec Regional Indicators, and is the number of employed people divided by the total working-age population in each municipality (also provided), to calculate a proportion.

Proportion of female-headed households: the total number of households that were headed by a woman appeared in the Community Survey, and these amounts were divided by the total number of households to obtain a proportion.

3.4. A panel dataset

We constructed a panel dataset 2010-2017 consisting of 147 municipalities, with the following main components:

Components of total water-related costs:

Employee-related costs

Interest paid

Loss on disposal of property, plant and equipment

Bad debts

Contracted services

Collection costs

Depreciation and amortisation

Impairment loss (PPE)

Repairs and maintenance

Bulk water purchases

Grants and subsidies paid to:

Households or individuals

Non-profit institutions serving households

General expenditure:

Accommodation, travelling and subsistence

Advertising, promotions, and marketing

Audit fees

Bank charges

Cleaning services

Consultancy and professional fees

Entertainment costs

Fuel and oil

Hiring of plant and equipment

Insurance costs

Pharmaceutical

Postal and courier services

Printing and stationery

Rebates for service charges

Rental of land, buildings and other structures

Rental of office equipment

Security services

Subscriptions and membership fees

Telecommunication services

Training and education

Transport costs

Other expenditure

The Water Service Providers dataset that was constructed in this study appears in **Appendix 1**. This same dataset is used for the empirical analysis undertaken in this study.

3.5. Concluding remarks

We set out to construct a panel dataset for South African water service providers that would allow us to undertake efficiency analysis. One of the most important advantages of panel data is that it allows you to control for variables you cannot observe. Most importantly, it allows for control of variables that change over time, but not across entities. This accounts for individual heterogeneity. The panel data we have constructed allows us to move to the next phases of this project, namely efficiency modelling, the determinants of efficiency scores, and linking efficiency to growth and employment.

Chapter 4: Measuring the efficiency of Water Services Authorities

4.1. Introduction

Climate change and the water-scarcity challenges currently plaguing the world have brought the debate concerning the sustainability and efficiency of water to the fore (Cole, 2004). However, efficiency analysis in the water sector is not a recent phenomenon; it has been in existence for over 50 years. In the 1970s and 1980s, governments and regulators in developed countries such as the USA and Australia noticed increased strain on the water sector, owing to factors including population growth and urbanisation. During this time, provision of water services was performed solely by central government or local governments, with no private participation. Increased demand for water services from a growing population necessitated policymakers and regulators in countries such as Australia, Italy and Portugal to propose reforms, as well as improving regulations in the sector (De Witte and Marques, 2009).

To our knowledge, studies conducted for South African WSAs have not employed the use of the double-bootstrap DEA methodology; this study contributes to the literature by assessing South African WSAs with a robust methodology. Previous studies using this methodology have used cross-sectional data. This study contributes further to the literature by making use of panel data from 2010 to 2013, and allows a trend analysis of the efficiency scores of a WSA to be estimated.

This study uses South Africa as a case study mainly because of its dual economy, which will allow a large number of countries to learn important lessons from our findings. According to the World Bank, South Africa has a dual economy with one of the highest inequality rates in the world. In many respects the first economy can be likened to that of a developed country, including in terms of the infrastructure and services offered. Many water utilities operating in urban areas in South Africa fall into this category. This implies that the lessons from the determinants of urban WSAs in South Africa are potentially important in developed countries as well. The second economy is plagued by significant poverty and inequality challenges. The water utilities operating in rural areas fall into this category, and are characterised by service delivery and infrastructural backlogs. The second economy is largely representative of a poor, developing country; and thus, lessons from the findings in this study will potentially be relevant in many developing countries.

The empirical investigations undertaken in this chapter seek to achieve twin objectives. Firstly, we compute the bias-corrected efficiency scores of the WSAs and compare the findings to those obtained by the conventional DEA model, to highlight the shortcomings of the latter. In countries where efficiency scores are used to compute tariffs, the estimation of bias-corrected efficiency scores allows for accurate policy implementation, with deserving WSAs being rewarded. Secondly, the drivers of efficiency scores for both urban and rural areas of South Africa are determined. The aim here is to present background, and review relevant studies in efficiency analysis conducted using the conventional DEA model and the modified double-bootstrap model. Thereafter we look at the methodology, followed by a presentation of the results.

4.2. Background

Two main regulatory methods are employed. Firstly, regulators require water utilities to report on a set of key performance indicators, and this was used to assess relative efficiency. The findings from these benchmarking exercises are used to define the tariff levels a water utility is permitted to charge each year. This means the best-performing utilities can charge higher tariffs, and in turn make higher profits, because of efficiency gains achieved through lower input costs (see Da Cruz, Marques, Romano and Guerrini, 2012). This has been the case in England and Wales (see De Witte and Marques, 2009).

The second regulatory method uses the findings of the benchmarking efficiency exercise to ‘name and shame’ poor-performing utilities. The ‘name and shame’ or ‘sunshine regulation’ policy is used to encourage underperforming utilities to improve their performance (see Da Cruz et al., 2012). According to De Witte and Marques (2009), the sunshine regulation remains an effective tool, as it encourages competitive pressure in the sector. This regulation has the added advantage of bringing transparency to the sector, allowing the public to participate and engage with service providers in an informed manner.

In Portugal in the 1990s, variances in water availability and rainfall patterns in different parts of the country made it necessary for regulators to advocate for reforms compatible with sustainability goals. The north and the coastline of Portugal received large volumes of rainfall, and thus had abundant water. However, the south of the country and the countryside experienced significant water shortages. The differences in water allocation across the country necessitated the reforms that took place in the 1990s, as it became increasingly evident that the exogenous location differences made uniform regulation ineffective (Da Cruz et al., 2012).

It was found that the efficiency scores of utilities located in water-scarce regions of the country were lower than those in water-abundant areas. Thus, it was important for the utilities to be assessed and compared to utilities with similar characteristics – and environmental characteristics – so as not to obtain misleading efficiency scores. This highlighted the significance of location in efficiency analysis. Similar results were found it Italy. The northern area of Italy has an abundance of water bodies, whereas the central-southern regions of the country suffer from pronounced water-scarcity challenges. During the 1990s, researchers and regulators in the water sector found that the water utilities in the water-scarce regions were less efficient than the utilities in the water-abundant jurisdictions. The utilities in the central-southern region were found to be inefficient in their use of inputs, particularly labour; and they charged significantly higher tariffs than those charged by utilities in the north (Da Cruz et al., 2012).

Beginning in the 1990s, private-sector participation was another reform enacted in Portugal, as policymakers believed this would enhance productivity in the sector. This was a popular sentiment at the time, with The Netherlands' Ministry of Economic Affairs conducting a study in 1997 on the water sector that found strong evidence in support of privatisation to reduce the price of water services and increase overall productivity (De Witte and Marques, 2009). In Portugal, local governments or municipalities were (and remain) legally responsible for the provision of water services, but were then granted permission to engage the private sector. Different models have existed since the 1990s, including concessionary companies, public-private partnerships and state-owned utilities (Marques, Da Cruz and Pires, 2015).

The impact of the reforms is largely still being debated, by policymakers and academics alike. On one hand, state-owned utilities have been found to have higher static efficiencies; whereas utilities with some level of private participation are more productive, with output of superior quality (Guerrini, Romano and Campedelli, 2011). Considering the various ownership structures, there is growing interest from policymakers and scholars in assessing whether the type of ownership matters. In Brazil, Da Motta and Moreira (2006) found that ownership did not influence the productivity gains of water utilities. Picazo-Tadeo et al. (2009) found that in Spain, location negatively affected the efficiency scores of water utilities located in the jurisdictions of Spain that receive large volumes of tourists, compared to the utilities in jurisdictions with fewer tourists.

Subsequent to the implementation of privatisation reforms and increased regulation, there has been interest in developing techniques to assess the effectiveness of these reforms. The common approach is to generate efficiency scores for the purposes of benchmarking, followed by identifying the drivers for observed efficiencies (De Witte and Marques, 2009). Water utilities provide an essential service; thus, regulators and policymakers are interested in minimising inefficiencies. Most efficiency analysis studies tend to use a production frontier approach (see Brettenny and Sharp, 2018; Romano and Guerrini, 2011; Romano, Molinos-Senante and Guerrini, 2017; Molinos-Senante et al., 2018).

Use of the production frontier approach requires three distinct considerations. Firstly, the utilities included in the sample should be homogenous, or significantly similar. Secondly, the choice of inputs and outputs used in the specification of the model is vital (Gomez, Gemar, Molinos-Senante, Sala-Garrido and Caballero, 2017); the variables chosen should have an impact on the efficiency scores of the utilities included in the study. Lastly, the specific methodology selected should be appropriate for the given objectives of the study.

Guided by the literature, we see there are common production frontier techniques that are used to assess efficiency: parametric and non-parametric techniques. The Stochastic Frontier Approach (SFA) is the most widely-used parametric approach (Li and Phillips, 2016; Worthington, 2014). According to Brettenny and Sharp (2018), one of the advantages of SFA is that it allows the decomposition of any inefficiency found into two components; the first reflects inefficiency, and the second, measurement errors. The model also makes provision for other explanatory variables and controls, such as external shocks. However, SFA also has a distinct disadvantage: the functional form of the production function under investigation must be known (Brettenny and Sharp, 2018), and this limits its usefulness in water-efficiency studies, as the functional relationship of variables is not always known *a priori.*

Non-parametric approaches, on the other hand, do not require assumptions about the production function's functional form. Data Envelopment Analysis (DEA) is the most widely-employed non-parametric approach (Romano and Guerrini, 2011; Romano et al., 2017; Molinos-Senante et al., 2018). Its non-parametric nature allows for efficiency analyses to be conducted for multiple inputs generating multiple outputs. The DEA method more often results in the correct estimation of a true production function, compared to the estimations given by parametric methods (Worthington, 2014). But despite its considerable advantages, it is not possible to make statistical inferences from the traditional DEA-model analysis output (Molinos-Senante et al., 2018).

A modified version of DEA called the double-bootstrap DEA, proposed by Simar and Wilson (2007), addresses the shortcomings associated with the standard DEA method. It allows for the estimation of bias-corrected efficiency scores in the first bootstrap stage, and this allows for statistical inferences and hypothesis testing to be conducted. The second bootstrap, or double-bootstrap stage, identifies the determinants of the efficiency scores found in the first stage. The study by Molinos-Senante et al. (2018) found that the efficiency scores of Chilean water and sewerage companies were significantly different when estimated using conventional DEA compared to using double-bootstrap DEA. The ability of the double-bootstrap methodology to not only provide bias-corrected efficiency scores, but also identify the determinants of estimated efficiency, has the potential for significant policy implications. Water utility managers and policymakers can identify the utilities that are most efficient, as well as identifying which factors to target to improve the efficiency levels of the underperforming utilities.

Notwithstanding its merits, the double-bootstrap methodology has not been widely employed in water-utility efficiency studies (Ananda, 2014; Molinos-Senante et al., 2018). For the first time, this study makes use of the double-bootstrap methodology to estimate bias-corrected efficiency scores and the determinants of efficiency for South African WSAs, factoring in the location, size and non-revenue water of the WSA jurisdictions. An input-oriented model using Variable Returns to Scale (VRS) is employed. An input-oriented model is preferable to an output-oriented model, as WSAs must meet a set demand; efficiency would thus mean a reduction in the inputs used to produce the same level of output (Romano and Guerrini, 2011).

4.3. Literature review

A vast number of efficiency studies have made use of the non-parametric DEA methodology (Romano and Guerrini, 2011; Romano et al., 2017; Molinos-Senante et al., 2018). Romano and Guerrini (2011) investigated the operative cost efficiency scores of 43 Italian water utility companies using 2007 cross-sectional data. The water utilities were placed into clusters based on ownership structure, size and geographical location. The conventional DEA model was used to estimate their efficiency scores, taking these external factors into consideration (Romano and Guerrini, 2011).

The study found that ownership affected efficiency scores, with public water utilities having higher efficiency scores than private water utilities. Location was also found to affect efficiency scores, with the utilities located in the central and southern parts of Italy being the most efficient. Small utilities were found to have the highest efficiency scores, and medium-sized utilities the lowest (Romano and Guerrini, 2011). These results indicate the likelihood that ownership, size and location are determinants of efficiency. However, the study did not employ a methodology to enable the determination of each external factor's contribution towards the estimated efficiency scores. The use of cross-sectional data further limits the inferences that can be made; the use of panel data would have highlighted possible trends.

A small number of efficiency analysis studies using the DEA methodology have been conducted in South Africa's water sector. One study investigated local government efficiency in expanding their services to groups previously excluded from the economy. The study was intended to gauge the compliance of local government with the Reconstruction and Development Programme (RDP). Labour costs and operational efficiency were used as inputs, and the number of houses receiving water, electricity and sanitation under the RDP were the outputs. Efficiency was found to vary by province (Van der Westhuizen and Dollery, 2009). The study was limited to populations affected by the RDP, and thus the policy implications are limited. Due to the use of the conventional DEA model, there was no estimation of the determinants of efficiency.

Brettenny and Sharp (2016) also conducted a study in South Africa, using the conventional DEA model exclusively on the water sector to determine efficiency scores for WSAs. The study estimated the efficiency scores of 88 urban and rural WSAs. In the specification of the DEA model, operating expenditure was used as the input, and number of connections served, length of mains, water delivered to clients (metered and unmetered), measured amount of water delivered, estimated remainder of water delivered, and expenditure incurred for repairs were used as outputs. The findings show there are more urban water utilities that are efficient than rural utilities.

The study assumed that location was a significant variable in efficiency analysis, without validating that assumption with econometric tests. It did not pool the rural and urban utilities' efficiency analyses, which would have allowed comparison. Also, it did not provide estimations of the determinants of the efficiency scores. The policy implications are thus limited, as the results only give an indication of which municipality is inefficient, but no insight as to which area to target to improve efficiency. By contrast, the current study computes the efficiency scores of urban and rural WSAs in a combined sample. The double-bootstrap truncated regression results test the significance of location as a determinant of efficiency.

A study that assessed the efficiency scores of three Spanish water utilities between 1985 and 2007 made use of the conventional DEA model. Operational costs were used as the input for the specification, and water delivered, type of property and length of mains were used as outputs. This study included an exogenous input variable, namely the rainfall figure for each geographical area. The inclusion of the rainfall variable is due to the differing climatic conditions experienced by different parts of the country. Some regions have water-scarcity challenges, and the effect of water scarcity on water-utility efficiency scores was investigated. The study found that including the exogenous input of rainfall resulted in efficiency levels comparable to global findings (García-Valiñas and Muñiz, 2007). However, the study did not estimate the determinants of efficiency, due to the limited methodology used.

An efficiency analysis of 53 water utilities in Australia was estimated over six years (2005-2006 to 2010-2011). The double-bootstrap model was used to estimate bias-corrected efficiency scores and the determinants of efficiency. Operating expenditure of water services and the length of water mains (MAINS) were used as inputs for the specification, and total urban water supplied and output quality measured by water-quality complaints were the two outputs. Conventional DEA estimations found 17 utilities to be operating on the frontier, and thus efficient; but when the estimates are corrected for bias using the bootstrap technique, the number of efficient utilities falls to seven. Customer density and total connected properties were the two external factors found to have a positive relationship with efficiency (Ananda, 2014). This may be evidence of economies of scale in the Australian water sector. The study was limited to urban Australian water utilities, and did not consider whether the location of a water utility in a rural jurisdiction could affect scores. The current study computes the efficiency scores of both urban and rural WSAs.

Molinos-Senante et al. (2018) investigated bias-corrected efficiency scores and determinants of efficiency for 23 Chilean water and sewerage companies. A double-bootstrap DEA model with truncated bootstrapped regression was employed for the analysis. Operating costs, labour and network length were the inputs used. The outputs considered in the assessment were volume of water delivered and number of properties connected. The study included five potential environmental factors that were thought to influence efficiency: ownership, customer density, non-revenue water, water source and peak factor. The estimations from the conventional DEA model yielded distinctly different results to those obtained from the double-bootstrap model. The water utility ranked first by conventional DEA was ranked 16th when the double-bootstrap method was employed. The most influential efficiency determinants were found to be customer density and non-revenue water.

These results have very important policy implications. Non-revenue water loss is an endogenous environmental variable to a large extent, and thus managers and policymakers can increase efficiency significantly by putting in place measures to reduce water loss. On the other hand, customer density is an exogenous variable; thus, a water and sewerage utility manager is unable to target efficiency improvements by focusing on this variable. When considering benchmarking results, policymakers should take note of the effects of customer density on efficiency scores. However, the study did not consider the potential effects of location (urban vs rural) on water-utility efficiency.

Most studies using the non-parametric conventional DEA model were conducted elsewhere in the world, with only a few studies investigating South Africa's water sector. The studies that employ conventional DEA may be categorised into two main groups. The first group estimates the efficiency scores in the water sector. The second group investigates the efficiency scores of water utilities as they relate to external environmental variables, including non-revenue water and population density. However, none of these studies estimates the determinants of efficiency scores due to methodological limitations. There have also been international efficiency studies that have used the double-bootstrap methodology. Both developed and developing countries have used the double-bootstrap method to estimate bias-corrected efficiency scores and the determinants of efficiency of their water utilities. However, to the best of our knowledge there have been no efficiency analysis studies in the South African water sector that have employed the double-bootstrap methodology; this study is the first.

4.4. Methodology

This study uses the double-bootstrap DEA model with a truncated regression, which is a non-parametric approach. This model allows for the estimation of bias-corrected efficiency scores and the identification of the drivers of efficiency in the water sector.

The double-bootstrap DEA model is a modified version of the conventional DEA model. The DEA model employs linear programming to compute the efficiency frontier used to compare firms against each other to determine efficiency scores. All the firms included in this analysis are DMU that convert a set of identical inputs to identical outputs.

The relative efficiency of each firm or unit is estimated by comparing the volume of its inputs and outputs in relation to the other firms being analysed. The DEA models are either input- or output-oriented, depending on the specific nature of the industry being investigated. This study uses an input-oriented model that employs VRS. An input-oriented model is preferable to output-oriented models, as WSAs must meet predetermined consumer demand; thus, efficiency would mean a reduction in the amount of inputs used to produce the same level of outputs (see Simar and Wilson, 2007; Romano and Guerrini, 2011).

The double-bootstrap DEA allows for the estimation of bias-corrected efficiency scores in the first bootstrap stage, which in turn allows for statistical inferences and hypothesis testing. The second bootstrap, or the double-bootstrap stage, identifies the determinants of the efficiency scores found in the first stage by applying statistical tests to them, to determine whether there are significant differences between the efficiency scores of units clustered according to factors that may affect efficiency (see Molinos-Senante et al., 2018). The double-bootstrap DEA model algorithm proposed by Simar and Wilson (2007) is used in this study, as it is in previous studies (Zhang et al., 2016; Molinos-Senante et al., 2018).

4.5. Efficiency scores

In this report we use the DEA double-bootstrap model to compute the efficiency scores for South African WSAs. These scores are only generated for WSAs that have no missing data for the variables included in the analysis. As a result, we are able to obtain efficiency scores for 77 WSAs, for the years 2009-2012 and 2014. The double-bootstrap DEA model is a cross-sectional model, and thus each WSA is four separate DMUs for each year under analysis; 308 DMUs are included in the analysis. Due to the cross-sectional nature of the model, this means the performance of the WSAs over the four years is compared to the overall best-performing municipality in that period.

The 77 WSAs in this study are categorised into 35 urban (140 DMUs) and 42 rural (168 DMUs), based on these criteria: A, B1 and B2 are urban WSAs, and B3, B4 and C2 are rural WSAs.

4.5.1 Double-bootstrap DEA model efficiency scores: urban

In this model, the highest efficiency is achieved by the WSA that produces a level of output with the least amount of input possible. The input in this model is length of mains (in km), which is a proxy for capital expenditure and operating expenditure. The outputs are water quality (%) and authorised consumption (kl). Table 6 below details the efficiency scores and rankings of the top 20 urban DMUs.

Table 6: Top 20 most efficient urban WSAs

WSA Code	WSA Name	Year	Efficiency Score	Ranking
TSH	City of Tshwane	2011	1.01	1
CPT	City of Cape Town	2010	1.01	2
TSH	City of Tshwane	2010	1.01	3
WC024	Stellenbosch	2010	1.02	4
EKU	City of Ekurhuleni	2010	1.02	5
CPT	City of Cape Town	2014	1.02	6
WC043	Mossel Bay	2012	1.02	7
EKU	City of Ekurhuleni	2012	1.02	8
JHB	City of Johannesburg	2010	1.02	9
WC032	Overstrand	2012	1.02	10
WC024	Stellenbosch	2012	1.02	11
JHB	City of Johannesburg	2014	1.02	12
WC023	Drakenstein	2012	1.02	13
EKU	City of Ekurhuleni	2011	1.02	14
CPT	City of Cape Town	2011	1.02	15
CPT	City of Cape Town	2012	1.02	16
TSH	City of Tshwane	2012	1.02	17
WC023	Drakenstein	2010	1.02	18
WC025	Breede Valley	2012	1.02	19
MP313	Steve Tshwete	2011	1.02	20

In Table 6 above, the City of Tshwane is the top-performing urban WSA, and is used as the benchmark WSA. This means that all other 139 urban DMUs included in this study are being compared to the City of Tshwane's 2011 performance. The top five DMUs include four metropolitan WSAs, with the City of Tshwane occupying positions 1 and 3. The City of Tshwane and the City of Ekurhuleni are among the 20 top-performing DMUs for all years except 2014. The City of Cape Town is among the 20 top-performing DMUs for all the years under review.

Table 7: Top 5 most efficient urban WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
CPT	City of Cape Town	2010	1.01	2
TSH	City of Tshwane	2010	1.01	3
WC024	Stellenbosch	2010	1.02	4
EKU	City of Ekurhuleni	2010	1.02	5
JHB	City of Johannesburg	2010	1.02	9
TSH	City of Tshwane	2011	1.01	1
EKU	City of Ekurhuleni	2011	1.02	14
CPT	City of Cape Town	2011	1.02	15
MP313	Steve Tshwete	2011	1.02	20
JHB	City of Johannesburg	2011	1.02	25
WC043	Mossel Bay	2012	1.02	7
EKU	City of Ekurhuleni	2012	1.02	8
WC032	Overstrand	2012	1.02	10
WC024	Stellenbosch	2012	1.02	11
WC023	Drakenstein	2012	1.02	13
CPT	City of Cape Town	2014	1.02	6
JHB	City of Johannesburg	2014	1.02	12
EKU	City of Ekurhuleni	2014	1.02	24
FS192	Dihlabeng	2014	1.03	37
TSH	City of Tshwane	2014	1.03	38

Table 7 above shows the top five most efficient WSAs in each year. The benchmark WSA remains the City of Tshwane's 2011 performance. In 2010 and 2011, four out of the five top-performing WSAs were metropolitan. However, in 2012 the City of Ekurhuleni was the only metropolitan to remain in the top five. In 2014, the trend seen in 2010 and 2011 appeared again, with four out of the top five most efficient WSAs being metropolitan. It is worth noting that the City of Cape Town, the City of Johannesburg, the City of Tshwane and the City of Ekurhuleni were all in the top five most efficient WSAs in every year except 2012. Buffalo City, Nelson Mandela Bay, eThekwini and Mangaung were not among the five best-performing WSAs in any year.

Table 8: Top 20 least efficient urban WSAs

WSA Code	WSA Name	Year	Efficiency Score	Ranking
LIM354	Polokwane	2012	1.08	121
NW373	Rustenburg	2011	1.01	122
LIM367	Mogalakwena	2014	1.01	123
WC024	Stellenbosch	2014	1.01	124
NC091	Sol Plaatjie	2014	1.01	125
KZN225	Msunduzi	2010	1.01	126
WC044	George	2014	1.01	127
GT485	Rand West City	2012	1.01	128
WC043	Mossel Bay	2014	1.01	129
NW373	Rustenburg	2012	1.01	130
GT485	Rand West City	2010	1.01	131
NW373	Rustenburg	2010	1.10	132
NW373	Rustenburg	2014	1.11	133
GT485	Rand West City	2011	1.11	134
WC043	Mossel Bay	2010	1.11	135
GT484	Merafong City	2012	1.11	136
GT484	Merafong City	2010	1.11	137
GT484	Merafong City	2011	1.11	138
GT485	Rand West City	2014	1.13	139
GT484	Merafong City	2014	1.14	140

Table 8 above shows the efficiency scores and rankings of the 20 least efficient urban DMUs in the period under review. Merafong City’s 2014 performance is the least efficient DMU overall. Merafong City occupies four out of the five least efficient DMU positions in 2010-2012 and 2014, with Rand West City occupying the fifth position and ranked 139th out of 140. It is worth noting that Rand West and Rustenburg are among the 20 least efficient DMUs for all four years under review.

Table 9: Top 5 least efficient urban WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
GT484	Merafong City	2010	1.11	137
WC043	Mossel Bay	2010	1.11	135
NW373	Rustenburg	2010	1.10	132
GT485	Rand West City	2010	1.10	131
KZN225	Msunduzi	2010	1.10	126
GT484	Merafong City	2011	1.11	138
GT485	Rand West City	2011	1.11	134
NW373	Rustenburg	2011	1.10	122
KZN282	uMhlathuze	2011	1.10	119
KZN252	Newcastle	2011	1.10	116
GT484	Merafong City	2012	1.11	136
NW373	Rustenburg	2012	1.10	130
GT485	Rand West City	2012	1.10	128
LIM354	Polokwane	2012	1.10	121
GT422	Midvaal	2012	1.10	111
GT484	Merafong City	2014	1.14	140
GT485	Rand West City	2014	1.13	139
NW373	Rustenburg	2014	1.11	133
WC043	Mossel Bay	2014	1.10	129
WC044	George	2014	1.10	127

Table 9 above shows the five least efficient WSAs in each year. Merafong, Rand West City and Rustenburg are among the top five least efficient WSAs in every year.

4.5.2. Double-bootstrap DEA model efficiency scores: rural

Efficiency in this model is achieved by the WSA that produces a level of output with the least possible amount of inputs. The input in this model is length of mains (in km), which is a proxy for capital expenditure and operating expenditure. The outputs are water quality (%) and authorised consumption (kl). Table 10 below details the efficiency scores and rankings of the top 20 rural DMUs.

Table 10: Top 20 most efficient rural WSAs

WSA Code	WSA Name	Year	Efficiency Score	Ranking
NC066	Karoo Hoogland	2012	1.01	1
NC061	Richtersveld	2010	1.01	2
NC077	Siyathemba	2011	1.02	3
FS196	Mantsopa	2010	1.02	4
NC077	Siyathemba	2010	1.02	5
NC077	Siyathemba	2014	1.02	6
NC077	Siyathemba	2012	1.02	7
FS191	Setsoto	2014	1.03	8
FS183	Tswelopele	2012	1.03	9
NC067	Khâi-Ma	2011	1.03	10
NC061	Richtersveld	2012	1.03	11
NC067	Khâi-Ma	2010	1.03	12
FS196	Mantsopa	2012	1.03	13
FS205	Mafube	2011	1.03	14
NC453	Gamagara	2011	1.03	15
FS196	Mantsopa	2014	1.03	16
LIM362	Lephalale	2014	1.04	17
NC453	Gamagara	2010	1.04	18
NC453	Gamagara	2014	1.04	19
NC061	Richtersveld	2014	1.04	20

In Table 10 above, Karoo Hoogland is the top-performing rural WSA, and is used as the benchmark WSA. This means that all other 165 rural DMUs included in this study are being compared to Karoo Hoogland's 2012 performance. Karoo Hoogland does not appear in the top 20 best-performing WSAs, aside from in 2012. Siyathemba is in the top 10 most efficient WSAs for all four years under review. Gamagara and Richtersveld are among the top 20 most efficient WSAs for three out of the four years under review. It is worth noting that none of the district WSAs are among the top 20 most efficient WSAs.

Table 11: Top 5 most efficient rural WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
NC061	Richtersveld	2010	1.01	2
FS196	Mantsopa	2010	1.02	4
NC077	Siyathemba	2010	1.02	5
NC067	Khâi-Ma	2010	1.03	12
NC453	Gamagara	2010	1.04	18
NC077	Siyathemba	2011	1.02	3
NC067	Khâi-Ma	2011	1.03	10
FS205	Mafube	2011	1.03	14
NC453	Gamagara	2011	1.03	15
FS191	Setsoto	2011	1.04	21
NC066	Karoo Hoogland	2012	1.01	1
NC077	Siyathemba	2012	1.02	7
FS183	Tswelopele	2012	1.03	9
NC061	Richtersveld	2012	1.03	11
FS196	Mantsopa	2012	1.03	13
NC077	Siyathemba	2014	1.02	6
FS191	Setsoto	2014	1.03	8
FS196	Mantsopa	2014	1.03	16
LIM362	Lephalale	2014	1.04	17
NC453	Gamagara	2014	1.04	19

Table 11 above shows the top five most efficient rural WSAs in each year. The benchmark WSA remains Karoo Hoogland's 2012 performance. Siyathemba is among the top five most efficient WSAs in every year under review. Mantsopa and Gamagara are among the top five most efficient WSAs for three out of the four years. It is also worth noting that the district WSAs are not among the top five most efficient WSAs in any year under review. This may indicate that no economies of scale exist in the South African Rural Water Sector.

Table 12: Top 20 least-performing rural WSAs

WSA Code	WSA Name	Year	Efficiency Score	Ranking
MP316	Dr JS Moroka	2011	1.22	149
FS161	Letsemeng	2011	1.22	150
DC14	Joe Gqabi District Municipality	2011	1.22	151
EC109	Kou-Kamma	2014	1.22	152
WC034	Swellendam	2010	1.22	153
EC105	Ndlambe	2014	1.22	154
NC062	Nama Khoi	2012	1.22	155
FS161	Letsemeng	2012	1.23	156
DC29	iLembe District Municipality	2012	1.24	157
DC29	iLembe District Municipality	2014	1.25	158
NC062	Nama Khoi	2010	1.25	159
FS161	Letsemeng	2014	1.26	160
NC062	Nama Khoi	2011	1.26	161
NC062	Nama Khoi	2014	1.30	162
FS162	Kopanong	2010	1.31	163
FS162	Kopanong	2011	1.31	164
FS162	Kopanong	2014	1.32	165
DC12	Amathole District Municipality	2011	1.34	166
DC12	Amathole District Municipality	2010	1.34	167
FS162	Kopanong	2012	1.38	168

Table 12 above shows the efficiency scores and rankings of the 20 least efficient rural DMUs in the period under review. Kopanong's 2012 performance is the least efficient DMU. Kopanong occupies three out of the five positions of the five least efficient DMUs from 2010-2012 and 2014, and the sixth position when considering the top 10 least efficient WSAs. Nama Khoi is among the 20 least efficient WSAs for all the years under review in this study. The Amathole district, iLembe district and Joe Gqabi district WSAs are among the 20 least efficient WSAs.

Table 13: Top 5 least efficient rural WSAs in each year

WSA Code	WSA Name	Year	Efficiency Score	Ranking
DC12	Amathole District Municipality	2010	1.34	167
FS162	Kopanong	2010	1.31	163
NC062	Nama Khoi	2010	1.25	159
WC034	Swellendam	2010	1.22	153
WC033	Cape Agulhas	2010	1.22	146
DC12	Amathole District Municipality	2011	1.34	166
FS162	Kopanong	2011	1.31	164
NC062	Nama Khoi	2011	1.26	161
DC14	Joe Gqabi District Municipality	2011	1.22	151
FS161	Letsemeng	2011	1.22	150
FS162	Kopanong	2012	1.38	168
DC29	iLembe District Municipality	2012	1.24	157
FS161	Letsemeng	2012	1.23	156
NC062	Nama Khoi	2012	1.22	155
EC109	Kou-Kamma	2012	1.22	148
FS162	Kopanong	2014	1.32	165
NC062	Nama Khoi	2014	1.30	162
FS161	Letsemeng	2014	1.26	160
DC29	iLembe District Municipality	2014	1.25	158
EC105	Ndlambe	2014	1.22	154

Table 13 above shows the five least efficient WSAs in each year under review. Kopanong and Nama Khoi are among the top five least efficient WSAs for every year under review.

4.6. Conclusion

This section computed the bias-corrected efficiency scores and the determinants of efficiency for rural and urban South African WSAs from 2010 to 2014. A double-bootstrap DEA model was used to carry out analysis. The results obtained in this study strongly highlight the importance of using robust techniques when estimating efficiency scores. The biased efficiency scores differed significantly from the bias-corrected scores. In regions where efficiency scores are used to determine tariff levels, the biased efficiency scores would be very misleading. A significant number of the WSAs' efficiency scores were overestimated by the conventional DEA model.

The double-bootstrap DEA efficiency scores above highlight some important findings for both the urban and the rural water sectors of South Africa. Among the urban WSAs, four out of the eight metropolitan WSAs are among the most efficient WSAs, and none of the eight are among the least efficient in any of the years under review. This may potentially indicate economies of scale in the urban sector. However, the rural efficiency scores are indicative of a different possible conclusion. The district WSAs are not among the most efficient WSAs for any of the years under review, but three district WSAs are among the least-performing WSAs. This may indicate the absence of economies of scale in the rural water sector.

Chapter 5: DEA benchmarking tool in MS Excel

5.1. Introduction

The origins of efficiency or benchmarking may be traced back to Farrell's 1957 study. Theoretical development of the DEA approach was started in 1978 by Charnes et al., who produced a measure of efficiency for DMU. DEA is a non-parametric linear programming-based technique that develops an efficiency frontier by optimising the weighted output/input ratio of each provider, subject to the condition that this ratio can equal, but never exceed, unity for any other provider in the dataset (Charnes et al., 1978).

The DEA tool has gained significant popularity among academicians and practicians in assessing the performance of both government and private organisations. Many developed countries and international organisations have adopted this tool in benchmarking their organisations, including water utilities (Renzetti and Dupont, 2018; Gupta, Kumar and Sarangi, 2012; DeWitte and Marques, 2009; Corton and Berg, 2009; Ozcan, 2008; Picazo-Tadeo et al., 2008).

DEA models can generate new alternatives to improve performance, compared to other techniques. Linear programming is the backbone methodology, and is based on an optimisation platform. Thus what differentiates the DEA from other methods is that it identifies the optimal ways of performance, rather than the average ways. In today's world, no manager can afford to be an average performer in a competitive market – before we even take into account the increasing demand for improved water quality, in aspects ranging from the social to the economic, and under financial and climate-change pressures. The identification of optimal performance leads to benchmarking in a normative way. Using DEA, WSA managers can not only identify top performers, but also discover alternative ways to spur their organisations on to becoming the best performers.

Despite the advantages of DEA in benchmarking its application, it has still been the subject of countless research publications, conferences, dissertations, and other academic exercises, with limited adoption as a standard tool for benchmarking and decision-making in some organisations. This is partly due to its complicated formulation, and to the failure of DEA specialists to adequately bridge the theory-practice gap. The aim of this section is to present DEA from a practical perspective, leaving the 'black box' of sophisticated formulations in the background so that WSA managers may easily apply it – by means of a user-friendly Microsoft Excel spreadsheet, which they are familiar with – to analyse the performance of their organisations.

The practical approach presented here is to enable managers to understand the pitfalls of the performed evaluations, so they will feel confident in presenting, validating, and making decisions based on DEA results. In addition, DEA will help them to 1) assess their organisation's relative performance; 2) identify top performers in the group of water and sanitation providers; and 3) identify ways to improve their performance if their organisation is not one of the top-performing organisations. This document describes the practical application of the MS Excel DEA tool to enable self-assessment among water and sanitation providers in South Africa.

The other sections in this chapter are organised as follows: Section 2 provides the conceptual framework of the DEA tool. Section 3 demonstrates the practical application of the software in benchmarking WSAs; and Section 4 provides a summary.

5.2. The conceptual framework of the DEA tool

To run the DEA model, some basic understanding of the tool is imperative. We are not going to unpack the 'black box'; rather, we provide the basic concepts and framework of the DEA model, to help the user understand some important choices and their implications when running the model. Here are some key concepts.

5.2.1. Efficiency measures

In simple terms, efficiency is the ratio of output to input. To improve efficiency, one must either increase the outputs or decrease the inputs. If both outputs and inputs increase, the rate of increase for the outputs should be greater than the rate of increase for the inputs. Conversely, if both outputs and inputs are decreasing, the rate of decrease for the outputs should be lower than the rate of decrease for the inputs. Another way to achieve higher efficiency is to introduce technological changes, or to re-engineer service processes – known as 'lean management' – which in turn may reduce inputs, or increase the ability to produce more outputs (Ozcan, 2009). The level of efficiency of WSA organisations may also be the result of other factors, such as the price of the inputs or the scope of the production process (scale). Thus, it is prudent to understand the types and components of efficiency in more depth. Major efficiency types may be divided into technical, scale, price and allocative efficiencies.

A) Technical efficiency

Consider WSA A, using a specific sophisticated pumping technology. The pump can supply 80 Megalitres of water per month, with 120 hours of technician time. Last month, WSA A supplied 60 Ml of water, while technicians were on the premises for 120 hours. As shown in Table 14 below, the best achievable efficiency score for WSA A is 0.667 (80/120); but due to their technical inefficiency – their output of 60 Ml – their current efficiency score is 0.5 (60/120). We assess that WSA A is operating at 75% efficiency (0.5/0.667). This is called its technical efficiency. For WSA A to become technically efficient, it would have to increase its current output by 20 Ml per month.

Table 14: Technical efficiency

WSA	Supplying Capacity per Month	Technician / Operators Time in Hours	Current Supply per Month	Best Achievable Efficiency	Efficiency
A	80 Ml	120	60 ML	0.667	0.500

B) Scale efficiency

Now consider WSA B, which has a less sophisticated pump than WSA A. WSA B uses standard pumping technology, which supplies only 30 Ml of water per month, with technician time of 180 hours. The efficiency score of WSA B is 0.167 (30/180). Compared to what WSA A could ideally provide, WSA B is at 25% efficiency (0.167/0.667) in its use of the technician's time. If we consider only what WSA A was actually able to achieve, WSB B is operating at 33.3% relative efficiency in this comparison (0.167/0.5). If WSA B used similar technology to WSA A, given the same amount of technician time (180 hours) it could supply 90 additional Megalitres; it would need to supply an additional 60 Ml to achieve the same efficiency level as WSA A. The total difference between WSA B's efficiency score and WSA A's best achievable efficiency score is 0.5 (0.667/0.167). The difference between WSA B's efficiency score and WSA A's current efficiency score is 0.333 (0.5/0.167). Thus, we can make the observations in Table 15 below.

Table 15: Technical and scale efficiency

WSA	Supplying Capacity Per Month	Technician / Operator Time in Hours	Current Supply Per Month	Best Achievable Efficiency	Efficiency	Scale Efficiency
A	80 Ml	120	60 Ml	0.667	0.500	
B	30 Ml	180	30 Ml	0.167	0.167	0.333

1) WSA B is technically inefficient, illustrated by the component 0.167.
2) WSA B is also scaled inefficient, illustrated by the difference of 0.333.

The scale inefficiency can only be overcome by adopting the new technology or new service production processes. By contrast, the technical inefficiency is a managerial problem, where more outputs are required for a given level of resources. We should also add that even though WSA A supplies 80 Ml per month, we cannot say that WSA A is absolutely efficient unless it is compared to other WSAs with similar technology. However, at this point we know that differences in technology can create economies of scale in the WSA service production process. Using various DEA methods, WSA managers can calculate both technical and scale efficiencies.

C) Price efficiency

Efficiency evaluations can be assessed using price or cost information for inputs and/or outputs. For example, if the charge for the sophisticated supply tech (WSA A) is R18 000 per Megalitre and the charge for traditional tech is R35 000 per Ml, the resulting efficiency for WSA A and WSB B would be as follows:

$$\text{Efficiency (A)} = (60*18\ 000) / 120 = \text{R}9\ 000.00 \quad \textbf{(2)}$$

$$\text{Efficiency (B)} = (30*35\ 000) / 180 = \text{R}5\ 833.33 \quad \textbf{(3)}$$

If a technician's time is reimbursed at the same rate for either the standard pumping tech or the sophisticated tech, WSA A appears more efficient than WSA B; however, the difference in this case is due to the price of the output. If WSA B used 120 hours to supply half as much water as WSA A (30 Ml), its price efficiency score would have been R8 750, which clearly indicates the effect of the output price. If WSA managers use the cost information in inputs or charge/revenue values for outputs, DEA can provide useful information for inefficient WSAs about potential reductions in input costs, and needed revenue/charges for their outputs. For WSAs, although charges/revenues are generally negotiated with third-party payers, these evaluations would provide valuable information to WSA managers, and provide a basis for their negotiations.

D) Allocative efficiency

When a WSA has more than one input (and/or output), the WSA manager is interested in the appropriate mix of inputs for supplying water in such a way that the organisation can achieve efficiency. Let us consider three group practices – A, B and C – in which two types of professionals, engineers (E) and technicians (T), are responsible for water supply. Furthermore, assume that an engineer's time costs R100/h, whereas a technician's time costs R60/h. Let us suppose that Group Practice A employs three engineers and one technician, Group Practice B employs two engineers and two technicians, and Group Practice C employs three engineers and three technicians. Assume that all group practices produce 500 Ml in a week. Further, assume that the practices are open for eight hours a day for five days a week (40 hours). Input prices for the group practices are:

A) Inputs for Group Practice A = [(3*100) + (1*60)] * 40 = R14 400 **(4)**
B) Inputs for Group Practice B = [(2*100) + (2*60)] * 40 = R12 800 **(5)**
C) Inputs for Group Practice C = [(3*100) + (3*60)] * 40= R19 200 **(6)**

Since the output is the same, evaluating the input mix for these three group practices per visit yields the following ratios:

A) Group Practice A = 14 400 / 500 = R28.80 **(7)**
B) Group Practice B = 12 800 / 500 = R25.60 **(8)**
C) Group Practice C = 19 200 / 500 = R38.40 **(9)**

Table 16: Allocative efficiency

Group practice	Engineer (R100/h)	Technician (R60/h)	Input: prices (R)	Output: supply (Ml)	Efficiency	Allocative Efficiency
A	3	1	14 400	500	R 28.80	0.889
B	2	2	12 800	500	R 25.60	1.000
C	3	3	19 200	500	R 38.40	0.667

Comparing these costs, one can conclude that Group Practice A is 88.9% (25.60/ 28.80) efficient compared to Group Practice B. Similarly, Group Practice C is 66.7% (25.60/38.40) efficient compared to Group Practice B.

5.2.2. Efficiency measure under Data Envelopment Analysis

Efficiency calculated by DEA is relative to the DMUs analysed in an evaluation. The efficiency score for best-performing (benchmark) DMUs in DEA evaluation would only represent the set of organisations considered in the analysis. The organisations identified as top performers in one year may not achieve this status if evaluations are repeated in subsequent years. Additionally, if more organisations (DMUs) are included in another evaluation, their status may change, since the relative performance will take the newcomers into consideration. Although DEA can clearly identify improvement strategies for those non-top-performing organisations, further improvement of top performers depends on other factors, such as new technologies and other changes in the production process.

DEA essentially forms a frontier using efficient organisations. Table 16 above illustrates the conceptualisation of the DEA frontier; Group B is on the frontier, and the other groups are evaluated against Group B. In DEA, the efficient WSA will receive a score of 1, and those that are not on the efficiency frontier line will be less than 1 but greater than 0. The DEA score will show the percentage of inefficiency (or the area for improvement), which is 1 minus the efficiency score. The inefficiency score suggests an organisation must reduce usage of both inputs and/or outputs (depending on the model orientation) proportionately to reach a point on the frontier (to perform like the organisation on the frontier). This is the normative power of DEA; it can suggest how much improvement is needed from each inefficient WSA in each dimension of the resources.

5.2.3. DEA model orientation

As discussed in the previous section, the orientation of the model is crucial in determining the direction of improvement for the DMU. In DEA we have several model orientations, but there are two main ones: input orientation and output orientation. When we calculate efficiency output over input and place emphasis on reduction of inputs (while attaining the same level of output) to improve efficiency, in DEA analysis this is called input orientation. Input orientation assumes managers have more control over the inputs than over the output, while output orientation implies the increase of output with the given inputs. The reverse argument can be made; that managers – through marketing, or by other means (such as reputation for quality of service) – are able to attract more customers to their facilities. This means they can augment their outputs, given the capacity of their inputs are fixed, to increase their organisation's efficiency. Output augmentation to achieve efficiency in DEA is called output orientation.

Various DEA models have been developed to use either input or output orientation, and these models emphasise proportional reduction of excessive inputs (input slacks) or proportional augmentation of lacking outputs (output slacks). However, there are also models managers can use to place emphasis on both output augmentation and input reduction at the same time, by improving output slacks and decreasing input slacks. These slack-based models are also called additive or non-oriented models in the DEA literature and software.

5.2.4. Basic DEA models

Various types of DEA models may be used, depending on the conditions present for the problem at hand. The type chosen for a particular situation will depend on the scale and orientation of the model. These are the basic DEA models available:

(a) Constant Returns to Scale (CRS)

If one can assume that economies of scale do not change as the size of the service facility increases, then the 'constant returns to scale' (CRS) type of DEA model is an appropriate choice. The initial basic frontier model was developed by Charnes et al.

(1978) and was known as the CCR model, from the initials of the developers' last names, but is now widely known as the constant returns to scale model.

(b) Variable Returns to Scale (VRS)

The other basic frontier model, initially known as BCC (Banker, Charnes and Cooper), followed CCR and is now called the 'variable returns to scale' (VRS) model. In this model, one cannot assume that economies of scale do not change as the size of the service facility increases. Figure 1 below shows the basic DEA models, based on returns to scale and model orientation. They will be referred to as 'Basic Envelopment Models'.

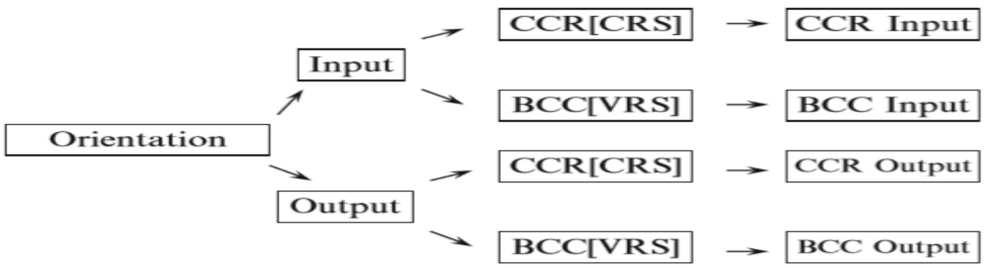

Figure 1: Performance measurement using Data Envelopment Analysis

5.2.5. Decision-Making Units

Organisations subject to evaluation in the DEA literature are called DMUs. For example, many popular DEA software programs consider WSAs, industries, group practices and other facilities evaluated for performance using DEA to be DMUs.

DEA is a comparative approach for identifying performance or its components by considering multiple resources that are used to achieve outputs or outcomes in an organisation. These evaluations can be conducted not only at the organisation level but also in sub-units; such as departmental comparisons, where many areas of improvement in savings of input resources or strategies to augment the outputs can be identified.

5.2.6. Limitations of DEA

In summary, a DEA identifies a group of optimally performing DMUs that are defined as efficient, and assigns them a score of one. These efficient DMUs are then used to create an ‘efficiency frontier’ or ‘data envelope’ against which all other DMUs are compared. DMUs that require relatively more weighted inputs to produce weighted outputs – or alternatively, produce less weighted outputs per weighted inputs than DMUs on the efficiency frontier – are considered technically inefficient. They are given efficiency scores that are strictly less than1, but greater than zero.

Although DEA is a powerful optimisation technique for assessing the performance of each DMU, it has certain limitations that must be addressed. When one is dealing with significantly large numbers of inputs and outputs in the service production process, but only a small number of organisations are under evaluation, the discriminatory power of a DEA is limited. However, an analyst could overcome this limitation by including only those factors (both input and output) that provide the essential components of the service's production process, thus not distorting the DEA results. This is generally done by eliminating one pair of factors that are strongly positively correlated with each other. Cooper et al. (2007) suggest that to have adequate numbers of degrees of freedom (adequate discriminatory power for the DEA model), the number of DMUs (n) should exceed the number of inputs (m) and outputs (s) by several times. More specifically, they suggest a rule-of-thumb formula that n should be greater than max {m*s, 3* (m + s)}.

5.3. Practical application of the DEA tool

This section describes a practical approach to benchmarking WSAs. As the policy leader, the DWS can either set up a regulatory body or appoint a service provider to undertake benchmarking on their behalf. The appointed body may adopt this approach:

- information gathering[
- ensuring data consistency, and performing data verification and cleansing;
- determining material KPIs;
- performing a quantitative assessment of each KPA service category, including the identification of appropriate benchmarking metrics and external benchmarking data;
- performing a qualitative assessment of the benchmarking results; and
- making recommendations for potential efficiency gains.

As an initial step, we propose using an MS Excel toolkit. For impartiality, it is vital that this tool is managed by a third party, and not by any of the WSAs. To get the buy-in of the WSAs it is important that they understand how it works, which is why we saw the need to share this in the report (see **Appendix 2**). Although in this instance the tool is run by a third party (a water regulator or consultancy), the results are formally shared with the DWS, the WSAs, and all water stakeholders. Moreover, they would be shared on the website. A functional and interactive website would enable anyone to access and generate efficiency scores.

5.4. Summary

To assist in identifying practical approaches to benchmarking in the regulatory environment, the research team surveyed international regulatory benchmarking practices around the world. Thereafter, the team looked at possible data that could be used for benchmarking in South Africa. South Africa has a comprehensive inventory of information (a bank of data) that may be collected, compared and mined for overall observations. However, the regulators have done little in the way of analysis of this information.

DEA is a useful tool in a benchmarking and performance-assessment exercise and has many advantages for informing decision making, if the tool is used appropriately and results are interpreted accordingly. We propose that this task be delegated to a third party; and that for credibility of results, reports on efficiency should be shared with all stakeholders, and made available on the website. We give an initial snapshot of potential software, and for data to be shared online. Moreover, we propose an online system for data retrieval that any water stakeholder or researcher can access. In addition, the online platform should allow any user to generate efficiency scores.

Chapter 6: Impact of water service efficiency on economic growth

6.1. Introduction

The efficient use of the country's scarce financial and water resources is key for the sustainable delivery of water services, while the effective delivery of water has significant economic benefits, both direct and indirect. Depending on the service delivery arrangement and appropriate funding, the efficiency and effectiveness of water service delivery, plays an important role in economic growth and industrial development at both regional and national level. Improved water provision impacts directly on economic growth through its use as an input in water-intensive industries, and indirectly through its impact on the quality and productivity of human capital in the overall economy. Therefore, we also assess the impact of improved efficiency and delivery of water services by municipalities on economic growth, industrial development, and employment absorption in South Africa.

One can also infer a connection between service delivery efficiency and economic growth and development on the one hand, and redress on the other hand, as well as sustainable development solutions. In terms of transformation and redress, the outcomes of this research could initiate transformation from traditional and conventionally accepted forms of service delivery to more innovative options. This would be further supported by the effect of a proposed framework for the assessment of the water sector on other macroeconomic indicators.

Quantifying the efficiency of the provision of water, a scarce resource, will assist in improving the sustainability of service provision, while simultaneously determining key solutions for effectively using water provision for economic and social development. To this end, this report quantifies the direct impact of improved water services on economic and industrial growth, and the indirect impact on employment creation. Such findings will allow policymakers to address and improve on the growth-enhancing aspects of water-service delivery.

Water-service provision and efficiency have recently become an important part of the debate on economic growth. Grey and Sadoff's 2006 World Bank report, 'Water for Growth and Development', pointed out the significance of water – that water has always played a central role in human society. As an input to almost all production in agriculture, industry, energy and transport, water is a key driver of sustainable growth and poverty alleviation for healthy people in healthy ecosystems. Better access to clean water, sanitation services and water management creates tremendous opportunities for the poor, and is a progressive strategy for economic growth.

Against this background, the motivation for this chapter is the empirical testing of the impact of water-service provision and the efficiency of water delivery on economic growth in South Africa**.** The aim of this section is to quantify the direct impact of efficiency of water provision (through municipal operating and capital expenditure) on local economic and industrial growth.

6.2. Background

A report commissioned by the governments of Norway and Sweden as an input to the Commission of Sustainable Development (CSD), because of its 2004-2005 focus on water, sanitation and related issues, articulated the close link between water and the economy, and made the case that investing in water management and services is essential for the eradication of poverty, and a necessary condition for enabling sustained economic growth. The report argued that the poor gain directly from improved access to basic water and sanitation services, through improved health, averted healthcare costs and time saved. Good management of water resources brings more certainty and efficiency in productivity across economic sectors, and contributes to the health of the ecosystem. Taken together, these interventions lead to immediate and long-term economic, social, and environmental benefits that make a difference to the lives of billions of people (SIWI, 2005).

Moreover, a report titled 'Exploring the links between water and economic growth' (Frontier Economics, 2012) suggested that water and its links to economic growth have multiple dimensions, ranging from sustainable agriculture, industries and ecosystems to communities in general. One link that can be highlighted concerns access to safe drinking water and basic sanitation services. Improved access has a direct positive impact on people and communities, leading to significant social, economic and environmental benefits. This explains why a United Nations (UN) Millennium Development Goal (MDG) is "to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 compared with 1990 levels". A February 2018 report by the World Health Organisation (WHO) indicates that "in 2010, the world met the United Nations Millennium Development Goals target on access to safe drinking water, as measured by the proxy indicator of access to improved drinking-water sources, but more needs to be done to achieve the sanitation target". Effective management of freshwater resources helps sustain agriculture, industries, ecosystems and communities (Frontier Economics, 2012).

However, water can also undermine economic growth; as a force for destruction, through drought, flood, landslides and epidemics; as well as progressively, through erosion, inundation, desertification, contamination and disease. Water is quite literally a source of life and prosperity and a cause of death and devastation. This destructive aspect of water, because of its extraordinary power, mobility, unavoidability and unpredictability, is arguably unique. Achieving basic water security, harnessing the productive potential of water and limiting its destructive impact, has been a constant struggle since the origins of human society (Grey and Sadoff, 2006).

Throughout history, water has also been a source of dispute and even conflict – between uses and between users – on both a local and larger scales. As water becomes ever scarcer relative to demand, fears are emerging of transboundary waters becoming a source of conflict, constraining economic growth; conversely, there is also an emerging experience of cooperation on transboundary waters, supporting regional integration as a driver of growth (Grey and Sadoff, 2006; 2007).

As then, so today; water resources development and management remain at the heart of the struggle for growth, sustainable development and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in water infrastructure, institutions and management capacity. It remains the case in many developing countries today, where investments in water development and management remain an urgent priority. In some developing countries – often the poorest – the challenge of managing their water legacy is almost without precedent.

The Stockholm International Water Institute (SIWI) report, 'Making Water a Part of Economic Development: The Economic Benefits of Improved Water Management and Services' (SIWI, 2005) indicates the link between water and the economy. The report also brings to the forefront direct and indirect costs related to inaction, the costs of action, and cost-benefit comparisons. The report draws the following conclusions:

- Improved water supply and sanitation and improved water resources management boost countries' economic growth, and contribute greatly to poverty eradication,
- The economic benefits of improved water supply and sanitation far outweigh the investment costs – surprisingly good news for both Northern and Southern decision-makers, who often view investments as mere costs,
- National economies are more resilient to rainfall variability, and economic growth is boosted when water-storage capacity is improved,
- Investing in water is good business – improved water resources management and improved water supply and sanitation contribute significantly to increased production and productivity within economic sectors,
- The overall public and private investment needs for improved water supply and sanitation and improved water resources management are considerable. However, at country level, meeting such investment challenges is highly feasible and within the reach of most nations.

Thus, as water management to ensure water provision and more efficient use is re–emerging as a policy focus on economic growth and development agendas, there is consensus that water resources development and management are essential to generate wealth, mitigate risk, and alleviate poverty (SIWI, 2005). Water-resources management approaches around the world are changing dramatically. This changing water paradigm has many components, including a shift away from sole – or even primary – reliance on finding new sources of supply to address perceived new demands; growing emphasis on incorporating ecological values into water policy; a re-emphasis on meeting basic human needs for water services; and a conscious breaking of the ties between economic growth and water use (Babier, 2004; Brown and Lall, 2006).

Reliance on physical solutions continues to dominate traditional planning approaches, but these solutions are facing increasing opposition. At the same time, new methods are being developed to meet the demands of growing populations without requiring major new construction or new large-scale water transfers from one region to another. More and more water suppliers and planning agencies are beginning to explore efficiency improvements, including implementing options for managing demand, and reallocating water among users to reduce projected gaps and meet future needs. The connections between water and economic growth are receiving increasing attention, as the concerns of economic growth experts begin to encompass the realities of water availability (Gleick, 2000; Musouwir, 2009).

An estimated three out of four jobs making up the global workforce are either heavily or moderately dependent on water. This means that water shortages and problems of access to water and sanitation could limit economic growth and job creation in the coming decades, according to a UN report. The 2016 edition of the United Nations World Water Development Report 'Water and Jobs' also notes that half of the world's workers – 1.5 billion people – are employed in eight water- and natural-resource-dependent industries (UNESCO, 2016). Failure to secure an adequate and reliable supply of water to support heavily water-dependent sectors results in the loss or disappearance of jobs (i.e. no water, no jobs). Floods, droughts and other water-related risks can also have economic and employment repercussions that go far beyond the immediately affected areas (ILO, 2013).

In addition to jobs in agriculture and industry, sectors with heavily water-dependent jobs include forestry, inland fisheries and aquaculture, mining and resource extraction, water supply and sanitation, and most types of power generation. This category also includes some jobs in the health care, tourism and ecosystem management sectors. While the dynamics of water, economic growth and employment are complex and highly dependent on specific physical, cultural, political and economic circumstances, sound public governance – together with public and private investment in water resources management, and water infrastructure and services – can generate and support employment across all sectors of the economy. These opportunities range from full-time decent jobs to more precarious informal ones, encompassing a wide range of skill sets (ILO, 2013).

6.3. The contribution of water to the South African economy

The reliable supply of water in enough quantities and required quality is a crucial input to economic growth and job creation. The contribution of water to the major economic sectors in South Africa is:

6.3.1. Agriculture sector

In South Africa, about 8.5 million people are directly or indirectly dependent on agriculture for employment and income (GCIS, 2011). The sector contributes about 3% of the GDP and 7% to formal employment. The agricultural sector is made up of commercial farmers and subsistence farmers: about 1.3 million hectares are irrigated. The New Growth Path has set a target of 300 000 households in smallholder schemes by 2020, as well as 145 000 jobs to be created in agro-processing by 2020 (DED, 2010). Irrigated agriculture is the largest single use of water in South Africa (60%), and has the potential for huge socio-economic impact in rural communities. Water is the major limiting factor to the growth of this sector, and poor water quality has a negative impact on agricultural exports and associated foreign income.

Irrigated agriculture is a vital component of total agriculture, and supplies many of the fruits, vegetables, and cereal foods consumed by humans; the grains fed to animals that are used as human food; and the feed to sustain animals for work, in many parts of the world (Howell, 2001). Insufficient or erratic water supply affects the quality and quantity of employment in the agri-food sector. It constrains agricultural productivity and compromises income stability, with dramatic effects on the poorest households, which have limited assets and safety nets to cope with risk (UNESCO, 2016).

6.3.2. Mining sector

According to the South African Chamber of Mines, the mining sector contributed 8.8% directly and 10% indirectly to the GDP of SA in 2009 (GCIS, 2011). It creates about

1 million direct and indirect jobs. The sector accounts for approximately one-third of the market capitalisation of the JSE, and it is also the major attractor of foreign investment. The New Growth Path (NGP) has set a potential employment target of 140 000 new jobs by 2020 for the mining sector (DED, 2010). Mining and related activities require significant quantities of water, while also impacting on the environment with associated potential pollution. The development of new mines in water-scarce areas requires forward planning to decide on the transfer of water and the development of new sources.

6.3.3. Energy Sector

Globally, the demand for energy is increasing, particularly for electricity in developing and emerging economies. The energy sector, with growing water withdrawal that currently accounts for about 15% of the world's total, provides direct employment. Energy production, as a requirement for development, enables direct and indirect job creation across all economic sectors (UNESCO, 2016). In South Africa, although the energy sector uses only 2% of total water used, it contributes about 15% to GDP and creates jobs for 250 000 people (GCIS, 2011).

The energy sector generates about 95% of the electricity in South Africa, and exports to other countries in Africa. Including Eskom, the national power generator, it is highly dependent on reliable water supply for the generation of electricity (steam generation and cooling processes), and an elaborate and sophisticated network of water transfer and storage schemes has been developed specifically to support this sector and ensure high levels of reliability. The other side of the coin is that the water sector is highly dependent on a constant and reliable supply of electricity to move water.

6.3.4. Manufacturing sector

Industry is an important source of employment worldwide, and accounts for a fifth of the world's workforce. Industry and manufacturing account for approximately 4% of global water withdrawals, and it has been predicted that by 2050, manufacturing could increase its water use by 400% (UNESCO, 2016). In South Africa in 2009, the manufacturing sector contributed 15.5% to GDP, and 13.3% to jobs (GCIS, 2011). The

NGP has set a target of 350 000 new jobs for this sector by 2020. Water is an input to manufacturing processes, and is also used for cooling.

6.3.5. Tourism sector

In 2009, the tourism sector directly and indirectly contributed 7% to the South African GDP, and created 575 000 jobs (GCIS, 2011). This sector is earmarked for high economic growth, and is expected to generate a huge number of new jobs. The NGP has set a target of 225 000 new jobs by 2015 (DED, 2010). Drinking-water quality that matches international standards, a reliable water supply and reliable sanitation services are critical to the success of this sector.

6.3.6. Food and beverage sectors

The food and beverage sectors are highly dependent on water to produce their products; however, the precise contribution of the food and beverage industries to the South Africa economy must still be reckoned.

6.4. Policies and strategies towards water and economic growth in South Africa

Water provision and efficiency issues have been integrated into several national and sectoral policies and strategies, including the following;

6.4.1. National Planning Commission Vision 2030

The National Planning Commission has paid attention to water issues and how they impact and influence development pathways and opportunities in South Africa. For more details, see the National Development Plan – Vision for 2030.

6.4.2. New Growth Path (NGP)

Water has a role to play in four out of five of the job drivers identified in the NGP, and the National Water Resource Strategy (NWRS-2) supports the NGP in the following areas:

Jobs Driver 1: Infrastructure for employment and development – The NWRS-2 includes a sub-strategy focusing on infrastructure development and management that will create new job opportunities over the next five years. The sub-strategy outlines a plan for funding infrastructure development needed to support economic growth in South Africa.

Jobs Driver 2: Improving job creation in economic sectors – The NWRS-2 includes reconciliation strategies for balancing water supply and demand in high-growth areas. It also provides a framework for strong sector leadership, streamlined water-use authorisation processes, and an economic regulator. The NWRS-2 also prioritises water conservation and water demand management (WC/WDM) in all sectors, to increase productivity per unit of water. This enables the possibility of the water saved being used in new or expanded enterprises.

Job Driver 3: Seizing the potential of new economies – The NWRS-2 makes provision for the recycling and re-use of waste water, and for water to be used in supporting the green economy and the creation of jobs in this area.

6.4.3. Industrial Policy Action Plan 2

The Industrial Policy Action Plan 2 (IPAP 2) is a central tool in the NGP job creation strategy (DTI, 2011). The NWRS-2 is in line with the IPAP2 support for job creation, through the promotion of rainwater harvesting, water recycling and the production of water- and energy-efficient appliances.

6.4.4. Rural Development Strategy

Water availability is a crucial input to the Rural Development Strategy. The NWRS-2 makes provision for supporting rural development through the multiple uses of dams, investment in appropriate water infrastructure, water-allocation reform, and a programme of support for small-scale water users.

6.4.5. National Biodiversity Management Strategy

This strategy falls under the auspices of the Department of Environmental Affairs, and is aimed *inter alia* at the integrated management of terrestrial and aquatic ecosystems (DEAT, 2005). Protection of aquatic ecosystems is addressed in a specific strategy in the NWRS-2.

6.4.6. Irrigation Strategy

The Irrigation Strategy, developed by the Department of Agriculture, Forestry and Fisheries, aims to increase the contribution of agriculture to the GDP, reduce poverty and create employment (DAFF, 2010). It also aims to increase water-use efficiency and redress imbalances in access to irrigated agriculture for historically disadvantaged groups. The NWRS-2 makes provision for infrastructure development to support the implementation of this strategy, and sets targets for water-use efficiency by the agriculture sector, and water reallocation to historically disadvantaged water users.

6.4.7. National Energy Efficiency Strategy

This strategy set a target for energy-efficiency improvement of 12% by 2015 (DE, 2010). After the implementation of this strategy, cumulative national energy-efficiency savings of at least 23% occurred between 2000 and 2012. These energy-efficiency savings surpassed the target of 12% outlined in the National Energy Efficiency Strategy (South Africa’s Lower Emission Development, 2018). This will contribute to a reduction in CO2, and reduce water use, which is a key input to energy generation. The NWRS-2 addresses water-demand management initiatives for the energy sector in the WC/WDM sub-strategy.

6.4.8. National Tourism Strategy

The National Tourism Sector Strategy (NDT, 2011) set a growth target of 3.5% in 2015, up from a rate of 3.2% in 2009. The NWRS-2 has made provision for infrastructure development in high-growth centres, which will ensure that there is adequate water for meeting the needs of tourists to South Africa. The NWRS also promotes the use of water resources for recreation, and the protection of water resources, which will support jobs and income generated from tourism.

6.4.9. Mineral Beneficiation Strategy

The government objectives with respect to mining focus not only on the mining of primary commodities, but also on significant contribution to the economy through beneficiation (manufacturing), and on mining tourism (services). The NWRS-2 makes provision for infrastructure development to support the implementation of this strategy, and also sets targets for water-use efficiency by the mining sector.

6.5. Methodology

6.5.1. Theoretical base

In this section, we present the Solow Growth Model, used by the majority of economists to study growth (Romer, 2002). The Solow model is the starting point for all growth analysis. The model used in this study is a production function of Solow, with a neo-classic basis. Most growth models used for developing countries fit into the frame of Solow's 1956 model. To show a clearer picture of the position of the water sector in the national economy, one part of this research is devoted to the water sector portion of national production and investment, and estimates the coefficient of economic growth to water provision and efficiency, as well as presenting an econometric method for exploring these impacts in a Panel Data model. We employ the Cobb-Douglas production function, assuming water resource as a factor of production (Gatto and Locnzafame, 2005) to explore the effects of water-sector investment and efficiency in economic growth. The Cobb-Douglas production function is specified as follows:

$$Q = A\,K^{a}\,L^{b} \qquad \textbf{(10)}$$

where A is multifactor productivity; a and b are less than one, indicating diminishing returns to a single factor; and a + b = 1, indicating constant returns to scale. Solow noted that any increase in Q (Output) could come from one of three sources:

1) an increase in L. However, due to diminishing returns of scale, this would imply a reduction in Q / L or output per worker.
2) an increase in K. An increase in the stock of capital would increase both output and Q / L.
3) an increase in A or in multifactor productivity could also increase Q / L or output per worker.

6.5.2. Model specification

We adopted a model specification from Frone and Frone (2012, 2014) and Tir, Momeni and Boboevich (2014). Equation 11 below describes the impact of water investment and provision on economic growth. In this study we use Gross Value Added (GVA) to proxy for economic growth; total investment is proxied by total expenditure (exp), while water provision is proxied by total water distributed and water quality; water investment is proxied by total water expenditure and consuming unit as a percentage of population (Krop, Hernick and Frantz, 2008; Jimenez and Perez-Fohuet, 2009). The model is specified as follows:

$$GVA_{it} = \alpha + \beta_1 exp_{it} + \beta_2 waterd\delta_{it} + \beta_3 wquality_{it} + \beta_4 wexp_{it} + \beta_5 consuming_{it} + \eta_i + e_i \quad \textbf{(11)}$$

where GVA_{it} = gross value added in municipality i in time t
exp_{it} = operating and capital expenditure in municipality i in time t
$waterd_{it}$ = total water distributed in municipality i in time t
$wquality_{it}$ = water quality in municipality i in time t
$wexp_{it}$ = total water expenditure in municipality i in time t
$consuming_{it}$ = total consuming unit in municipality i in time t
η_i = time-invariant municipal specific effects
e_i = error term

Question 3: Impact of water supply efficiency on economic growth. In this study, we have used Gross Value Added (GVA) as a proxy for economic growth. Total investment was proxied by total expenditure (exp), while the population is used to proxy labour and as a control variable.

$$GVA_{it} = \alpha + \beta exp_{it} + \delta eff_{it} + \lambda population_{it} + \eta_i + e_i \quad \textbf{(12)}$$

where GVA_{it} = gross value added in municipality I in time t
exp_{it} = operating and capital expenditure in municipality I in time t
eff_{it} = efficiency of water provision in municipality I in time t
$population_{it}$ = population in municipality I in time t
η_i = time-invariant municipal specific effects
e_i = error term

6.5.3. Data analysis

The data was analysed using a panel regression analysis with a fixed-effect model; the decision to use a fixed-effect model rather than a random-effect model was informed by the Hausman test. Multiple South African data sources were used to obtain the data to form a five-year panel dataset from 2010 to 2015. Data sources used in this study include municipal capital expenditure and operating expenditure. The data was extracted from Municipal Money Data[2], while the population and employment data was extracted from Quantec (Easy Data)[3].

Gross Value Added (GVA) and operating expenditure were obtained from the National Treasury website, under Section 71: 'Consolidation of revenue and expenditure numbers for each municipality'. Consuming units and customer density data were collected from the StatsSA website, under section P9115: 'Non-financial census of municipalities'. The volume of water distributed, and of non-revenue water, was obtained from the DWA website, under 'Water conservation and demand management'. Water quality was obtained from Blue Drop report (see DWA, 2012). However, not all the municipalities had the data required to carry out this study; these municipalities were excluded.

6.6. Empirical results

This study shows that water investment and provision are fundamental and basic components that can be employed as growth engines in the economy. These findings are derived from the results, which are presented in Table 17 below.

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[2] municipaldata.treasury.gov.za

[3] https://municipaldata.treasury.gov.za/table/capital/?municipalities=EC103andamp;year=2017andamp;items=4100andamp;amountType=ADJB

Table 17: Impact of water investment and provision on economic growth results

GVA	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Expenditure	(6.23e-07)	(1.27e-07)	4.91	(0.000)	3.66e-07	8.81e-07
Water quality	(1.706)	(0.327)	5.2	(0.000)	0.492	0.833
Water distributed	(0.0002)	(0.00007)	3.25	(0.002)	0.00009	0.0004
Consuming units	(0.082)	(0.033)	2.49	(0.018)	0.015	0.149
Water operating expenditure	(6.44e-06)	(6.95e-07)	9.27	(0.000)	5.03e-06	7.85e-06
Constant	(6743.024)	(6274.885)	1.07	(0.290)	-5971.1	19457.15
Overall R^2	(0.989)					
Sigma_u	(17459.492)					
Sigma_e	(2515.587)					
Rho	(0.98)	(fraction of variance due to u_i)				

Table 17 above shows that total investment as measured by the total expenditure of a municipality has a positive and significant contribution to economic growth; an increase in expenditure of R1 million will result in an increase in GVA of R0.623 million, while an increase in water quality of 1 unity will result in an increase in GVA of R1.7 million. An increase in water distributed in the municipality of 1 Megalitre has the potential to increase GVA by R338. Moreover, for every 1% increase in the consuming unit per population, there is a potential increase in GVA of R81 000. Investing R1 million in water supply has the potential to increase GVA by R6.4 million.

These results are comparable to those of several similar studies reported in UNESCO (2016). The report notes several studies that find correlations between water-related investments and economic growth. It was found that investment in small-scale projects providing access to safe water and basic sanitation in Africa could offer an estimated economic return of about US$28.4 billion a year, or nearly 5% of the GDP of the continent. Such investments also seem to have a beneficial effect on employment. In the United States, every US$1 million invested in the country’s traditional water supply and treatment infrastructure generates between 10 and 20 additional jobs. Meanwhile, the US Department of Commerce's Bureau of Economic Analysis found that each job created in the local water and wastewater industry creates 3.68 indirect jobs in the national economy. Another study in the report found that if Latin America invested US$1 billion in expanding its water supply and sanitation network, it would result in 100 000 jobs.

The efficiency of water provision and management is now included in the policy orientation of most economic and development agendas. The empirical results in this study support the claims made concerning the effect of efficiency of water provision and management on economic growth. These results are presented in Table 18 below:

Table 18: Impact of water supply efficiency on economic growth

GVA	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
Population	(0.194)	(0.012)	16.09	(0.000)	0.17	0.219
Expenditure	(6.42e-07)	(1.24e-07)	5.17	(0.000)	3.91e-07	8.94e-07
Efficiency	(81.364)	(9.886)	8.23	(0.000)	9.665	20.81
Constant	(-89102.79)	(10345.5)	-8.61	(0.000)	-110028.5	-68177.04
Overall R^2	(0.9854)					
Sigma_u	(156099.39)					
Sigma_e	(2475.098)					
Rho	(0.99974865)	(fraction of variance due to u_i)				

Table 18 above presents results showing empirical evidence of the impact of water-supply efficiency on economic growth. They show that an increase in investment/expenditure of R1 million will result in a return of more than R6 million in GVA. Interestingly, water efficiency was found to be a significant variable in determining municipal GVA. An increase of 0.1 in a water efficiency score[4] would lead to an increase of R81 million in GVA. This could be due to the fact that an increase in efficiency would entail a change in several variables, such as more revenue collected, more water distributed and therefore more jobs being created (water and jobs are inextricably linked on various levels, whether we look at them from an economic,

[4] Efficiency score ranges between 0 and 1.

environmental or social perspective), and higher water quality achieved. This has implications on the health and productivity of people in the area affected.

6.7. Conclusion

Our findings suggest there are strong ties between water provision and efficiency, and economic growth. As the UNESCO (2016) report points out, investing in water is investing in jobs and economic growth. Failure to secure an adequate and reliable supply of water to support heavily water-dependent sectors results in the loss or disappearance of jobs (UNESCO, 2016); and consequently, no economic growth.

Chapter 7: Impact of water service provision and the efficiency of water delivery on employment

7.1. Introduction

It is an indisputable fact that water is vital to human life. As pointed out by Grey and Sadoff (2006), water has always played a central role in human society. As an input to almost all production – in agriculture, industry, energy and transport – water is a key driver of sustainable growth and poverty alleviation. Moreover, access to water has the potential to reduce poverty and increase economic growth (SIWI, 2005). Water-service provision has been reported to have a significant impact on job creation. The 2016 edition of the United Nations World Water Development Report, titled 'Water and Jobs', shows that nearly three out of four jobs in the global workforce (3.2 billion people) are moderately or highly dependent on access to water and water-related services.

Water shortages and problems of access to water and sanitation could limit economic growth and job creation in the coming decades, according to a UN report. 'Water and Jobs' also notes that half of the world's workers – 1.5 billion people – are employed in eight water and natural-resource-dependent industries (UNESCO, 2016).

In many discussions, 'work force' is mentioned as the most important factor of production. Principally, work force is a factor that to a large extent can compensate for the physical and material limitations and shortcomings of other factors, which can help to increase production levels. On the other hand, employment is considered an effective factor in social issues (Davijani, 2016). Water stress and a lack of decent work can exacerbate security challenges, force migration, and undo the progress made in the fight to eradicate poverty. Failure to secure an adequate and reliable supply of water to support heavily water-dependent sectors results in the loss or disappearance of jobs. Floods, droughts and other water-related risks can also have economic and employment repercussions that go far beyond the immediately affected areas (ILO, 2013).

In addition to jobs in agriculture and industry, sectors with heavily water-dependent jobs include forestry, inland fisheries and aquaculture, mining and resource extraction, water supply and sanitation, and most types of power generation. This category also includes some jobs in the health care, tourism and ecosystem management sectors (ILO, 2013).

While the dynamics of water, economic growth and employment are complex and highly dependent on specific physical, cultural, political and economic circumstances, sound public governance – together with public and private investment in water resources management, water infrastructure and services – can generate and support employment across all sectors of the economy. These opportunities range from full-time jobs to more precarious informal ones – encompassing a wide range of skill sets (ILO, 2013). The UNESCO analysis highlights the fact that water is work – it requires workers for its safe management, and at the same time it can create work and improve conditions. From its extraction to its return to the environment, via numerous uses, water is a key factor in the creation of jobs. Investment in small-scale projects providing access to safe water and basic sanitation in Africa could offer an estimated economic return of about US$28.4 billion a year, or nearly 5% of the GDP of the continent (UNESCO, 2016).

Such investments also seem to have a beneficial effect on employment. In the United States, every US$1 million invested in the country's traditional water supply and treatment infrastructure generates between 10 and 20 additional jobs. Meanwhile, the US Department of Commerce's Bureau of Economic Analysis found that each job created in the local water and wastewater industry creates 3.68 indirect jobs in the national economy. Another study in Latin America found that investing US$1 billion in expanding the water supply and sanitation network would directly result in 100 000 jobs (UNESCO, 2016). The transition to a greener economy, in which water plays a central role, will also lead to more jobs. The International Renewable Energy Agency (IRENA) estimates that 7.7 million people were already employed in renewable energy in 2014.

A report titled ‘More crops and jobs per drop’ argues that the potential contribution of irrigation development to poverty alleviation is considerable. It was found that the more intense the production of water through technological change, with water as the leading input, the greater the number of jobs created. This is crucial to achieving production growth and intensification of smallholder income (Van Koppen, 1999). Water and jobs are inextricably linked on various levels, whether we look at them from an economic, environmental or social perspective. Against this background, this study is motivated to empirically test the impact of water-service provision and the efficiency of water delivery on employment in South Africa**.**

7.2. Contribution of water to the job market

In economic terms, water use can also be classified or defined as an intermediate or final good. An example of the former is water used in the production of another good or service, such as the irrigation of crops or the driving of turbines to make electricity at large dams. Water can also be used directly by the final consumer in the household, or for swimming and other recreational activities. The concepts of economic value in these categories differ somewhat: the consumer's uses of water provide personal happiness or utility directly, while the producer's uses of water have value derived from the ultimate value of the resultant good or service (Gibbons, 2013).

From the use of water we see, it is evident that most sectors need water as input or final demand. In general, water contributes positively to employment; but some studies have indicated that water reduction can lead to significant reduction in employment. For a comprehensive empirical review of this literature, see Howitt, Medellín-Azuara and MacEwan (2009).

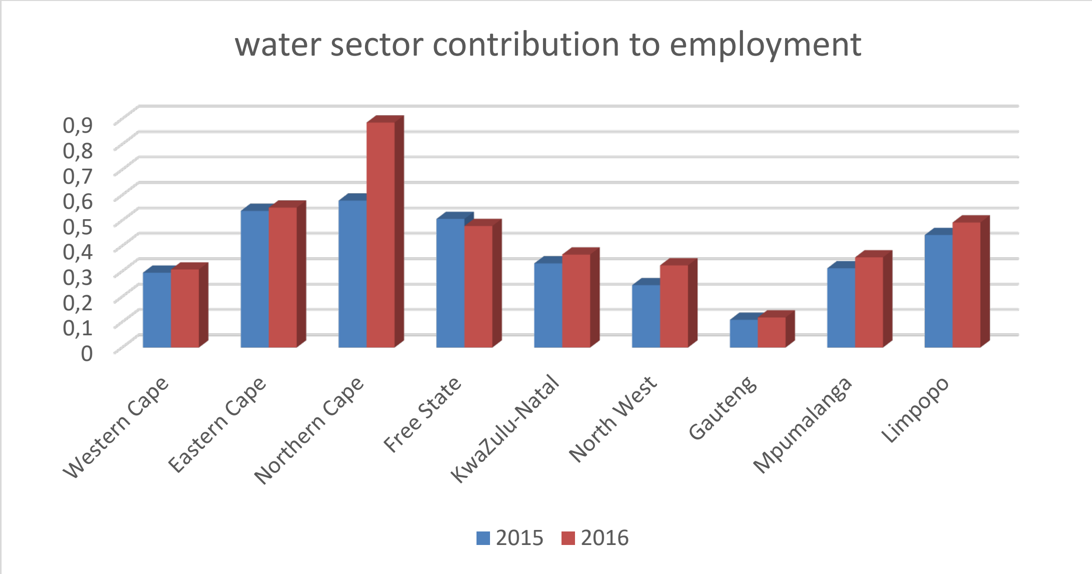

Figure 2: Water-sector employees in South Africa

Source: Provincial employment Quantec Easy Data, 2019; Water sector employment from Municipal Benchmarking Initiatives, 2016.

Figure 2 above shows that water-sector employment, which includes water and wastewater employees both full-time and part-time, has contributed less than 1% of the employment in provinces. While the water sector makes a great contribution to employment in the Northern Cape province, at about 0.9% of the people employed in 2016, the sector makes minimal contribution to Gauteng province, where it contributes about 0.2% of employees in the province. This variation in the sector contribution between the provinces could be attributed to the fact that Gauteng is a business hub, with higher employment opportunities created by other sectors compared to the Northern Cape. These figures do not mean that Gauteng has fewer workers in the water sector than the Northern Cape; Gauteng has higher employment density, making the number of people directly employed by the water sector miniscule relative to total employment in the province.

Though the water sector's direct contribution to total employment is minute, the significance of the sector is considerable. A reliable supply of water in enough quantities and of the required quality is a crucial input to economic growth and job creation. The indirect contribution of water to employment in the major economic sectors in South Africa can be seen in each sector's water input consumption percentage. Water usage by sector is presented in Table 19 below:

Table 19: Water use in South Africa by sector

S/N	Sector	Percentage
1	Irrigation	59%
2	Urban use	25%
3	Mining and bulk industrial use	6%
4	Rural use	4%
5	Afforestation	4%
6	Power Generation	2%

Source: BusinessTech, 2015

7.2.1. Agriculture sector

Table 19 above shows that the agricultural sector is the largest consumer of water, using almost 60%. The agricultural sector employs (both directly and indirectly) more than 8.5 million people (GCIS, 2011). The formal employment contribution of the sector is about 7% of all formal employment, and accounts for about 3% of GDP.

The agricultural sector is made up of commercial farmers and subsistence farmers: about 1.3 million hectares are irrigated. The New Growth Path has set a target of 300 000 households in smallholder schemes by 2020, and 145 000 jobs to be created in agro-processing by 2020 (DED, 2010). At 60%, irrigated agriculture is the largest single use of water in South Africa, and it has huge potential socio-economic impact in rural communities. Water is the major limiting factor to the growth of this sector, and poor water quality has a negative impact on agricultural exports and associated foreign income.

Irrigated agriculture is a vital component of total agriculture, and supplies many of the fruits, vegetables, and cereal foods consumed by humans; the grains fed to animals that are used as human food; and the feed to sustain animals for work, in many parts of the world (Howell, 2001). Insufficient or erratic water supplies affect the quality and quantity of employment in the agri-food sector. They constrain agricultural productivity and compromise income stability, with dramatic effects for the poorest households, which have limited assets and safety nets to cope with risks (UNESCO, 2016).

7.2.2. Urban and rural usage

About 30% of water in SA is for urban and rural use (including domestic use, which accounts for only 12% of all water use in the country). It is vital for health that the quality of drinking water matches international standards; it is also among the key determinants for tourism attraction. In 2009, the tourism sector directly and indirectly contributed 7% to GDP, and created 575 000 jobs (GCIS, 2011). This sector is earmarked for high economic growth, which is expected to generate a huge number of new jobs. The NGP has set a target of 225 000 new jobs by 2015 (DED, 2010). Drinking-water quality that matches international standards, as well as a reliable water supply and sanitation services, are critical to the success of this sector.

7.2.3. Mining and industrial sector

According to the Chamber of Mines of SA, the mining sector contributed 8.8% directly and 10% indirectly to the GDP of SA in 2009 (GCIS, 2011). It creates about 1 million direct and indirect jobs. The sector accounts for approximately one third of the market capitalisation of the JSE, and it is also the major attractor for foreign investments. The NGP set a potential employment target of 140 000 new jobs for the mining sector by 2020 (DED, 2010). Mining and related activities require significant quantities of water, while they also impact on the environment with associated potential pollution. The development of new mines in water-scarce areas requires forward planning to make decisions about the transfer of water and development of new sources.

Industry is an important source of decent employment worldwide, and accounts for a fifth of the world's workforce. Industry and manufacturing account for approximately 4% of global water withdrawals, and it has been predicted that by 2050, manufacturing alone could increase its water use by 400% (UNESCO, 2016). The manufacturing sector contributed 15.5% to GDP and 13.3% to jobs in 2009 (GCIS, 2011). The NGP has set a target of 350 000 new jobs for this sector by 2020. Water is an input in manufacturing processes, and is also used for cooling. In addition, food and beverage manufacturing are highly dependent on water.

7.2.4. Energy sector

Globally, the demand for energy is increasing, particularly for electricity in developing and emerging economies. The energy sector, with growing water withdrawals that currently account for about 15% of the world's total (in South Africa the sector consumes about 2.2% of water supplied), provides direct employment. Energy production, as a requirement for development, enables direct and indirect job creation across all economic sectors (UNESCO, 2016). Though the energy sector only uses 2% of water, it contributes about 15% to the GDP of South Africa and creates jobs for 250 000 (GCIS, 2011).

The sector generates about 95% of the electricity in South Africa, and also exports it to other countries in Africa. Including Eskom, the national power generator, it is highly dependent on reliable water supply for the generation of electricity (steam generation and cooling processes), and an elaborate and sophisticated network of water transfer and storage schemes have been developed specifically to support this sector and ensure high levels of reliability. The other side of the coin is that the water sector is highly dependent on a constant and reliable supply of electricity to move water.

7.3. Methodology

7.3.1. Theoretical base

This study used a quantitative approach employing deductive logic, led by the hypothesis that investing in water provision and efficiency has significant impacts on employment (accounting for both direct and indirect employment). The quantitative approach has the advantage of using quantitative data to determine whether empirical evidence supports the existing hypothesis.

The modelling of employment in this paper is based on a labour demand equation, derived from a production function following Greenway, Hine and Wright (1999), Milner and Wright (1998), and Hine and Wright (1997). The analysis is based on a simple model of a profit-maximising firm with a Cobb-Douglas production function, where the derived demand for labour is obtained by this equation:

$$\ln L = c_0 - c_1 \ln\left(\frac{WR}{C}\right) + C_2\, lnQ, \ldots\ldots \quad \textbf{(13)}$$

where L is employment, WR is real returns to labour, C is real cost of capital, and Q is real output. At the level of the firm or industry, the demand for labour is expected to be negatively affected by real wages, and positively by real output. An interesting question is which effect is stronger in absolute terms. For the sake of simplicity, the cost of capital is supposed to vary only over time, assuming perfect capital markets; thus, its variation is captured by time investment at the stage of estimation. It is also possible that the cost of capital may have no direct impact on the demand for labour, if technology is fixed in the short term. This would also be the case if the firm has excess capacity.

The water-provision investment is captured under investment; as discussed earlier, water provision has both direct and indirect impact on employment creation. The direct impact is the provision of employment in the water sector, while the indirect employment is attributed to the contribution of water as an input to other sectors, such as agriculture and mining. In theory, therefore, water provision is expected to have positive and significant impact on employment in the country.

The effect of trade (captured by Gross Value Added) is incorporated into the model as a factor that affects technical efficiency via trade-induced technological change (Greenway, Hine and Wright, 1999), as well as the changes in the labour intensity of production as a response to the comparative advantage of the country (Milner and Wright, 1998; Hine and Wright, 1997).

The effects of international trade and capital flows on employment vary between economic theories. Based on the Heckscher-Ohlin theorem, traditional trade theory indicates that after trade liberalisation in a labour-abundant country, particularly an unskilled-labour-abundant developing country, the employment of unskilled labour – and employment in export sectors in general – increases due to the comparative advantage of the economy in more labour-intensive sectors. However, the employment of skilled labour or certain groups of labour specialising in import-competing industries may fall, in spite of aggregate welfare gains.

Apart from trade theory, labour economics approaches based on factor content analysis evaluate the effects of trade with regard to shifting labour demand in response to exports, which is a source of demand, and to imports, which is a reduction in demand (e.g. Wood, 1994). Thus exports increase employment, whereas imports decrease it. However, this methodology is criticised by trade theoreticians, since it takes changes in trade volumes – not relative prices – as the starting point. Moreover, in the case of imports, if imports are not substitutes for domestically produced goods, but mostly complementary input goods that are not being produced domestically, this negative effect will not be observed.

Finally – according to a third approach, based on a microeconomic perspective – trade not only shifts demand schedules, but may also bring together trade-induced technological change or efficiency gains (Greenway, Hine and Wright, 1999; Rodrik, 1997). As highlighted by Tybout (2003), adjustment to trade liberalisation also takes place within each industry, and at plant level. In that respect, firm dynamics (such as upgrading in response to increased foreign competition) become important for understanding the adjustment process fully. Competition on the world market could push exporting firms to innovate; and if this technological change is labour saving, then the expected positive effect of exports on employment might not materialise, and a negative effect could even come out. Also, import penetration is expected to lead to technical change, unless increased import penetration causes a decline in the output level of import-competing firms.

Reshuffling of resources among plants and reallocation of output from less efficient to more efficient plants within an industry in response to falling prices after trade liberalisation – particularly in import-competing sectors – would lead to productivity improvements in the economy. In that respect, conditions of entry and exit as well as barriers to plant turnover affect the implications of trade liberalisation for the economy (Pavcnik, 2002). In particular, in the empirical literature for the advanced countries there is increasing consensus that the magnitude of trade flows is far too low to account for the changes in labour market outcomes; but defensive innovation stimulated by international competition may have an indirect negative effect on employment (e.g., Stehrer, 2004; Greenway, Hine and Wright, 1999). Gosh (2003) illustrates the same argument for the case of major developing countries.

7.3.2. Model specification

This study adopted the model specification from Hine and Wright (1997) and Greenaway, Hine and Wright (1999). In this chapter we have used total municipality employment (emp) as a dependent variable, and Gross Value Added (GVA) as a proxy for trade; total investment was proxied by total expenditure (exp), while water provision was proxied by total water distributed and water quality; and water investment was proxied by total water expenditure and consuming unit as a percentage of population. The impact of water investment and provision on employment model is specified as follows:

$$emp_{it} = \alpha + \beta_1 exp_{it} + \beta_2 waterd\delta_{it} + \beta_3 wquality_{it} + \beta_4 wexp_{it} + \beta_5 consuming_{it} + \eta_i + e_i \quad \textbf{(14)}$$

where emp_{it} = total employment in municipality i in time t

exp_{it} = operating and capital expenditure in municipality i in time t

$waterd_{it}$ = total water distributed in municipality i in time t

$wquality_{it}$ = water quality in municipality i in time t

$wexp_{it}$ = total water expenditure in municipality i in time t

$consuming_{it}$ = total consuming unit in municipality i in time t

η_i = time-invariant municipal specific effects

e_i = error term

Here, we use employment (emp) in the municipality as a dependent variable, and Gross Value Added (GVA) to proxy for trade. Total investment was proxied by total expenditure (exp), while the population is used as a control variable:

$$emp_{it} = \alpha + \beta gva + \beta exp_{it} + \delta eff_{it} + \lambda control_{it} + \eta_i + e_{it} \quad \textbf{(15)}$$

where emp_{it} = total employment in municipality i in time t

exp_{it} = operating and capital expenditure in municipality i in time t

eff_{it} = efficiency of water provision in municipality i in time t

control = a set of control variables

η_i = time invariant municipal specific effects

e = error term

7.3.3. Data analysis

The data was analysed using a panel regression analysis with a fixed-effect model; the decision to use a fixed-effect model rather than a random-effect model was informed by the results of a Hausman test.

Multiple South African data sources were used to create a five-year panel dataset, from 2010 to 2015. The data sources used in this study include capital expenditure and operating expenditure. These were extracted from Municipal Money data[5], while population and employment data were extracted from Quantec (EasyData)[6]. Gross Value Added (GVA) and operating expenditure were obtained from the National Treasury website under Section 71: 'Consolidation of revenue and expenditure numbers for each municipality'.

Consuming units and customer-density data were collected from the StatsSA website, under section P9115 – 'Non-financial census of municipalities'. The volume of water distributed and non-revenue water was obtained from the DWA website, under the section 'Water conservation and demand management'. Water quality was obtained from the Blue Drop report (DWA, 2012). However, not all the municipalities in the study had the data required, and were thus excluded from the study.

7.4. Empirical results

In conducting the analysis, we first inspected the correlation of the variable of interest as specified in the theoretical background. The results for the variables used in equation 12 are shown in Table 20 below:

[5] municipaldata.treasury.gov.za

[6] https://municipaldata.treasury.gov.za/table/capital/?year=2019&municipalities=EC103&amountType=AUDA

Table 20: Correlation of the variables of interest to employment

Variable	Employment
Employment	1.00
Gva	1.00
Water distributed	1.00
Water quality	0.55
All employees	1.00
Consuming units	1.00

The findings in Table 20 show that municipality employment is positive and highly correlated to the Gross Value Added (GVA) of the municipality. The water distributed in the municipality, water quality, employment in the water sector (i.e. there is a trickle-down effect from employment in the water sector that influences other employment in the municipalities) and the consuming unit also correlate highly and positively to municipal GVA. A positive correlation implies that there is a positive relationship between these variables and employment generated in the municipality (as anticipated in priori theoretical explanations). The higher the value of the variable, the higher the employment numbers. Water quality is the only variable that has a positive, low correlation with municipal GVA. These findings are validated by the panel regression analysis results with fixed effects (the decision to use fixed effects rather than random effects was informed by a Hausman test) provided in Table 20 above.

The variables shown in Table 20 above are all positive and significant in explaining employment in a municipality, which generally implies that water-service provision and investment have significant impact on job creation. Specifically, as the GVA in the municipality increases by R1 million, employment figures increase by seven people. These findings suggest that increase in GVA is a significant variable affecting employment. As far as water provision and investment are concerned, four variables were considered:

1) Water distributed in the municipality is positive and significant, at a 1% level of significance; which implies that when water distributed in the municipality increases by 1 million litres, it leads to an increase in formal employment of

four jobs. The total impact of formal employment on informal employment depends on multiplier effects.

2) The second variable is water quality. It was found that water quality is positively related to employment, and significant at te 5% level of significance. This implies that when water quality improves by 1% it leads to four additional employment opportunities created in the municipality. This could be due to the reduction in purification costs in beverage manufacturing. Increased production may require more people for marketing and distribution of products.

3) The third variable is investment in water. As investment in water increases by R1 million, three employment opportunities in the municipality are created. Investment in water is statistically significant at the 5% level of significance. These findings are consistent with those in UNESCO's 2016 report, which showed that providing access to safe water and basic sanitation in Africa could offer an estimated economic return of about US$28.4 billion a year, or nearly 5% of the continent's GDP (UNESCO, 2016). This is estimated to account for more than a million jobs, both formal and informal. On average, the UNESCO figures suggest that a R1 million investment would create 15 jobs.

However, it must be clear that the jobs that are analysed in this study are formal jobs. The informal sector is larger than the formal sector in terms of employment. Some 80-90% of new jobs are created in the informal economy, while the formal economy has been contracting in most African countries. Far from being replaced by the formal economy over time, the African informal economy is rapidly becoming the 'real' economy. While this is prevalent in Africa, South Africa is different; informal employment ranges between 36% in the agriculture sector, 38% in industry and 44% in service (ILO, 2018). The addition of four formal jobs found in this study (considering the informal sector jobs) is consistent with what was found by (UNESCO, 2016). See table 21 below for assessment of water investment on employment.

Table 21: Impact of water investment and provision on employment results

Employment	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
GVA	(7.297)	(0.966)	7.56	(0.000)	0.533	0.925
Water distributed	(0.004)	(0.001)	6.83	(0.000)	0.0003	0.0005
Water quality	(4.402)	(1.466)	3.00	(0.025)	0.001	0.108
Operating expenditure	(3.23e-03)	(8.81e-04)	3.66	(0.001)	1.44e-03	5.01e-03
Consuming units	(5.481)	(0.264)	2.08	(0.045)	0.001	0.108
Constant	(172057.3)	(4718.546)	36.46	(0.000)	162496.6	181618
Overall R^2	(0.994)					
Sigma_u	(328068.69)					
Sigma_e	(1897.9196)					
Rho	(0.99997)	(fraction of variance due to u_i)				

4) The fourth variable investigated in this study regarding water service provision is number of consuming units. It was found that an increase of 1 000 consuming units in the municipality creates five employment opportunities. This could be attributed to the fact that water accessibility reduces the time spent getting water from faraway sources, therefore the time that was to be devoted to fetching water could be used for other activities (opportunity cost). It could also be due to an increase in entrepreneurial activities that require water as input or final demand.

The estimated model has overall R^2 of 99, indicating that the model explains employment by 99%; thus, only 1% could be explained by other variables not specified in this model. The model estimated is a good fit to explain employment.

The second objective of this chapter was to estimate the impact of water-supply efficiency on employment. The correlation of the variables of interest that were used to estimate the equation are given in Table 22 below:

Table 22: Correlation of variables of interest

Variable	Employment	GVA	Population	Efficiency
Employment	1.0000			
GVA	0.9965	1.0000		
Population	0.9914	0.9920	1.0000	
Efficiency	0.7241	0.4290	0.4348	1.0000

As indicated in the literature, employment is created with trade, and Table 22 shows that Gross Value Added (GVA) is positive and highly correlated with employment. Similarly, population in this equation is used as the control variable. It has positive and significant effects on employment. In theory, high employment means bigger market (which implies high demand for workers) and greater supply of labour. These have a positive impact on employment. This highly positive correlation is as anticipated in a prior theoretical prediction. After the correlation analysis we estimate the panel regression analysis with fixed effects; the results are presented in Table 23 below:

Table 23: Impact of water-supply efficiency on employment

Employment	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]	
GVA	(6.725)	(0.653)	10.29	(0.000)	0.301	0.444
Expenditure	(9.09e-03)	(8.56e-04)	7.78	(0.000)	9.71e-04	1.81e-03
Population	(2.301)	(0.072)	31.26	(0.000)	0.215	0.245
Efficiency	(0.681)	(1.735)	3.9	(0.069)	-2.833	4.194
Constant	(63805.49)	(3641.05)	17.52	(0.000)	56434.57	71176.41
Overall R^2	(0.986)					
Sigma_u	(144688.99)					
Sigma_e	(545.698)					
Rho	(0.99999)	(fraction of variance due to u_i)				

Table 23 shows that an increase in GVA of R1million will increase employment by seven jobs. The variable is statistically significant at the 99% level of confidence (or at the 1% level of significance), implying that the variable has potential impact on employment. Municipality expenditure is also found to have a positive and significant (at the 99% level of confidence) impact on employment; an increase in municipality expenditure by R1 million will lead to an increase in employment of nine formal jobs.

A population increase of 1 000 people will increase employment by two in a municipality. Population has positive and statistically significant (at a 99% level of confidence) impact on employment. A water-efficiency improvement of 10% will create six jobs. Water efficiency implies that WSAs increase water quality, water distribution and consuming units, while reducing water loss and input costs when all these factors are taken into consideration. Water efficiency is a statistically significant variable to explain employment, at a 90% level of confidence (at a 10% level of significance). The overall model has R^2 of 98%, which suggests that the variables used are fit to explain employment by 98%; only 2% is not explained by the specified variable (and is captured by the error term).

7.5. Conclusion

Investing in water quality, water distribution and efficiency of water provision has a statistically significant impact on creating jobs in South Africa, where it is estimated that between five and 20 formal jobs will be created by increasing water efficiency by 10%, and investing in water distribution and quality. The impact on employment could be even more, if we consider the informal sector – it is estimated that one in six South Africans work in the informal sector.

Chapter 8: Summary, conclusions and recommendations

8.1. Summary

A World Bank review of benchmarking by Kingdom and Jagannathan (2001) concluded that in some regions or countries, regulators routinely publish indicators of water-service provider performance for public use, using platforms such as the media. Exposing the 'worst in class' has proven a powerful way of pressuring water providers to provide better service to consumers. By focusing political attention on service quality, benchmarking can also assist in shielding regulators from political interference.

Despite the rapid global revitalisation of water-provision policy, and the universal need to measure and strive for efficiency and productivity in the water sector as a means of ensuring the sustainability of this key resource, it is only recently that the most advanced econometric and mathematical programming frontier techniques have been applied to water utilities. The application of these sophisticated tools is currently undertaken mostly in developed and emerging economies such as the USA, Spain, Australia and Brazil, among others. The overall aim of this research project is to assess the levels of relative performance between South African water utilities, and evaluate the determinants of inefficiency.

As discussed, a small but slowly growing body of work has been carried out using frontier efficiency techniques, though mostly in developed countries; hence, this study is instrumental in strengthening efforts to conduct such investigations in developing countries. This research evaluates the efficiency of water utilities in South Africa, and explores the impact of exogenous variables on measured efficiency. A significant limitation was the lack of a comprehensive dataset for South Africa that would allow exhaustive and thorough analysis. This research constructed such a dataset, enabling this exploratory work to be undertaken.

Almost all water utilities in South Africa are operated by local municipalities. The representation of these utilities in benchmarking initiatives is almost negligible, due to a lack of awareness, issues related to data availability, the absence of data managers, financial constraints, and a lack of consensus regarding KPAs and KPIs. In general, WSAs in South Africa have only participated in descriptive benchmarking, which is less robust, lacks precise predictive powers, and is unable to control or even identify factors that impact on efficiency. Presently WSAs rely on descriptive rankings of some indicators' responses to know their performance gaps.

The issue is exacerbated by confusion between KPAs and KPIs. For this study, the WRC commissioned the Public and Environmental Economics Research Centre (PEERC) at the University of Johannesburg to develop a benchmark model. This entails the consideration of various KPIs for different functional components of WSAs, such as physical operating assets, quality of service, water quality, and financial aspects. Although there were a number of concerns raised about the potential challenges of benchmarking, the project team was able to provide a short initial list of KPIs. Due to a lack of good-quality data, conventional metric and non-parametric benchmarking methods cannot be used for such utilities.

The findings and recommendations established in this work provide a baseline to initiate a robust benchmarking process for water utilities in South Africa. Double-bootstrap DEA is recommended, enhanced to handle the uncertainties associated with the data variables, expert opinions and exogenous factors that impact on relative performance.

8.2. Conclusions

We investigated whether South African water service providers' performance is related to certain relevant variables that have been discussed broadly in the existing literature. Among these are 'non-revenue water', 'ratio of metered to unmetered connections', and 'consuming units'. In addition, we accounted for geographical location (i.e. urban versus rural water-service providers).

This study was conducted to generate the bias-corrected efficiency scores and determinants of efficiency for South African rural and urban water utilities (provided that 'location' was found to be a significant determinant of efficiency), from 2010 to 2012 and in 2014. A double-bootstrap DEA model was used to carry out the analysis. Location was found to be a determinant of efficiency, and thus the sample was divided into rural and urban samples. The results obtained in this study strongly highlight the importance of using robust techniques when estimating efficiency scores. The biased efficiency scores differed significantly when compared to the bias-corrected scores, in both the urban and rural samples. In regions where efficiency scores are used to determine tariff levels, the biased efficiency scores would be very misleading. In this study, a significant number of utilities' efficiency scores were overestimated by the conventional DEA model.

The conventional DEA efficiency scores are not only misleading in terms of the ranking of utilities, but also indicated that 17 urban and 20 rural utilities (a total of 37 utilities) had perfect efficiency; yet the bias-corrected scores show that not a single utility is 100% efficient. The findings of the truncated regression analysis shed light on the differences in the drivers of efficiency in the rural and urban South African contexts. In the urban sample, non-revenue water was found to be significant and to positively influence efficiency, which appears counterintuitive. However, it is possible that non-revenue water could impact efficiency scores positively in the short term, for utilities whose cost of maintaining infrastructure to reduce leakage costs is larger than the realised revenue losses from leakage and unauthorised consumption. Policymakers and utility managers should be cautious when interpreting the findings dependent on this coefficient. Non-revenue water could potentially impact efficiency scores negatively, if volumes increase significantly. In the rural sample, non-revenue water was found to be an insignificant variable in explaining efficiency.

The number of consuming units was found to be insignificant in the urban sample, but highly significant with a negative impact on efficiency for the rural sample. This means lower numbers of consuming units will positively impact efficiency scores for rural utilities. The final explanatory variable investigated in this study was the ratio of metered to unmetered connections. In the urban sample, utilities with a higher ratio of metered to unmetered connections were found to be more efficient, as expected. However, the opposite result was found for the rural sample. A higher ratio of connected meters was found to negatively impact the bias-corrected efficiency scores of the utilities. Due to missing data, this study was only able to compute bias-corrected efficiency scores for 77 utilities over four years, as well as their determinants of efficiency. It is imperative that utilities report accurately and consistently, to enable more robust analysis to be conducted. Further studies over a longer period are required to confirm these results. Other technical factors that could affect the utilities' performance should also be monitored, including information on investments, frequency of burst pipes, leakages, water losses, and water sources.

Although the South African water sector is critically important both socially and economically, there are few robust studies available to assist analysts, practitioners and decision-makers in better comprehending the performance patterns in the industry and revealing the drivers of the sector's efficiency or inefficiency, as well as the impact of the water sector on the economy. This study is an attempt to shed light on these crucial issues, and hopes to spark further academic interest in this area.

According to Guerrini (2015), efficiency improvement is one of three trends a public water-service provider should follow to obtain investment funding. The other two are recourse to bank credit or private equity, and water-tariff increases. Efficiency can be improved, for example by growth and vertical integration, and may be conditioned by environmental variables such as customer and output density. Previous studies into the effects of these variables on the efficiency of water utilities do not agree on certain points (e.g. scale and economies of scope), and rarely consider others (e.g. density economies).

Water provision and efficiency have a significant contribution to economic growth; all economic sectors are dependent on water supply as an input to their production. The return on investment in water provision and efficiency is high, and statistically significant for economic growth. The returns channel is complex, ranging from health and productivity to greater job creation and timesaving in the economy – all these variables are imperative for economic growth.

The empirical results suggest there are strong ties between water provision and efficiency, and economic growth. The UNESCO 2016 report points out that investing in water is investing in jobs and economic growth. Failure to secure an adequate and reliable supply of water to support heavily water-dependent sectors results in the loss or disappearance of jobs (i.e. no water, no jobs); and consequently, no economic growth (UNESCO, 2016).

8.3 Policy implications

The results of this study highlight the importance of using robust methodologies when estimating efficiency. Using the conventional DEA model would result in the under- or over-estimation of inefficiency for some water utilities. Misleading results limit the usefulness of benchmarking, as an inefficient utility could mistakenly be ranked first, and thus its managers would continue to operate without necessarily trying to reduce input levels.

Policymakers may also consider using efficiency results to reward best-performing utilities; the conventional DEA approach would reward inefficient water utilities. Although it may be an eventual goal to use benchmarking for rewards and penalties in the regulatory process, this work in South Africa is in the early stages of data collection and analysis. It would be premature to consider applying incentive and punitive measures for WSAs based on an initial set of metrics collected for information purposes.

The metrics selected here are intended to provide a snapshot of water-utility operations and a primary comparison for information purposes. Further analysis is needed – on a larger scale, with all stakeholders – to identify KPAs and KPIs that reconcile the objectives of all stakeholders, as well as the development of an implementation guideline by the DWS to understand the implementation requirements and the role of statistical benchmarking. Among other actions this will include exploring the value of the information, data-collection costs, sources of funding, accountability for data collection and analysis, and the governance of the entire data-collection process. Although these are all important implementation issues, they are beyond the scope of this research project, which has produced these recommendations:

1. Any benchmarking initiatives should account for the geographic location of water utilities.

2. As geographic location affects the efficiency and productivity of a water utility, policymakers should rethink their funding models.

3. Smaller WSAs may benefit from merging, since larger water utilities are more efficient.

4. Corporatisation of WSA operations could potentially bring about many of the performance gains of privatisation.

5. Non-revenue water has a negative impact on efficiency. This should promote discussion as to which legal framework would foster the improvement and modernisation of existing ageing infrastructures.

6. The water sector is one in which monopoly conditions are common, so improvements in performance can only be brought about with economic regulation.

7. There is a need for regulatory incentives as a way to promote performance improvement.

8. As we have flagged the potential for worsening water scarcity becoming a potential constraint on economic growth and employment, there is a need for substitution; and this can only be accelerated by the introduction of economic incentives for conservation.

9. Improved water efficiency has the potential to alleviate the worst effects of water scarcity.

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Appendix 1: Water Service Providers (WSA) Dataset

Table A1: South African Water Service Providers (WPS) dataset

Catego-ry	Urban Dum-my	WSA (Municipali-ties)	DMU	ID	Year	Operating Expenditure (Rands)	Consu-ming Units	Full-Time Employees	All Employees	Water Distributed	Non-Revenue Water	Network Length	Water Qua-lity
A	**1**	Buffalo City	BUF	1	2010	1 715 278	226 000	4 609	4 633	376 20 667	25 060 816	3 918.258833	95
	1		BUF	1	2011	2 145 010 768	211 236	4 672	4 684	30 000 000	30 000 000	3 918.388337	91
	1		BUF	1	2012	2 165 027 709	219 351	4 586	4 600	39 160 850	23 115 450	4 014.66	93
A	**1**	Nelson Mandela Bay	NMA	2	2010	3 713 073 114	321 570	7 219	7 660	58 914 000	35 075 428	8 713.559407	95
	1		NMA	2	2011	4 020 980 315	334 000	5 836	6 221	51 869 000	35 891 795	8 798.413303	90
	1		NMA	2	2012	4 804 170 385	321 570	6 613	7 420	70 202 390	21 497 710	4 327	90
B3	0	Blue Crane Route	EC102	3	2010	51 404 594	7 118	291	301	1 508 877	834 390	216.4367945	30
	0		EC102	3	2011	56 596 478	7 143	280	280	1 527 128	844 483	219.0523291	40
	0		EC102	3	2012	102 905 166	7 166	300	300	2 548 500	897 500	222.1048083	59
B2	1	Makana	EC104	4	2010	110 553 413	20 633	473	473	1 780 000	1 322 199	447.4282373	28
	1		EC104	4	2011	158 517 460	22 475	541	541	2 764 662.619	1 170 000	465.3253668	55
	1		EC104	4	2012	173 690 127	23 381	591	591	6 151 500	1 080 000	483.9383815	72
B3	0	Ndlambe	EC105	5	2010	104 183 347	28 683	398	446	3 233 899.417	1 293 339	345.7772489	38
	0		EC105	5	2011	125 083 802	18 492	402	474	3 247 606.708	1 232 714	347.5061351	21
	0		EC105	5	2012	125 775 126	18 492	478	566	2 797 000	1 511 757	349.2436658	42

B3	0	Sundays River Valley	EC106	6	2010	18 929 110	11 529	159	159	1 888 520.645	1 634 672	191.3828947	47
	0		EC106	6	2011	22 466 082	11 529	174	176	1 859 789.381	1 260 045	191	36
	0		EC106	6	2012	37 023 541	12 070	166	166	1 859 789.24	1 260 045	191.382	25
B3	0	Kouga	EC108	7	2010	187 626 402	25 737	1 088	1 088	4 700 000	2 604 000	512.0451753	61
	0		EC108	7	2011	166 493 692	25 737	1 057	1 057	3 699 977	3 283 812	518.1897174	75
	0		EC108	7	2012	209 279 266	21 950	953	953	3 819 500	3 593 608	524.407994	61
B3	0	Kou-Kamma	EC109	8	2010	124 504 781	12 337	108	108	1 676 119.106	626 482	209.6789	16
	0		EC109	8	2011	2 203 047	8 306	123	123	1 669 812.024	753 871	212.1372915	14
	0		EC109	8	2012	55 457 442	8 306	157	168	1 336 434.5	597 761	212.6673008	6
C2	0	Amathole District Municipality	DC12	10	2010	334 584 436	277 669	1 104	1 104	5 902 070.104	20 189 491.2	920 328	68
	0		DC12	10	2011	359 461 546	250 810	1 227	1 227	5 896 925.968	20 950 753.2	1 518.74298	65
	0		DC12	10	2012	423 719 768	251 810	1 477	1 477	12 064 467.59	19 093 500	1 490.468727	75
C2	0	Joe Gqabi District Municipality	DC14	12	2010	164 635 129	64 470	1 489	379	1 801 875.063	12 687 572.4	179.4515525	55
	0		DC14	12	2011	156 551 712	64 470	452	476	1 798 453.271	12 609 777.6	179.8114967	83
	0		DC14	12	2012	169 409 739	66 425	431	431	1 820 620	14 311 470	179.6315246	85
A	**1**	Mangaung	MAN	13	2010	1 829 783 272	165 785	3 590	3 630	39 305 132	39 780 180	3 401	95
	1		MAN	13	2011	1 681 761 892	187 783	3 627	3 660	53 123 304	23 859 830	3 500	85
	1		MAN	13	2012	2 124 570 085	168 715	3 566	3 626	50 829 700.52	32 104 277	3 658	84
B3	0	Letsemeng	FS161	14	2010	31 868 163	7 026	134	136	1 007 337.145	889 096	274.9945802	42

	0		FS161	14	2011	31 943 147	7 591	125	132	920 023.7717	1 054 278	274.9945802	55
	0		FS161	14	2012	37 439 408	7 670	128	150	774 628.6405	1 158 059	277.7740626	50
B3	0	Kopanong	FS162	15	2010	123 280 882	17 630	463	463	1 980 000	2 427 706	397.9976854	60
	0		FS162	15	2011	121 348 258	17 630	474	474	1 853 240	2 711 091	397.9976854	44
	0		FS162	15	2012	181 403 627	17 880	460	464	1 419 994.609	4 331 279	401.4366245	69
B3	0	Tswelopele	FS183	16	2010	39 927 294	11 000	209	209	2 404 671.431	458 160	263.37516	50
	0		FS183	16	2011	45 537 458	11 000	216	216	2 436 042.927	567 776	263.37516	55
	0		FS183	16	2012	51 478 940	11 463	230	230	2 999 062.889	630 219	267.1726735	92
B1	1	Matjhabeng	FS184	17	2010	530 328 095	92 300	2 092	2 092	21 926 844	12 384 076	1 570.464	47
	1		FS184	17	2011	508 813 460	108 251	2 230	2 230	20 594 851.67	15 651 077	1 570.779501	80
	1		FS184	17	2012	581 300 243	96 925	2 130	2 130	19 736 905.05	18 498 580	1 570.687047	95
B3	0	Setsoto	FS191	18	2010	70 611 855	26 168	679	679	4 263 893	4 297 574	380	33
	0		FS191	18	2011	57 101 863	27 326	627	627	6 670 000	4 279 000	264.29	59
	0		FS191	18	2012	120 286 618	29 838	578	585	7 722 715.782	4 911 499	271.4108673	89
B2	1	Dihlabeng	FS192	19	2010	172 690 482	29 616	824	824	4 000 000	6 000 000	797.4444512	5
	1		FS192	19	2011	172 150 660	30 212	924	924	6 067 356	6 790 825	797.4444512	31
	1		FS192	19	2012	259 076 597	30 212	833	1 070	4 206 435.21	8 896 201	804.632008	69
B3	0	Mantsopa	FS196	20	2010	59 502 778	12 759	253	267	3 075 605	2 285 702	128	28
	0		FS196	20	2011	71 159 683	12 797	253	265	2 744 750.01	2 525 767	129.1666667	38
	0		FS196	20	2012	81 256 869	13 982	302	312	2 949 889.136	2 480 537	130.6023522	47
B3	0	Ngwathe	FS203	22	2010	129 703 321	36 681	683	917	6 240 000	2 600 558	688.125224	25
	0		FS203	22	2011	171 156 540	36 681	686	920	6 681 018.436	2 227 898	688.125224	45
	0		FS203	22	2012	204 120 988	32 889	879	879	8 016 527.253	1 760 531	694.1994141	21
B3	0	Mafube	FS205	24	2010	75 142 699	17 407	384	384	1 371 487.81	602 052	337.0688482	11
	0		FS205	24	2011	79 771 353	19 379	387	387	1 377 754.175	630 922	337.0688482	15

	0		FS205	24	2012	102 003 997	20 157	451	451	1 418 867.891	822 447	339.8943729	18
A	**1**	City of Ekurhuleni	EKU	25	2010	10 257 173 207	643 944	16 514	16 519	218 162 990	104 086 626	10077	97
	1		EKU	25	2011	14 371 852 500	635 010	16 457	16 461	227 135 518.5	105 420 145	11 158.91444	97
	1		EKU	25	2012	15 896 079 609	647 381	16 507	16 520	232 716 270.6	106 026 481	11 489.15487	99
A	**1**	City of Johannes-burg	JHB	26	2010	15 722 670 267	872 578	25 610	27 184	310 677 660	192 129 250	11 199.79723	98
	1		JHB	26	2011	19 672 304 736	896 452	25 270	26 456	315 131 000	207 456 320	11 338.54808	98
	1		JHB	26	2012	21 548 683 408	942 251	25 750	27 049	352 151 845	184 160 156	11 526	99
A	**1**	City of Tshwane	TSH	27	2010	9 726 428 079	775 524	13 625	14 578	195 064 410	65 679 005	10 332	96
	1		TSH	27	2011	11 608 130 387	806 745	15 778	15 863	217 229 729	109 395 796	10 627.76	90
	1		TSH	27	2012	12 962 260 156	730 047	18 445	21 946	240 902 105	77 831 360	10 757	96
B1	**1**	Emfuleni	GT421	28	2010	2 178 423 664	235 000	2 579	2 579	44 248 813	35 324 366	5 122.710106	95
	1		GT421	28	2011	1 787 741 932	238 293	3 974	3 974	41 416 380	40 597 799	5 179.906168	96
	1		GT421	28	2012	2 041 154 273	239 714	2 865	2 865	42 180 349	40 219 791	5 234.069754	97
B2	**1**	Midvaal	GT422	29	2010	191 613 966	13 646	410	565	8 896 469	3 158 024	537.6795177	74
	1		GT422	29	2011	256 764 823	13 809	581	581	8 896 469	4 643 764	537.6795177	68
	1		GT422	29	2012	283 602 907	14 108	430	611	8 896 469	4 643 764	542.5402644	84

B3	0	Lesedi	GT423	30	2010	191 109 729	21 678	834	898	5 042 445.075	1 208 877	304	59
	0		GT423	30	2011	240 021 178	21 678	488	543	4 500 000	1 406 229	304	87
	0		GT423	30	2012	313 204 155	21 678	480	586	4 876 122	1 455 606	304	93
B1	1	Mogale City	GT481	31	2010	621 962 855	40 894	1 784	1 956	20 180 070	7 086 831	685	97
	1		GT481	31	2011	889 924 002	43 692	2 129	2 129	19 219 114	8 124 045	693.7561035	96
	1		GT481	31	2012	1 253 252 059	48 000	1 658	1 658	19 219 114	7 925 172	676.5150749	99
B2	1	Merafong City	GT484	32	2010	281 440 453	87 264	1 248	1 284	7 613 536	2 675 192	1 377.681514	77
	1		GT484	32	2011	347 433 128	89 272	1 249	1 274	7 613 536	3 434 841	1 377.681514	86
	1		GT484	32	2012	553 070 447	90 613	1 093	1 100	7 613 536	4 584 367	1 391.570368	92
A	1	eThekwini	ETH	33	2010	12 717 049 618	851 040	17 582	19 797	208 119 455	124 853 022	11 643	96
	1		ETH	33	2011	15 005 038 527	870 304	19 300	22 862	210 000 000	103 934 000	12 124.28947	96
	1		ETH	33	2012	15 421 137 094	891 609	19 726	23 003	206 297 410	111 253 863	12 478.76316	99
C	**0**	Ugu District Municipality	DC21	34	2010	392 750 851	102 321	868	868	20 191 067.85	20 013 001.2	3 882.5	87
	0		DC21	34	2011	438 508 903	102 321	952	952	18 302 642.23	21 301 050	3 882.5	93
	0		DC21	34	2012	281 806 402	102 321	913	913	18 261 779.28	23 811 085.2	3 882.5	93
B1	1	Msunduzi	KZN225	35	2010	1 526 167 926	109 415	3 146	3 146	21 653 346	36 849 966	1 594.38	73
	1		KZN225	35	2011	1 685 784 879	110 373	3 096	3 205	32 940 000	28 883 950	1 637.940885	96
	1		KZN225	35	2012	1 876 759 463	110 403	2 659	2 659	34 386 293	32 398 898	1 673.883624	95

C	**0**	uThukela District Municipality	DC23	36	2010	151 545 616	115 900	870	870	14 016 127	35 894 498.4	3 023.6	54
	0		DC23	36	2011	271 223 215	115 900	692	692	13 354 750.67	36 633 196.8	3 129.989526	55
	0		DC23	36	2012	106 819 982	117 501	648	648	14 026 329.56	35 823 242.4	3 378.211971	57
B1	1	Newcastle	KZN252	37	2010	735 673 680	65 971	929	1 020	16 642 472.08	14 171 264	671.4285714	75
	1		KZN252	37	2011	744 724 219	72 673	1 028	1 119	18 229 642.35	14 265 000	677.9285714	76
	1		KZN252	37	2012	1 114 563 434	79 151	1 182	1 462	21 386 180	13 729 719	684.4285714	97
B1	1	uMhlathuze	KZN282	38	2010	1 154 011 073	71 660	1 749	1 772	31 059 590	11 490 633	1 450	80
	1		KZN282	38	2011	1 306 133 156	72 260	1 806	1 806	27 224 595	11 998 551	1 588.9443	89
	1		KZN282	38	2012	1 564 543 724	72 260	1 857	1 857	29 706 777	10 826 592	1 588.944	93
C	**0**	iLembe District Municipality	DC29	39	2010	200 286 000	113 264	402	407	7 851 916	16 647 040.8	2 205	51
	0		DC29	39	2011	235 992 888	115 103	413	413	7 646 910	18 545 666.4	2 488.588783	86
	0		DC29	39	2012	285 041 341	124 074	423	423	7 553 082.333	20 971 633.2	2 823.679238	88
B1	1	Polokwane	LIM354	42	2010	634 711	130 361	1 605	2 001	19 523 972	14 026 059	1 363	81
	1		LIM354	42	2011	867 581 797	130 675	1 703	2 043	19 225 693	16 585 647	1 473.860425	93
	1		LIM354	42	2012	1 071 310 987	175 945	1 758	1 758	19 374 832.5	15 297 694	1 494.39122	87
B3	0	Lephalale	LIM362	43	2010	133 156 177	26 231	346	346	4 652 200	886 400	512.297	34
	0		LIM362	43	2011	101 614 698	26 610	410	414	4 950 503.079	922 369	515.0285781	83
	0		LIM362	43	2012	134 165 279	27 950	442	442	5 456 557.309	895 461	489.8014539	93

B2	1	Mogala-kwena	LIM367	44	2010	183 041 294	77 100	659	659	5 625 640	3579 618	152.3	47
	1		LIM367	44	2011	213 890 179	77 143	651	651	5 000 000	3 996 000	319.3196367	78
	1		LIM367	44	2012	293 441 913	77 143	587	703	5 331 986.06	4 254 338	308.9683785	61
B1	1	Govan Mbeki	MP307	46	2010	515 817 851	69 167	1 445	1 553	16 617 156	5 626 826	1 412.567531	79
	1		MP307	46	2011	592 431 785	88 457	1 443	1 501	19 898 350	5 133 728	1 412.567531	78
	1		MP307	46	2012	701 290 399	87 474	1 335	1 412	25 834 008	6 740 996	1 427.80289	78
B1	1	eMalahleni	MP312	47	2010	590 314 940	64 000	1 331	1 331	21 880 000	24 755 220	1 850.065082	30
	1		MP312	47	2011	798 384 046	65 000	1 336	1 336	19 666 298	22 516 942	1 850.065082	47
	1		MP312	47	2012	779 430 835	71 260	1 287	1 287	25 428 596	18 856 500	1 868.371039	38
B1	1	Steve Tshwete	MP313	48	2010	438 844 479	37 205	1 198	1 198	10 325 501	5 273 622	717	92
	1		MP313	48	2011	541 520 265	41 892	1 267	1 267	11 903 000	4 096 768	883.133802	97
	1		MP313	48	2012	644 131 542	39 094	1 240	1 240	11 036 710.62	4 933 690	897.1073262	97
B4	0	Dr JS Moroka	MP316	49	2010	84 744 393	52 725	535	535	6 572 166	16 824 600	225	96
	0		MP316	49	2011	112 336 612	57 881	481	481	4 350 000	19 015 040	1 205.35673	84
	0		MP316	49	2012	144 447 552	58 345	559	568	5 342 903	18 025 980	1 259.086415	93
B3	0	Richtersveld	NC061	50	2010	8 369 879	2 942	118	118	220 606	127 400	55.16242952	26
	0		NC061	50	2011	17 135 005	2 980	140	140	449 246	120 210	55	36
	0		NC061	50	2012	15 970 057	3 126	132	132	488 692	99 428	55	37
B3	0	Nama Khoi	NC062	51	2010	49 080 236	11 735	290	290	1 690 736.408	1 780 019	243.4852736	22
	0		NC062	51	2011	72 044 562	11 870	302	302	1 672 140	1 863 049	243	58
	0		NC062	51	2012	74 067 640	11 996	342	342	1 586 858	501 146	243	63

B3	0	Hantam	NC065	52	2010	17 911 277	4 608	141	141	685 613	145 496	148.698	69
	0		NC065	52	2011	20 420 922	4 234	146	146	651 902	237 456	149	75
	0		NC065	52	2012	25 410 221	4 380	140	140	678 551	269 029	149	82
B3	0	Karoo Hoogland	NC066	53	2010	9 448 754	2 616	74	108	556 843.8594	246 552	55.15685507	39
	0		NC066	53	2011	16 479 209	2 616	107	118	530 685	284 784	65	51
	0		NC066	53	2012	31 222 864	2 808	110	195	804 118	109 206	65	40
B3	0	Khâi-Ma	NC067	54	2010	15 184 686	2 065	46	46	642 261.6633	148 783	62.71824458	34
	0		NC067	54	2011	20 287 999	2 097	45	45	640 920	118 520	45.55824793	47
	0		NC067	54	2012	23 606 589	2 131	51	62	678 783	122 541	46.47239008	53
B3	0	Umsobomvu	NC072	55	2010	25 723 263	7 276	184	184	855 330	579 897	71.5	23
	0		NC072	55	2011	31 825 168	7 276	200	200	816 399.5634	591 356	85	36
	0		NC072	55	2012	44 008 411	7 841	185	185	802 175.946	610 380	87.38666667	16
B3	0	Emthanjeni	NC073	56	2010	63 007 993	8 041	345	345	1 982 352	480 376	274	68
	0		NC073	56	2011	82 276 477	8 186	360	360	1 993 181	485 602	274	60
	0		NC073	56	2012	94 071 885	8 310	318	318	2 365 159	477 842	274	63
B3	0	Thembelihle	NC076	57	2010	13 112 708	2 514	67	67	968 288.0538	568 545	63	55
	0		NC076	57	2011	13 048 681	2 585	63	77	857 076	405 277	63	46
	0		NC076	57	2012	20 773 077	3 431	78	78	990 749	457 514	63	73
B3	0	Siyathemba	NC077	58	2010	24 849 639	4 954	98	112	1 164 246.75	541 535	63	53
	0		NC077	58	2011	27 436 249	3 628	121	141	1 159 067.954	594 300	63	41
	0		NC077	58	2012	42 274 650	3 834	141	153	1 383 968	865 716	68	62
B3	0	!Kheis	NC084	60	2010	7 220 231	2 420	53	53	595 328	261 080	63	46
	0		NC084	60	2011	9 571 762	3 038	66	82	595 329	221 383	65	53
	0		NC084	60	2012	10 161 471	2 417	64	88	607 051	327 092	65	50

B3	0	Tsantsabane	NC085	61	2010	2 228 800	9 895	200	200	1 200 000	692 472	63	75
	0		NC085	61	2011	145 728 315	10 667	200	200	1 019 711.575	744 873	63.70861446	59
	0		NC085	61	2012	38 787 993	10 709	219	219	1 021 705.867	825 831	65.6221988	66
B1	1	Sol Plaatjie	NC091	62	2010	458 099 650	41 878	1 644	2 061	15 624 720	16 985 650	63	64
	1		NC091	62	2011	523 616 281	42 072	1 566	1 905	11 624 885	18 794 880	875.25	84
	1		NC091	62	2012	698 089 149	42 862	1 612	1 988	14 971 985	17 703 995	912	72
B1	1	Rustenburg	NW373	64	2010	1 793 046 305	99 345	1 427	1 427	21 697 394.29	13 876 761	2 821.948934	95
	1		NW373	64	2011	1 822 881 124	105 000	1 230	1 230	20 000 000	12 000 000	2 821.948934	93
	1		NW373	64	2012	1 340 285 976	106 267	1 554	1 566	23 497 749	19 686 339	2 854.514989	92
A	1	City of Cape Town	CPT	66	2010	18 425 498 533	616 624	24 005	24 179	247 787 926	83 427 747	10 418.06897	98
	1		CPT	66	2011	20 233 328 386	624 189	25 522	25 789	237 618 170.2	57 203 052	10 418.06897	98
	1		CPT	66	2012	13 530 139 208	773 710	24 927	25 200	237 618 170.2	50 496 264	10 805	98
B3	0	Matzikama	WC011	67	2010	77 180 868	8 430	346	346	3 075 542.345	1 768 700	366.5633137	30
	0		WC011	67	2011	68 345 328	8 556	345	356	2 822 015.48	1 763 171	366.7345931	33
	0		WC011	67	2012	92 023 407	8 835	395	395	2 842 932.77	1 041 417	370.3777303	70
B3	0	Cederberg	WC012	68	2010	74 121 288	6 687	279	295	1 711 244	900 805	263.4540035	60
	0		WC012	68	2011	59 516 412	6 687	293	309	2 025 484.447	487 370	263.4540035	51
	0		WC012	68	2012	112 996 783	8 407	324	331	1 910 913.176	325 271	265.5263177	80
B3	0	Bergrivier	WC013	69	2010	75 972 912	7 848	377	513	2 114 962.102	489 844	313.2610742	63
	0		WC013	69	2011	82 701 321	7 993	349	375	2 213 770.438	532 766	313.2610742	85
	0		WC013	69	2012	117 046 082	8 272	359	383	2 153 683.766	244 737	315.7147652	91

B2	1	Saldanha Bay	WC014	70	2010	225 042 307	22 075	939	939	10 815 000	1 879 156	524	81
	1		WC014	70	2011	236 523 417	23 736	877	877	11 101 818.28	1 399 735	528.1498288	88
	1		WC014	70	2012	353 290 530	23 734	985	985	12 737 465.78	407 678	532.1008337	95
B3	0	Swartland	WC015	71	2010	163 180 117	17 982	542	542	4 446 321.434	664 133	493	69
	0		WC015	71	2011	180 042 902	18 457	551	551	4 600 722.386	863 500	504.0071951	93
	0		WC015	71	2012	250 547 328	19 586	540	540	4 630 433.53	643 765	514.7740317	95
B3	0	Witzenberg	WC022	72	2010	142 252 663	11 553	519	542	4 465 968.5	1 878 070	503.6855876	93
	0		WC022	72	2011	133 380 391	11 582	519	551	4 260 156.21	2 194 790	503.8570869	98
	0		WC022	72	2012	174 117 546	11 608	495	544	4 390 452.665	2 281 482	508.500092	98
B1	1	Drakenstein	WC023	73	2010	676 045 408	46 218	1 794	1 944	14 884 000	1 086 300	1 094.804055	92
	1		WC023	73	2011	733 239 292	41 107	1 631	1 711	15 638 970.75	1 972 793	1 108.122431	96
	1		WC023	73	2012	845 684 368	41 427	1 765	1 955	15 528 628.37	1 918 877	1 123.309154	96
B1	1	Stellenbosch	WC024	74	2010	302 832 388	25 177	1 022	1 025	9 760 091.618	2 471 330	734.2776083	95
	1		WC024	74	2011	356 109 186	27 963	1 100	1 103	10 466 586.11	2 327 608	743.9701174	96
	1		WC024	74	2012	437 567 287	28 612	1 104	1 104	10 042 689.51	2 702 312	759.0155507	96
B2	1	Breede Valley	WC025	75	2010	241 651 735	26 000	885	886	11 056 790	3 782 291	472	74
	1		WC025	75	2011	325 694 895	26 200	907	908	8 099 911.677	3 509 126	530.3883682	86
	1		WC025	75	2012	414 566 555	27 693	892	896	12 314 965.85	3 134 821	536.7761777	89
B3	0	Theewaters-kloof	WC031	77	2010	162 507 131	24 390	517	553	3 832 051.988	643 535	282	49
	0		WC031	77	2011	101 894 630	17 473	549	549	3 800 713.63	665 183	599.6	75
	0		WC031	77	2012	116 977 553	17 473	510	510	3 692 062.858	698 317	603.8135821	72
B2	1	Overstrand	WC032	78	2010	364 373 433	26 920	968	968	6 278 973.9	1 928 868	708	72

	1		WC032	78	2011	463 306 480	27 130	1 013	1 013	5 501 948.761	1 893 730	520.68	91
	1		WC032	78	2012	516 888 321	27 672	1 023	1 023	5 175 404.098	1 837 681	524.2868663	97
B3	0	Cape Agulhas	WC033	79	2010	60 477 436	8 068	282	282	1 962 435	265 034	226	79
	0		WC033	79	2011	77 510 392	8 372	353	353	1 781 709.514	299 773	229.5142857	73
	0		WC033	79	2012	88 455 582	9 294	333	334	1 842 079.476	404 503	229.0690523	87
B3	0	Swellendam	WC034	80	2010	37 290 521	6 071	236	236	1 489 506	466 870	125	67
	0		WC034	80	2011	47 323 981	5 863	245	245	1 145 115.343	454 522	125	81
	0		WC034	80	2012	59 914 287	5 871	261	261	1 212 947.568	684 920	125	85
B2	1	Mossel Bay	WC043	81	2010	219 785 129	31 508	836	859	5 169 247.17	1 142 668	740.948	85
	1		WC043	81	2011	374 156 319	32 317	805	827	4 473 582.588	965 268	6 781.067981	95
	1		WC043	81	2012	339 796 712	32 790	843	843	6 200 664.378	658 626	6 891.579427	96
B1	1	George	WC044	82	2010	439 947 720	44 844	949	1 106	7 144 402	2 577 152	913.1834844	97
	1		WC044	82	2011	539 347 766	32 836	1 004	1 141	8 460 935.547	836 758	922.891686	96
	1		WC044	82	2012	675 019 974	35 702	1 033	1 290	9 548 060.568	428 864	940.4495728	98
B3	0	Bitou	WC047	83	2010	161 200 742	12 052	527	527	1 691 123	1 145 538	319	98
	0		WC047	83	2011	167 478 845	13 967	511	561	1 668 403.14	946 655	319	96
	0		WC047	83	2012	174 937 750	14 118	512	561	2 197 195.426	743 747	328.6051739	98
B2	1	Knysna	WC048	84	2010	267 674 696	20 541	476	616	2 851 493	990 918	370.4611709	75
	1		WC048	84	2011	347 585 258	20 931	611	616	3 166 329	704 079	373.9595697	90
	1		WC048	84	2012	320 753 728	20 931	638	638	3 492 784	587 571	377.4579685	92
B3	0	Beaufort West	WC053	85	2010	100 914 362	10 020	339	339	1 357 945.342	721 993	170	84
	0		WC053	85	2011	636 23 989	10 331	382	382	1 104 384.814	729 696	170.2230627	92
	0		WC053	85	2012	75 662 151	10 845	349	349	1 219 929.322	1 120 698	175.6946588	95

Appendix 2: Practical application of the DEA tool

A2.1. How to run the DEA efficiency score in Microsoft Excel

Without taking much time over how the algorithm in the 'black box' works, let's focus on the application of the MS Excel tool to benchmark the DMUs, in our case the WSAs. There are many software packages developed to analyse the DEA using MS Excel (through Excel add-ins), among others DEA Frontier and DEA Solver. Most of these software packages are commercial; however, they have free versions that have limited capacity in terms of number of DMUs, variety of models that can be performed, and functionality.

NB: For a general demonstration of the software applicability, we use the free version of DEAFrontier.

A2.2. Practical application of the DEA tool

A2.2.1. Step 1: Download the software

Let's install the DEAFrontier free software: it can be downloaded from http://www.deafrontier.net/deafree.html

NB: this version does not work under Ms Excel 97, 2002 and 2003 (XP)

Once you click on the link, the screen in Figure A1 below will appear;

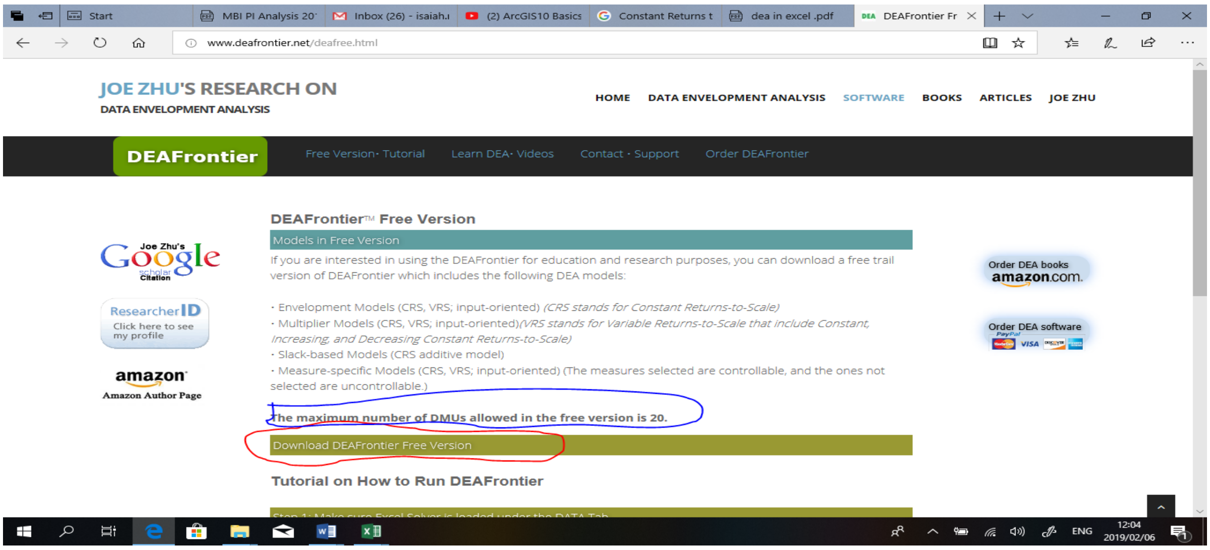


Figure A1: The free version of DEAFrontier

The free software is limited to 20 DMUs (see in Figure A1 above: **The maximum number of DMUs allowed in the free version is 20**) and there are other functional limitations.

To download the software, click on 'Download DEAFrontier free software (circled in red). In the next screen that opens, scroll down to look for a downloadable folder [download DEA.zip (857 kb)], circled in red on Figure A2 below:

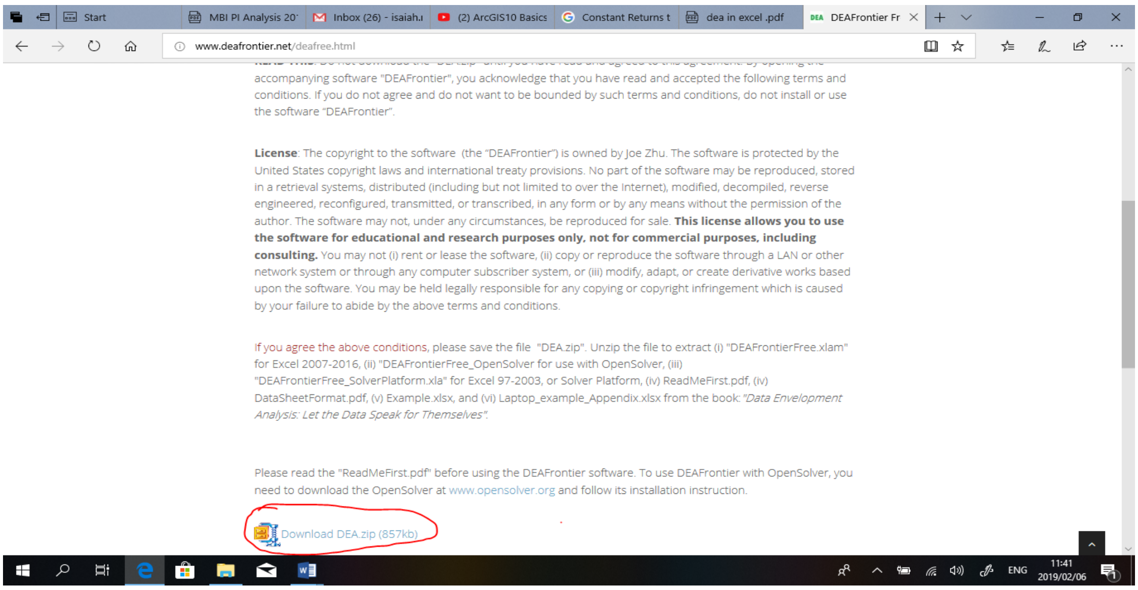
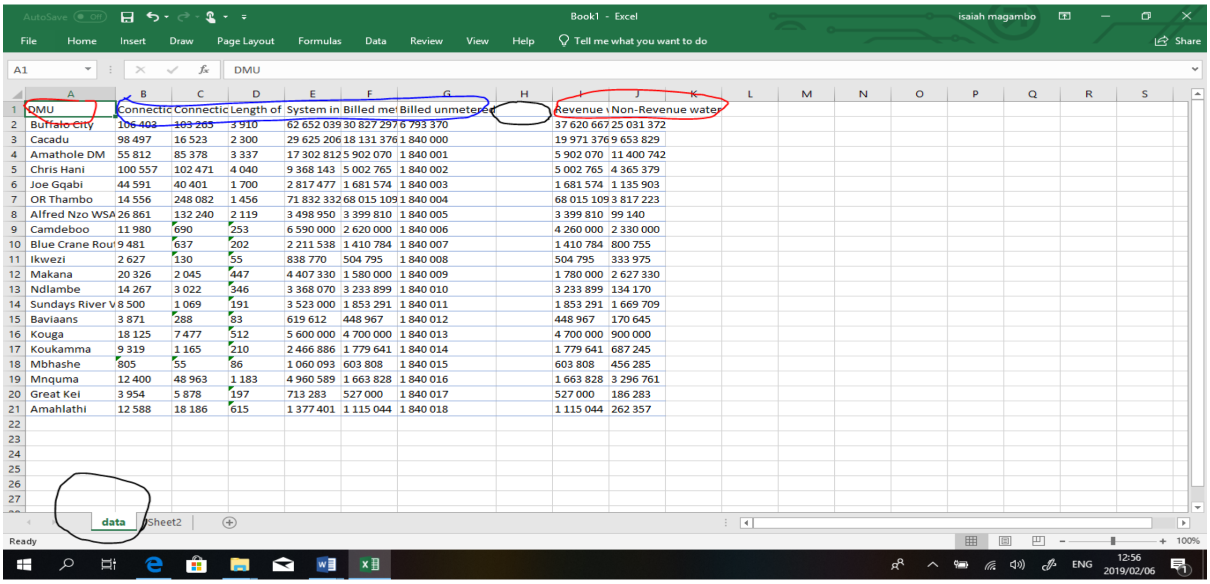


Figure A2: Download the DEA Frontier free software

NB: You will need to download and save this folder on your computer.

A2.2.2. Step 2: Prepare your dataset in an Excel sheet

Different software might have different arrangements and naming of variables and spreadsheet; in our software, the data must be prepared as in Figure A3 below:



	A	B	C	D	E	F	G	H	I	J
1	DMU	Connectic	Connectic	Length of	System in	Billed met	Billed unmetered		Revenue v	Non-Revenue water
2	Buffalo City	106 403	103 265	3 910	62 652 039	30 827 297	6 793 370		37 620 667	25 031 372
3	Cacadu	98 497	16 523	2 300	29 625 206	18 131 376	1 840 000		19 971 376	9 653 829
4	Amathole DM	55 812	85 378	3 337	17 302 812	5 902 070	1 840 001		5 902 070	11 400 742
5	Chris Hani	100 557	102 471	4 040	9 368 143	5 002 765	1 840 002		5 002 765	4 365 379
6	Joe Gqabi	44 591	40 401	1 700	2 817 477	1 681 574	1 840 003		1 681 574	1 135 903
7	OR Thambo	14 556	248 082	1 456	71 832 332	68 015 109	1 840 004		68 015 109	3 817 223
8	Alfred Nzo WSA	26 861	132 240	2 119	3 498 950	3 399 810	1 840 005		3 399 810	99 140
9	Camdeboo	11 980	690	253	6 590 000	2 620 000	1 840 006		4 260 000	2 330 000
10	Blue Crane Rout	9 481	637	202	2 211 538	1 410 784	1 840 007		1 410 784	800 755
11	Ikwezi	2 627	130	55	838 770	504 795	1 840 008		504 795	333 975
12	Makana	20 326	2 045	447	4 407 330	1 580 000	1 840 009		1 780 000	2 627 330
13	Ndlambe	14 267	3 022	346	3 368 070	3 233 899	1 840 010		3 233 899	134 170
14	Sundays River V	8 500	1 069	191	3 523 000	1 853 291	1 840 011		1 853 291	1 669 709
15	Baviaans	3 871	288	83	619 612	448 967	1 840 012		448 967	170 645
16	Kouga	18 125	7 477	512	5 600 000	4 700 000	1 840 013		4 700 000	900 000
17	Koukamma	9 319	1 165	210	2 466 886	1 779 641	1 840 014		1 779 641	687 245
18	Mbhashe	805	55	86	1 060 093	603 808	1 840 015		603 808	456 285
19	Mnquma	12 400	48 963	1 183	4 960 589	1 663 828	1 840 016		1 663 828	3 296 761
20	Great Kei	3 954	5 878	197	713 283	527 000	1 840 017		527 000	186 283
21	Amahlathi	12 588	18 186	615	1 377 401	1 115 044	1 840 018		1 115 044	262 357

Figure A3: Data preparation

Note:

A) Ensure all the DMUs are in the first column.

B) The columns following should contain the input variables (circled in blue).

C) Skip the next column (in this case, column H, circled in black).

D) Enter the output variables in the following columns (circled in red).

E) The spreadsheet must be renamed 'data' (bottom left, circled in black).

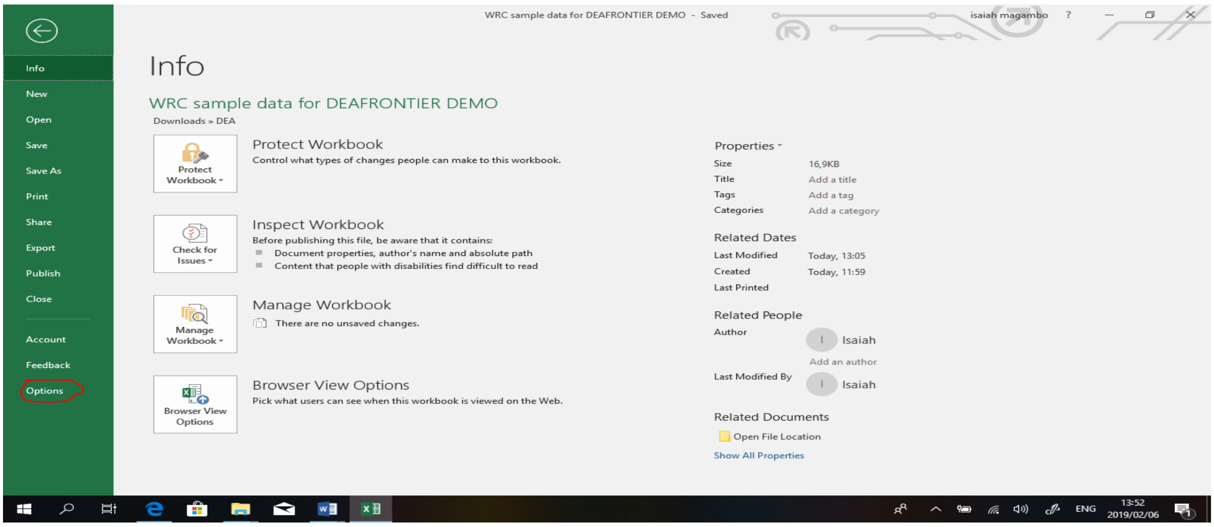
F) The dataset was prepared using 2010 data.

For the sake of demonstration, the example spreadsheet is embedded here:

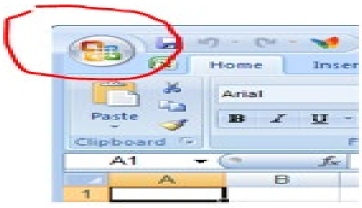
WRC sample data
for DEAFRONTIER D

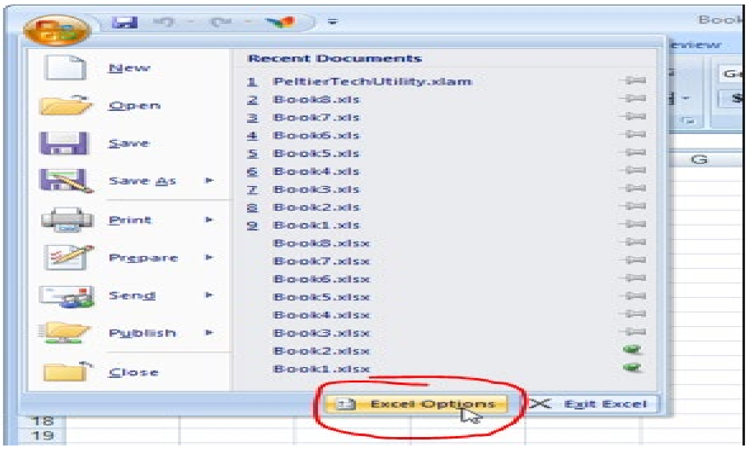
A2.2.3. Step 3: Install the Software in Excel

How to do this will depend on what version of Excel you have installed. Newer versions should display this screen:

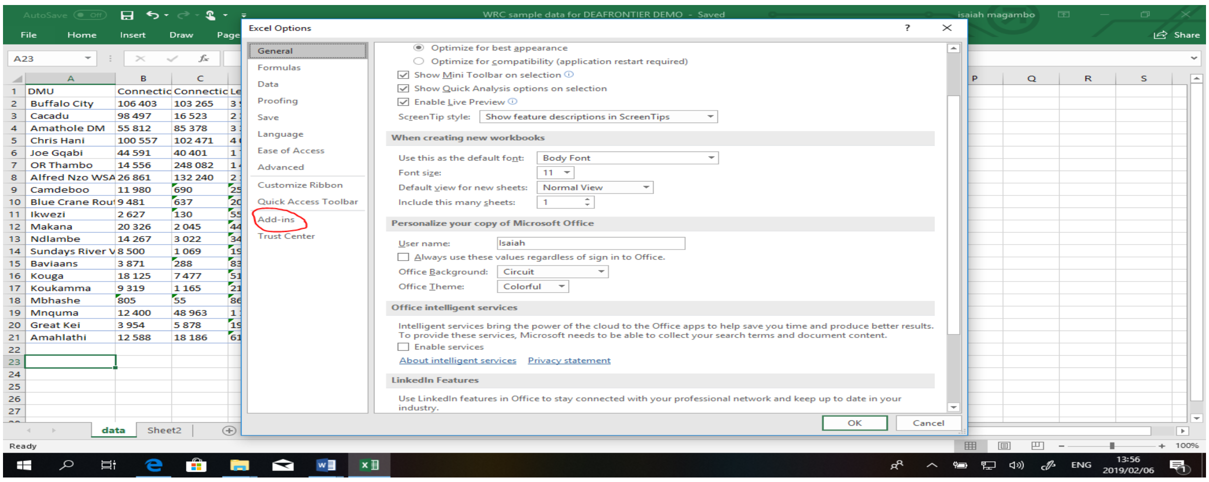


Older versions of Excel will show the following:

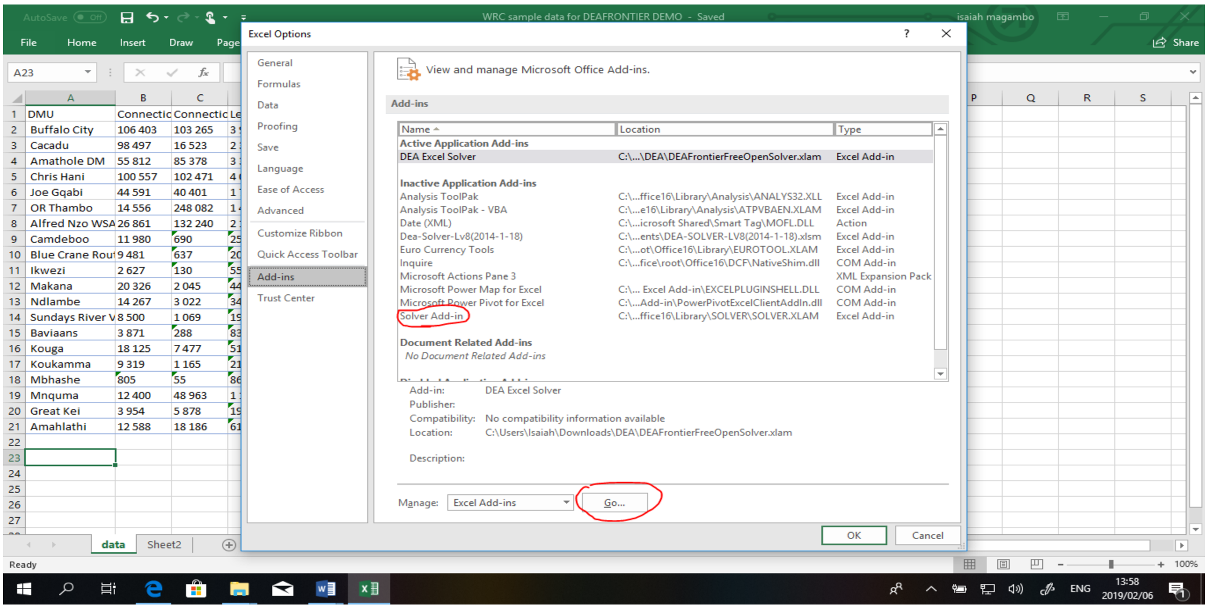




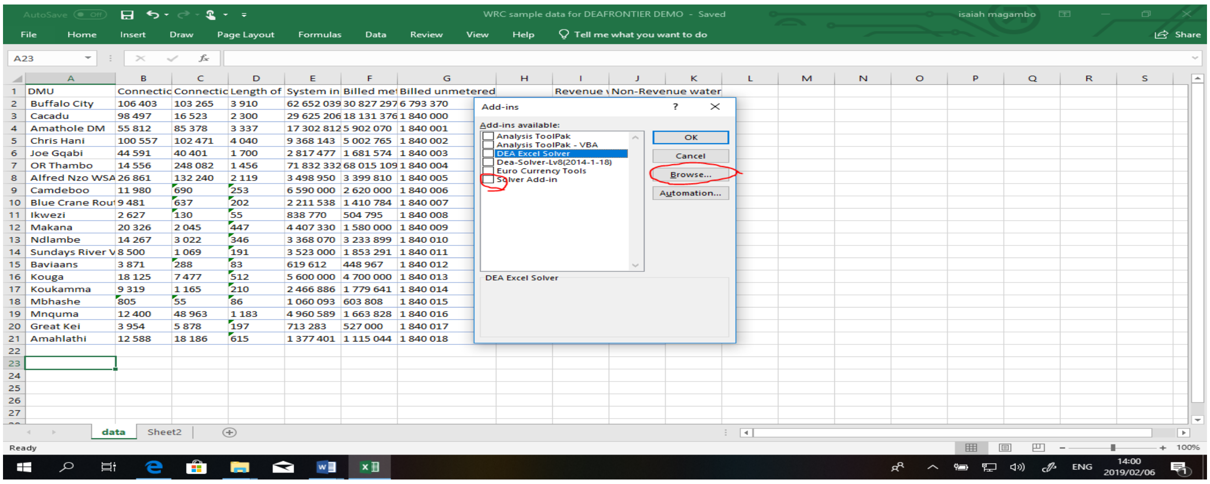
For the next step, whichever version you have, click ‘Add-ins’:



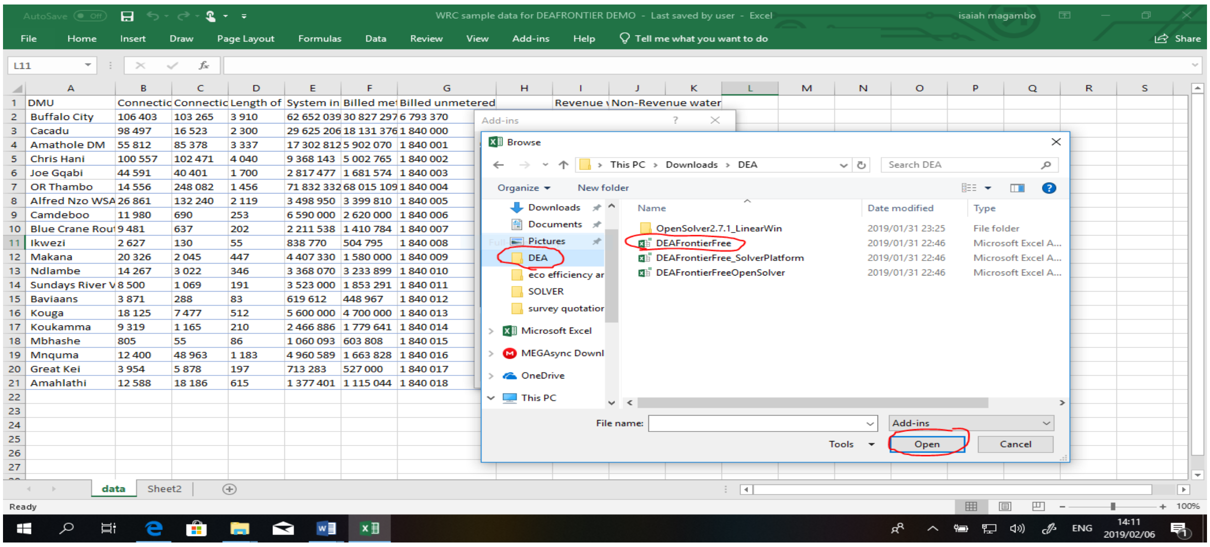
Then click ‘Go…’:



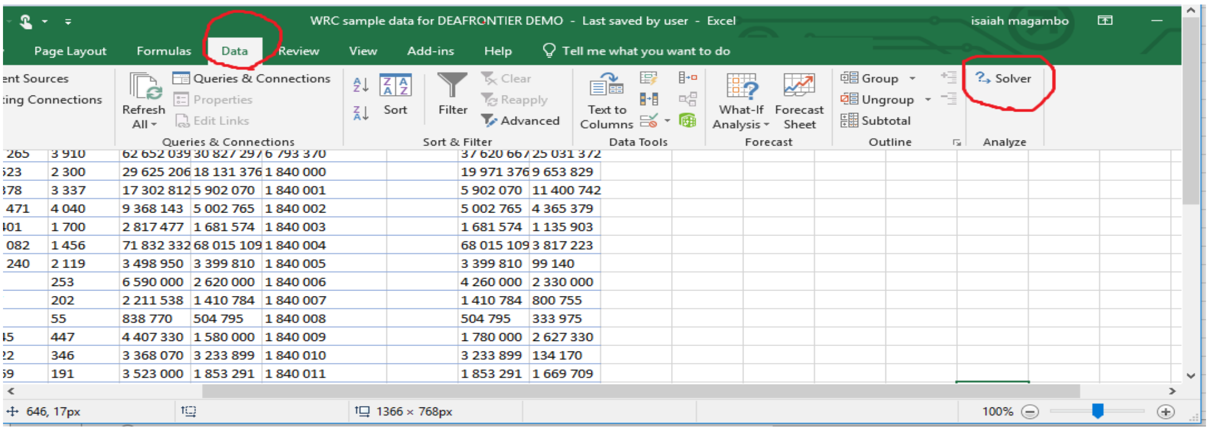
Now tick the ‘Solver Add-in’ box, and click on ‘Browse…’:



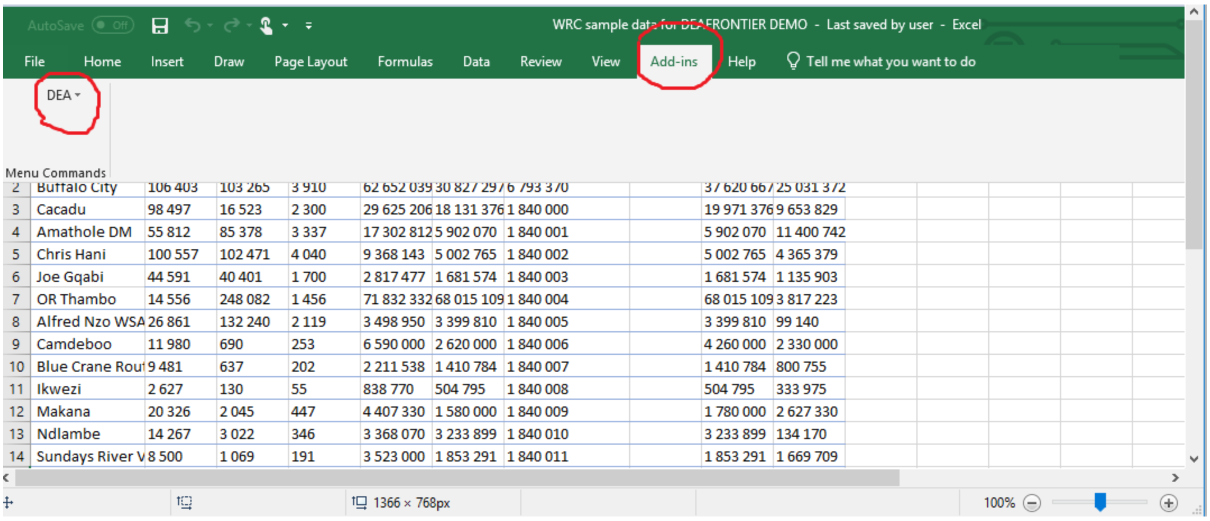
Then browse your files to find the file you downloaded in Step 1 above, and open to select the software:



On your Excel sheet you will see that the Solver tool has been added (circled in red):

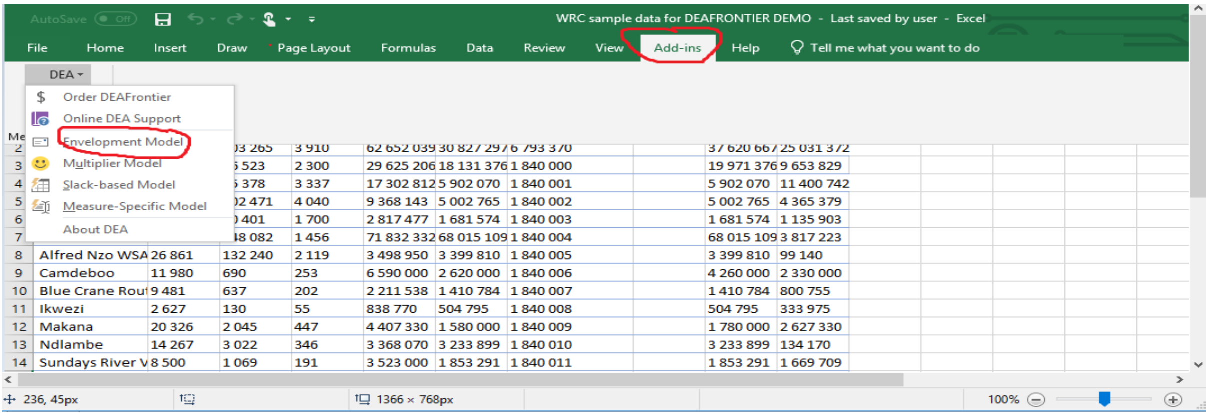


You will also see that the ‘Add-ins’ function has been activated; if you click the ‘Add-ins’ tab, you will see your DEA model added to your Excel Solver:

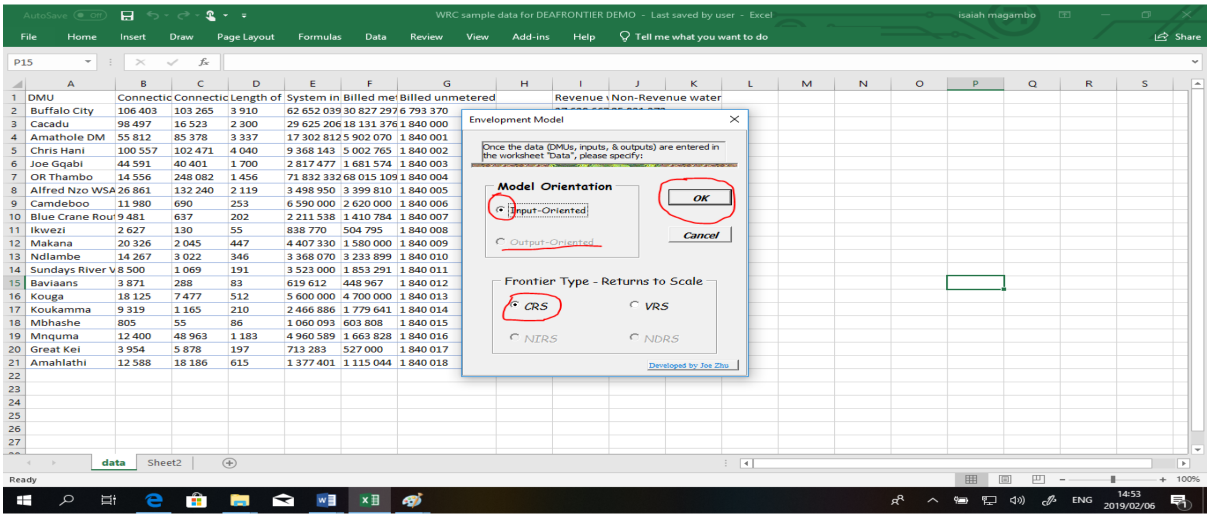


A2.2.4. Step 4: Running the DEA model in MS Excel

Click the ‘DEA’ drop-down menu, and then click ‘Envelopment Model’:

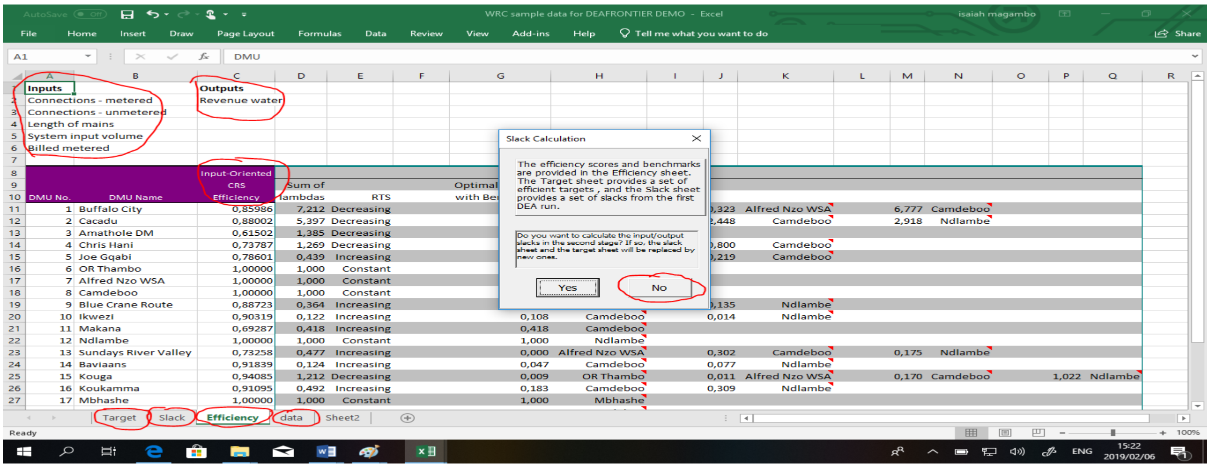


The small ‘Envelopment Model’ window shown below will pop up. Select model orientation (in this case, input orientation – refer to the theoretical explanations in DEA model orientation). Select frontier type (in this case, CRS – Constant Returns to Scale – refer to basic DEA models). Now click ‘OK’ to run your DEA model:



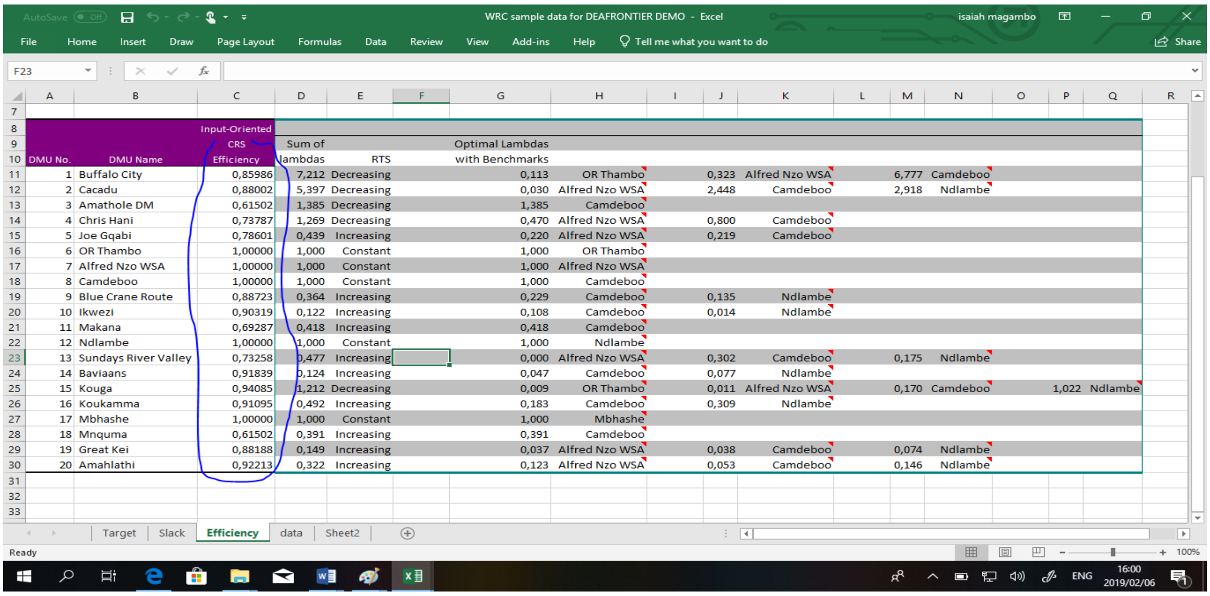
A2.2.5. Step 5: Interpreting DEA model results

The result will be displayed in the same datasheet, as seen below, with additional auto-generated worksheets: Target, Slack and Efficiency. Click ‘No’ on the small Slack Calculation window shown (circled in red). The efficiency results are shown in the purple strip. At top left are the inputs and output used.



G) Efficiency score

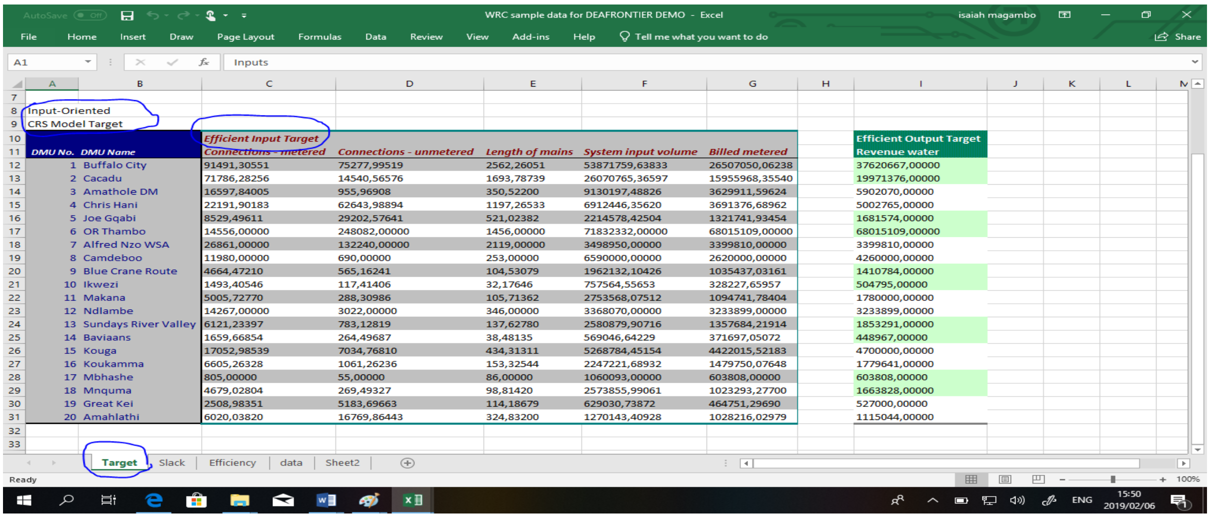
The figure below shows that OR Tambo, Alfred Nzo WSA, Camdeboo, Ndlambe and Mbhashe WSAs are efficient (they are on the frontier, indicated by their efficiency score of 1), while the rest are inefficient. The inefficient WSAs can improve their efficiency, or reduce their inefficiencies proportionately, by augmenting their inputs (since we are running an input-oriented model). For instance, Buffalo City has an efficiency score of 0.86, which implies it could augment its inputs by 14% ((1-.86) x 100) and become efficient.



DMU No.	DMU Name	Input-Oriented CRS Efficiency	Sum of lambdas	RTS	Optimal Lambdas with Benchmarks							
1	Buffalo City	0,85986	7,212	Decreasing	0,113	OR Thambo	0,323	Alfred Nzo WSA	6,777	Camdeboo		
2	Cacadu	0,88002	5,397	Decreasing	0,030	Alfred Nzo WSA	2,448	Camdeboo	2,918	Ndlambe		
3	Amathole DM	0,61502	1,385	Decreasing	1,385	Camdeboo						
4	Chris Hani	0,73787	1,269	Decreasing	0,470	Alfred Nzo WSA	0,800	Camdeboo				
5	Joe Gqabi	0,78601	0,439	Increasing	0,220	Alfred Nzo WSA	0,219	Camdeboo				
6	OR Thambo	1,00000	1,000	Constant	1,000	OR Thambo						
7	Alfred Nzo WSA	1,00000	1,000	Constant	1,000	Alfred Nzo WSA						
8	Camdeboo	1,00000	1,000	Constant	1,000	Camdeboo						
9	Blue Crane Route	0,88723	0,364	Increasing	0,229	Camdeboo	0,135	Ndlambe				
10	Ikwezi	0,90319	0,122	Increasing	0,108	Camdeboo	0,014	Ndlambe				
11	Makana	0,69287	0,418	Increasing	0,418	Camdeboo						
12	Ndlambe	1,00000	1,000	Constant	1,000	Ndlambe						
13	Sundays River Valley	0,73258	0,477	Increasing	0,000	Alfred Nzo WSA	0,302	Camdeboo	0,175	Ndlambe		
14	Baviaans	0,91839	0,124	Increasing	0,047	Camdeboo	0,077	Ndlambe				
15	Kouga	0,94085	1,212	Decreasing	0,009	OR Thambo	0,011	Alfred Nzo WSA	0,170	Camdeboo	1,022	Ndlambe
16	Koukamma	0,91095	0,492	Increasing	0,183	Camdeboo	0,309	Ndlambe				
17	Mbhashe	1,00000	1,000	Constant	1,000	Mbhashe						
18	Mnquma	0,61502	0,391	Increasing	0,391	Camdeboo						
19	Great Kei	0,88188	0,149	Increasing	0,037	Alfred Nzo WSA	0,038	Camdeboo	0,074	Ndlambe		
20	Amahlathi	0,92213	0,322	Increasing	0,123	Alfred Nzo WSA	0,053	Camdeboo	0,146	Ndlambe		

H) Efficiency targets for inputs and outputs

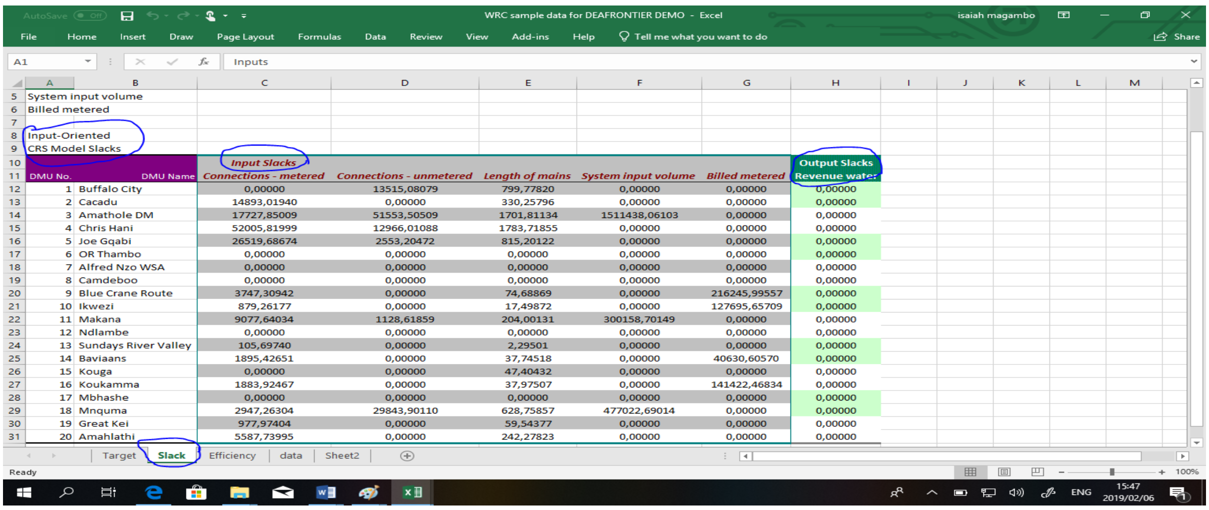
We can summarise the efficiency targets/projection by examining the 'Target' worksheet, shown below. Here, for each WSA, target input and output levels are prescribed. These targets are the results of respective slack values added to proportional reduction amounts.



DMU No.	DMU Name	Efficient Input Target: Connections - metered	Connections - unmetered	Length of mains	System input volume	Billed metered	Efficient Output Target: Revenue water
1	Buffalo City	91491,30551	75277,99519	2562,26051	53871759,63833	26507050,06238	37620667,00000
2	Cacadu	71786,28256	14540,56576	1693,78739	26070765,36597	15955968,35540	19971376,00000
3	Amathole DM	16597,84005	955,96908	350,52200	9130197,48826	3629911,59624	5902070,00000
4	Chris Hani	22191,90183	62643,98894	1197,26533	6912446,35620	3691376,68962	5002765,00000
5	Joe Gqabi	8529,49611	29202,57641	521,02382	2214578,42504	1321741,93454	1681574,00000
6	OR Thambo	14556,00000	248082,00000	1456,00000	71832332,00000	68015109,00000	68015109,00000
7	Alfred Nzo WSA	26861,00000	132240,00000	2119,00000	3498950,00000	3399810,00000	3399810,00000
8	Camdeboo	11980,00000	690,00000	253,00000	6590000,00000	2620000,00000	4260000,00000
9	Blue Crane Route	4664,47210	565,16241	104,53079	1962132,10426	1035437,03161	1410784,00000
10	Ikwezi	1493,40546	117,41406	32,17646	757564,55653	328227,65957	504795,00000
11	Makana	5005,72770	288,30986	105,71362	2753568,07512	1094741,78404	1780000,00000
12	Ndlambe	14267,00000	3022,00000	346,00000	3368070,00000	3233899,00000	3233899,00000
13	Sundays River Valley	6121,23397	783,12819	137,62780	2580879,90716	1357684,21914	1853291,00000
14	Baviaans	1659,66854	264,49687	38,48135	569046,64229	371697,05072	448967,00000
15	Kouga	17052,98539	7034,76810	434,31311	5268784,45154	4422015,52183	4700000,00000
16	Koukamma	6605,26328	1061,26236	153,32544	2247221,68932	1479750,07648	1779641,00000
17	Mbhashe	805,00000	55,00000	86,00000	1060093,00000	603808,00000	603808,00000
18	Mnquma	4679,02804	269,49327	98,81420	2573855,99061	1023293,27700	1663828,00000
19	Great Kei	2508,98351	5183,69663	114,18679	629030,73872	464751,29690	527000,00000
20	Amahlathi	6020,03820	16769,86443	324,83200	1270143,40928	1028216,02979	1115044,00000

I) The slacks

The figure below comes from the 'Slack' worksheet of the DEA run results. We observe that the efficient DMUs have zero ('0') slacks; slacks exist only for those DMUs identified as inefficient. It is interesting to note, for instance, that in order for Cacadu to become efficient, it must decrease its metered connections by 14 893 and length of mains by 330 km. But despite the resulting augmentation of output, it still would not achieve efficiency. No other output can be increased.



DMU No.	DMU Name	Input Slacks: Connections - metered	Connections - unmetered	Length of mains	System input volume	Billed metered	Output Slacks: Revenue water
1	Buffalo City	0,00000	13515,08079	799,77820	0,00000	0,00000	0,00000
2	Cacadu	14893,01940	0,00000	330,25796	0,00000	0,00000	0,00000
3	Amathole DM	17727,85009	51553,50509	1701,81134	1511438,06103	0,00000	0,00000
4	Chris Hani	52005,81999	12966,01088	1783,71855	0,00000	0,00000	0,00000
5	Joe Gqabi	26519,68674	2553,20472	815,20122	0,00000	0,00000	0,00000
6	OR Thambo	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
7	Alfred Nzo WSA	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
8	Camdeboo	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
9	Blue Crane Route	3747,30942	0,00000	74,68869	0,00000	216245,99557	0,00000
10	Ikwezi	879,26177	0,00000	17,49872	0,00000	127695,65709	0,00000
11	Makana	9077,64034	1128,61859	204,00131	300158,70149	0,00000	0,00000
12	Ndlambe	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
13	Sundays River Valley	105,69740	0,00000	2,29501	0,00000	0,00000	0,00000
14	Baviaans	1895,42651	0,00000	37,74518	0,00000	40630,60570	0,00000
15	Kouga	0,00000	0,00000	47,40432	0,00000	0,00000	0,00000
16	Koukamma	1883,92467	0,00000	37,97507	0,00000	141422,46834	0,00000
17	Mbhashe	0,00000	0,00000	0,00000	0,00000	0,00000	0,00000
18	Mnquma	2947,26304	29843,90110	628,75857	477022,69014	0,00000	0,00000
19	Great Kei	977,97404	0,00000	59,54377	0,00000	0,00000	0,00000
20	Amahlathi	5587,73995	0,00000	242,27823	0,00000	0,00000	0,00000