

Performance Evaluation of Water Services Provision in Counties and Water Services Boards of Kenya

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Abstract
Principal component analysis has been applied to eight dimensionless water services provision parameters for forty three administrative counties and eight water services boards of Kenya, in order to group the parameters under different components based on significant correlations. Good correlation (r=0.63) exist between Water Supply coverage (C_w) and the viability of water services utilities (C_{omc}), while the hours of supply (H_s) is also correlated (r=0.55) to the viability of water services utilities (C_{omc}). Non-Revenue Water (NRW) showed negative correlation with the coverage of water supply and viability of water services utilities. In fact these two parameters showed low correlation (r<0.3) with any of the other remaining parameters. Furthermore, the similarity and dissimilarity between the counties and water services boards in terms of water services provision is evaluated. In relation to benchmark conditions, a lot of work still needs to be done to realise ideal status. Tharaka-Nithi, Uasin-Gishu, Kakamega, Bungoma, Busia, Trans-Nzoia, Meru, Garissa and Kisumu counties formed the cluster of best performing counties with a strong showing in Non-Revenue Water, viability of water services utilities, coverage of water services, Hours of supply and a weak showing in C_{wb} i.e the ratio of cost of water billed to the average tarrif. Migori, Homa-Bay, Elgeyo-Marakwet, Vihiga, and West-Pokot counties are clustered together with a strong showing on ratio of cost of water produced to the average tariff (C_{wp}) and NRW but weak sewerage service coverage (C_s), Population within the service area (WSP_p) and C_{omc} and appear to be the worst performers. Athi and Lake Victoria North Water services boards though not clustered together are the best performers while Tanathi water services board is the worst performer. Generally, utilities with weak technical performance were found to do poorly financially and also offered poor customer care and quality of service. This study therefore, is key in facilitating cross-utility comparison.
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1. Introduction

The architecture of the water supply and sanitation subsectors in Kenya has experienced substantial transformation in the last decade, in response to a gradual worsening of urban services through the last two decades of the 20th century. Presently, players in the reform process often refer to the adoption of the Water Act (2002) as the starting point for these reforms (Zeraebruk et al., 2014). However, the water sector reform must be seen in the context of extensive neoliberal reforms that swept across Africa from the 1980s under the Structural Adjustment Programmes, led by the Bretton Woods Institutions (International Monetary Fund and the World Bank) (Lannier and Porcher 2014). Many countries in Africa subsequently undertook reforms of their water sectors in the 1990s, often with strong backing of donor organisations such as the World Bank (Bayliss 2003; Ballance and Tremolet 2005). Some of the problems facing water supply in Kenya then included: inadequate metering, unaccounted for water, uneconomic tariffs, ineffective collection of water revenue, exclusion of the poor from the service, overstaffing of water services providers, conflict of roles in water management, and low connection to the sewerage networks (K'Akumu and Appida 2006). All the above reasons emanated from the fact that provision of water services was overcentralized, and water was provided as a social rather than an economic commodity.

Privatisation of water and sewerage services at the start of the 21st century was expected to solve the problem of poor and inadequate service provision occasioned by the failings of the state ownership. This was to be achieved through decentralisation that would guarantee economic viability of the water service providers. Transformation of water services to a trade-able commodity means that, access to water is now pegged on consumer ability to pay as opposed to need (Smith, 2004). Many have cited privatisation as means to raise revenue for the state, promote economic efficiency, reduce government interference in the economy, promote wider share ownership, introduce competition, and subject state-owned enterprises to market discipline (Prasad 2007). Privatization of water services has progressively led to the formation of 122 water companies spread across the country, leading to improved service delivery in their respective areas of operation (WSRB, 2015). Improvement in service delivery is gauged by looking at the key indicators of operational efficiencies which mirror the ability of a water company to address the problems affecting delivery of water services prior to privatisation.

Privatization of water services has greatly improved availability and accessibility to water services (Asingo 2005), however, the performance across counties vary considerably. Key performance indicators used in evaluating water services provision include: (i) improvement in access to improved water supply by residents (ii) improvements in access to improved sanitation (iii) improvement in the quality of service provision (i.e. increased number of hours of supply, reduction of NRW, reduction of hours spent in fetching water, improved response time to registered customers' complaints), iv) improved viability of the water services provider (WSP) amongst others. This study examines likeness or variations in water service provision among counties, as well as water services boards across Kenya.

2. Study area and data

Kenya, in East Africa lies a-stride the equator between longitudes 34^0E and 42^0E and latitudes 5^0N and 4.5^0S, covering an area of approximately 590 000km^2. This East African country is made up of forty seven administrative unit called counties which were the units of the current study. In terms of water services provision, the country is divided into eight water services boards (table 2). Figure 1 below show a map of Kenya and its counties. Data used in the study was accessed at https://opendata.go.ke.

Figure 1: Map of Kenya and its forty seven administrative counties

3. Methodology

3.1 Water services provision parameters

Eight salient parameters that are indicative of the level of service provision as well as operational efficiency level of the water service providers are selected in this study. This parameters include:

1. WSP_s: proportion of the county population within the service areas of the water services providers (i.e. company that provides water and sewerage services).
2. C_w: proportion of population within the jurisdiction of the water services provider that is supplied with water.
3. C_s: proportion of population within the jurisdiction of the water services provider that is offered sewerage services.
4. H_s: proportion of the day over which there is a continuous supply or flow of water from service provider to the consumers.
5. NRW: represents the difference between the volume of water put into a water distribution system and the volume of water billed to customers. Non-Revenue Water is attributed to aging water distribution systems leading to non-detected leakages, pipe bursts, leakages, illegal connections, faulty meters and meter by-passes.
6. C_{omc}: denotes the viability of service providers. It represents the level at which the water service providers are able to meet the cost of operation and maintenance from their generated revenues. Utilities that do not achieve operational cost recovery, reduces the amount available for capital investment and will require to be subsidized from the public purse (Cabrera et al., 2011). Operation and

maintenance costs in the provision of water services include; personnel costs, energy costs, chemicals, network rehabilitation and expansion expenses. While, water company revenues are mainly sourced from the water bills collected from clients.

7. C_{wp}: denotes the ratio of unit cost of water produced to the average tariff. Review of water tariff is based on an awareness that water charges are the main sources of income for a water company to achieve cost recovery. Nonetheless, there have been fears that a rising water tariffs would result in an increase in the cost of water. The resultant high cost of water would deny low income households access to water services (Makaya and Hensel 2014).
8. C_{wb}: denotes the ratio of unit cost of water billed to the average tariff. A value of C_{wp} that is close to C_{wb} is a proxy indicator of low NRW.

The evaluated values of the selected water services provision parameters of administrative counties in Kenya are shown in table 1, while those of the Water services boards are shown in Table 2. Data for Tana-River, Mandera, Bomet and Wajir counties was unavailable and therefore the analysis was based on data from forty three out of the forty seven counties.

Table 1: Water services provision parameters of counties in Kenya

County	WSP_p	C_w	C_s	H_s	NRW	C_{omc}	C_{wp}	C_{wb}
Nyamira	0.96	0.36	0.84	0.58	0.48	0.74	0.77	1.43
Kericho	0.41	0.60	0.41	0.92	0.49	0.74	0.66	1.25
Baringo	0.06	0.42	0.00	0.42	0.69	0.22	1.47	4.81
Kirinyaga	0.78	0.32	0.00	0.79	0.66	1.08	0.40	1.06
Kisii	0.53	0.36	0.84	0.58	0.48	0.73	0.77	1.43
Kitui	0.96	0.32	0.00	0.67	0.61	0.55	0.70	1.72
Laikipia	0.36	0.86	0.49	0.96	0.40	0.65	0.75	0.99
Siaya	0.43	0.29	0.00	0.79	0.53	0.50	1.02	2.14
Murang'a	0.90	0.44	0.03	0.79	0.58	0.97	0.59	1.18
Kajiado	0.66	0.32	0.00	0.52	0.57	0.70	0.70	1.41
Mombasa	0.97	0.57	0.09	0.25	0.48	0.92	0.60	1.12
Turkana	0.07	0.44	0.00	0.79	0.45	0.85	0.73	1.27
Taita-Taveta	0.20	0.61	0.00	0.38	0.43	0.73	0.84	1.41
Kisumu	0.37	0.63	0.14	0.96	0.42	1.03	0.60	0.99
Narok	0.07	0.32	0.00	0.88	0.41	0.90	0.76	1.23
Nyandarua	0.38	0.32	0.00	0.88	0.41	0.66	0.76	1.23
Marsabit	0.14	0.23	0.00	0.33	0.38	0.30	0.46	0.74
Samburu	0.16	0.23	0.00	0.33	0.40	0.31	2.30	3.66
Kilifi	0.84	0.63	0.00	0.75	0.37	0.95	0.71	1.12
Migori	0.24	0.17	0.00	0.46	0.37	0.55	1.52	2.38
Nakuru	0.55	0.77	0.21	0.71	0.38	0.92	0.71	1.10
Garissa	0.20	0.61	0.05	0.92	0.42	0.93	0.72	1.13
Bungoma	0.24	0.80	0.31	0.92	0.38	0.92	0.75	1.16
Trans Nzoia	0.40	0.80	0.31	0.92	0.38	0.92	0.75	1.16
Embu	0.84	0.61	0.06	0.92	0.44	1.30	0.61	0.90
Kiambu	0.87	0.70	0.13	0.83	0.37	1.00	0.71	1.07
Meru	0.38	0.51	0.06	0.92	0.39	1.06	0.72	1.07
Kwale	0.40	0.66	0.00	0.63	0.32	0.77	0.95	1.40
Isiolo	0.41	0.53	0.10	0.50	0.35	0.90	0.81	1.18
West Pokot	0.13	0.19	0.00	0.79	0.29	0.45	1.57	2.22
Homa Bay	0.11	0.26	0.14	0.29	0.31	0.49	1.50	2.11
Lamu	0.19	0.70	0.00	0.25	0.36	0.85	0.94	1.28

County	WSP_p	C_w	C_s	H_s	NRW	C_{omc}	C_{wp}	C_{wb}
Nyeri	0.76	0.69	0.09	0.96	0.41	1.12	0.69	0.91
Makueni	0.34	0.32	0.00	0.54	0.27	0.76	1.05	1.39
Uasin Gishu	0.37	0.70	0.30	0.67	0.35	1.07	0.83	1.03
Nairobi	0.97	0.80	0.46	0.75	0.39	1.05	0.65	0.96
Nandi	0.09	0.44	0.00	0.88	0.37	0.94	1.05	1.14
Machakos	0.80	0.43	0.09	0.46	0.49	0.80	0.66	1.20
Busia	0.47	0.72	0.13	0.83	0.39	1.24	0.89	0.88
Kakamega	0.22	0.72	0.13	0.83	0.39	1.24	0.89	0.88
Tharaka-Nithi	0.31	0.73	0.00	1.00	0.38	1.15	1.00	0.91
Vihiga	0.35	0.15	0.00	0.50	0.42	0.91	2.64	1.12
Elgeyo- Marakwet	0.12	0.18	0.00	0.50	0.32	0.25	1.08	1.54

Table 2: Water services provision parameters for Water Services Board (WSB) in Kenya

WSB	WSP_p	C_w	C_s	H_s	NRW	C_{omc}	C_{wp}	C_{wb}	Counties coverage
Athi	0.96	0.71	0.32	0.79	0.39	0.61	0.65	1.07	Nairobi, Kiambu, Parts of Muranga
Coast	0.66	0.56	0.03	0.45	0.42	0.14	0.81	1.27	Kwale, Taita-Taveta, Kilifi, Mombasa, Lamu, Tana River
Lake Victoria North	0.20	0.64	0.20	0.76	0.37	1.00	1.31	1.07	Kakamega, Busia, Bungoma, TransNzoia, Uasin-Gishu, Nandi, Parts of Elgeyo-Marakwet
Lake Victoria South	0.27	0.41	0.08	0.69	0.45	1.00	0.99	1.61	Siaya, Kisumu, Migori, Homabay, Kisii, Nyamira, Bomet Kericho, Parts of Nandi
Northern	0.12	0.61	0.20	0.61	0.40	0.87	1.01	1.54	Isiolo, Laikipia, Samburu, Marsabit, Garissa, Wajir Mandera
Rift Valley	0.27	0.51	0.09	0.71	0.44	0.79	1.01	1.91	Nakuru, Baringo, Narok, W-Pokot, Turkana, Nyandarua, Keiyo in Elgeyo-Marakwet
Tana	0.62	0.46	0.03	0.90	0.51	0.96	0.67	1.01	Nyeri, Muranga, Kirinyaga, Embu, Meru, Tharaka-Nithi
Tanathi	0.72	0.29	0.02	0.55	0.58	1.00	0.78	1.43	Kitui, Machakos, Makueni, Kajiado

3.2 Principal component analysis

The method of principal component analysis is based upon the early work of Pearson with the specific adaptation to principal component analysis suggested by the work of Hotelling (1933). Correlation indicates that some of the information contained in one variable is also contained in some of the other remaining variables. More specifically, the first principal component is that linear combination of the original variables which contributes a maximum to the total variance; the second principle component, uncorrelated with the first, contributes a maximum to the residual variance, and so on until the total variance is analysed. Since the method is so dependent on the total variance of the original variables, it is most suitable when all the variables are measures in the same units. Hence, it is customary to express the variables in standard form, i.e. to select the units of measurements for each variable so that its sample variance is one. Then, the analysis is made on the correlation matrix with the total variance equal to *n*. the objectives are achieved in two steps:

1. Correlation matrix is calculated
2. Principal component loading matrix is calculated by principal component analysis
3. From the principal component loading matrix, Eigen values greater than one signify significant principal component loading.

3.2.1 Correlation matrix

The Intercorrelation matrix of the water services provision parameters is obtained by using the following procedure:
The parameters are standardised

$$X = \frac{(x_{ij} - x_j)}{s_j}$$

where

x	matrix of standardised parameters
x_{ij}	i^{th} observation on j^{th} parameter
i	$1,\ldots, N$ (number of observations)
j	$1,\ldots, N$ (number of parameters)
x_j	mean of the j^{th} parameter
s_j	standard deviation of the j^{th} parameter

the correlation matrix of parameters is the minor product moment of the standardised predictor measures divided by N and is given by

$$R = \frac{(x' * x)}{N}$$

where, x' denotes the transpose of the standardised matrix of predictor parameter.

3.2.2 Principal component loading matrix

The principal component loading matrix reflecting how much a given parameter is correlated with different factors is the product of the characteristic vector and the square root of the characteristic value of the correlation matrix.

$$M_{pcl} = CM_{vector} * CM_{value}{}^{0.5}$$

where

M_{pcl}	principal component loading matrix
CM_{vector}	characteristic vector of the correlation matrix
CM_{value}	characteristic value of the correlation matrix

3.2.3 Relationship between variables and counties/water services boards

A correlation monoplot was used to evaluate the relationship between variables. The angle between the vectors indicate an approximation of correlation between the variables. A smaller angle was indicative of a strong positive correlation, a 90^0 angle between variables meant no correlation between them, while an angle close to 180^0 indicated a negative correlation. In addition the length of the line was indicative of how well the variable was represented. Well represented variables had longer lines and vice versa. The likeness of performance between counties and between water services boards was evaluated using a Bi-plot which plots the counties and water services boards. To distinguish between better and poorly performing counties and water services boards, an ideal county and water services board with benchmark values of the parameters was added to the plot. Counties and water services boards that plotted closer to the ideal situation were considered to be offering better services than those plotting further away. The parameter values for the ideal county/water services board used in benchmarking are presented in table 3.

Table 3: Water services provision parameters of an ideal county used for benchmarking

County	WSP_p	C_w	C_s	H_s	NRW	C_{omc}	C_{wp}	C_{wb}
Ideal	0.9	0.9	0.9	0.9	0.05	1	1	1

4. Result and discussion

The correlation matrix (Table 4) of the eight selected parameters reveal a good correlation (correlation coefficient of 0.63) between water supply coverage (C_w) and viability of water services providers (C_{omc}), implying that as the WSP increases its coverage in terms of the number of people receiving water supply its ability to meet the costs associated with operation and maintenance also improved. The proportion of the day that has a continuous supply (H_s) is correlated (correlation coefficient of 0.55) to the parameter C_{omc}. Parameter C_{omc} is negatively correlated (correlation coefficient of -0.69) to the ration of unit cost of water billed to the average tariff (C_{wb}). However, C_{omc} is positively correlated (correlation coefficient of 0.58) to the ratio of unit cost of water produced to the average tariff (C_{wp}). Parameters C_s (Coverage of sewerage services), NRW (Non-revenue water) show low correlation (correlation coefficient less than +/- 0.3) with any of the other parameters.

Table 4: Intercorrelation matrix of water services provision parameters

Parameter	WSP_p	C_w	C_s	H_s	NRW	C_{omc}	C_{wp}	C_{wb}
WSP_p	1.000	0.199	0.289	0.094	0.380	0.372	-0.426	-0.314
C_w		1.000	0.290	0.445	-0.172	0.630	-0.468	-0.426
C_s			1.000	0.129	0.019	0.100	-0.219	-0.165
H_s				1.000	-0.016	0.548	-0.369	-0.414
NRW					1.000	-0.088	-0.196	0.295
C_{omc}						1.000	-0.394	-0.685
C_{wp}							1.000	0.575
C_{wb}								1.000

The correlation monoplot (figure 2) also shows the relationship between variables and how well they are represented. The coverage of sewerage services in counties is seen to be poorly represented. Parameters C_{omc}, C_w and H_s are positively correlated but these three parameters are all negatively correlated to C_{wb}. Similarly, parameters WSP_s and C_s are positively correlated but negatively correlated to C_{wp}. Parameter NRW show low or negative correlation with the remaining seven parameters, with its correlation with WSP_s being closest among them.

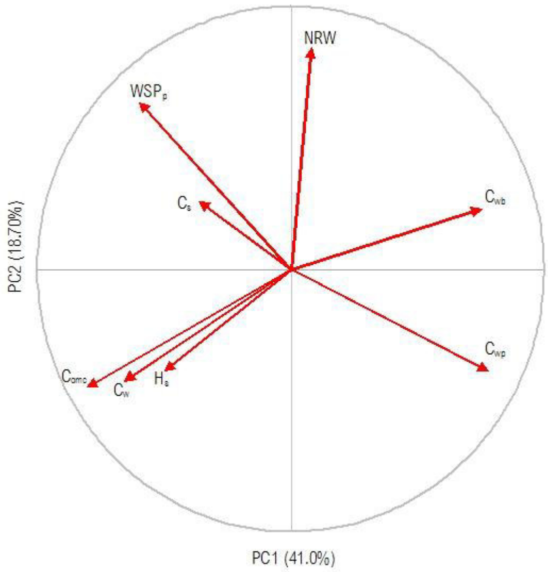

Figure 2: Correlation mono-plot of the water services provision parameters

The principal component loading matrix obtained from correlation matrix (Table 5) reveals that the first two components whose Eigen values are greater than one, together account for about 60% of the total explained variance. The first component is positively correlated (loadings of more than 0.4) with C_{wp} and C_{wb}. The second component is correlated to with WSP_p (0.54) and NRW (0.71).

Table 5: Principal component loading matrix of water services provision parameters

	Principal component							
Parameter	1	2	3	4	5	6	7	8
WSP_p	-0.285	0.539	-0.018	-0.378	-0.406	-0.077	0.558	0.036
C_w	-0.417	-0.164	-0.163	0.271	-0.121	0.735	0.114	0.364
C_s	-0.201	0.213	-0.870	0.199	0.015	-0.250	-0.218	-0.091
H_s	-0.362	0.153	0.242	0.638	0.029	-0.502	0.350	0.065
NRW	0.025	0.709	0.313	0.326	-0.006	0.050	-0.458	0.285
C_{omc}	-0.462	-0.138	0.215	-0.041	-0.490	0.021	-0.443	-0.532
C_{wp}	0.406	-0.233	-0.104	0.105	-0.739	-0.193	-0.092	-0.408
C_{wb}	0.442	0.196	-0.058	0.467	-0.178	0.315	0.302	-0.568
Eigen value	3.278	1.501	0.956	0.767	0.583	0.523	0.280	0.111

The correlation bi-plot (figure 3) show a cluster plot of the counties in relation to the ideal county. The counties performance are not close to the ideal situation meaning that there is more room for improvement in terms of service provision. Tharaka-Nithi and Kakamega counties are the most closest to the ideal situation. Tharaka-Nithi, Kakamega, Bungoma, Uasin-Gishu, Busia, Trans-Nzoia, Meru, Garissa and Kisumu show similarities in performance and is the cluster of counties closest to the ideal. Machakos, Kisii, Mombasa, Muranga, Kirinyaga and Nyamira cluster together with a poor showing in NRW. Nairobi, Embu, Nyeri, Kiambu, Kericho, Kilifi, Nakuru, Laikipia cluster together. Migori, Homa-Bay, Elgeyo-Marakwet, Vihiga and West-Pokot cluster together. Nyandarua, Turkana, Isiolo, Narok, Taita-Taveta, Kwale, Lamu and Nandi also cluster together. Other counties show distinct performance and are not clustered, this include: Baringo, Siaya, Samburu, Kitui, Kajiado, Marsabit and Makueni.

Table 6: Summary of clustering of the counties in the correlation bi-plot

Cluster	Counties
1	Tharaka-Nithi, Kakamega, Bungoma, Busia, Trans-Nzoia, Meru, Garissa, Kisumu
2	Nairobi, Embu, Nyeri, Kiambu, Kericho, Kilifi, Nakuru, Laikipia
3	Nyandarua, Turkana, Isiolo, Narok, Taita-Taveta, Kwale, Lamu, Nandi
4	Machakos, Kisii, Mombasa, Muranga, Kirinyaga, Nyamira
5	Migori, Homa-Bay, Elgeyo-Marakwet, Vihiga, West-Pokot

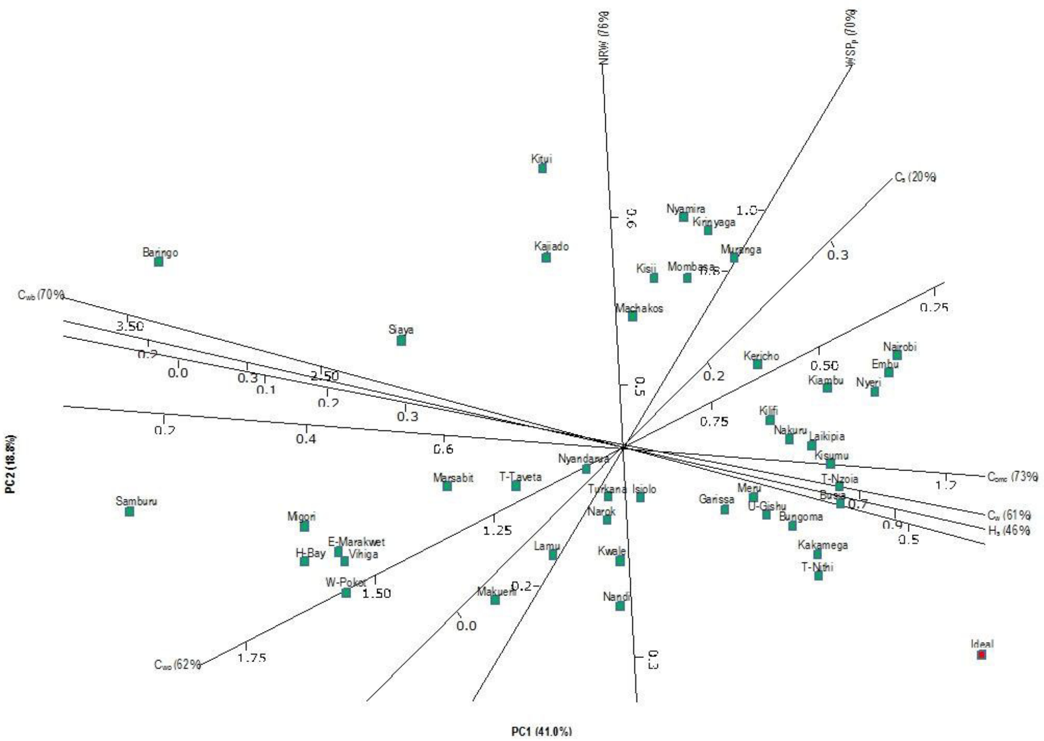

Figure 3: correlation biplot of water services provision parameters of counties in Kenya

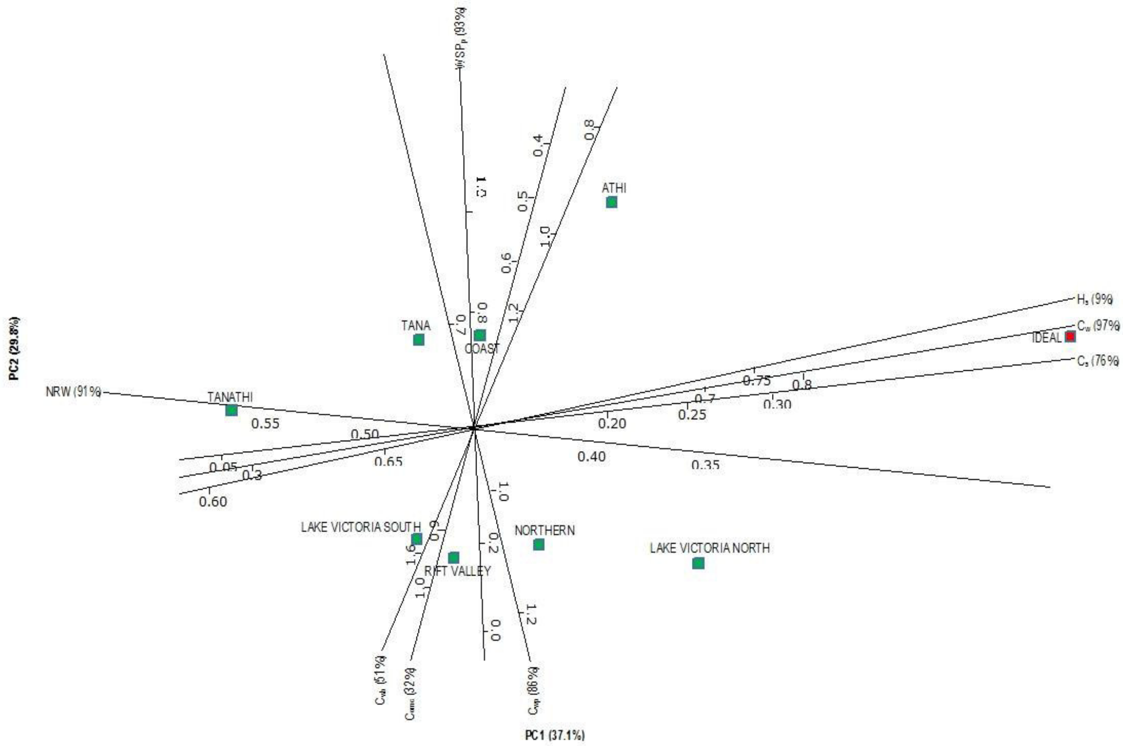

Figure 4: Correlation biplot of water services provision parameters for Water Services Boards in Kenya

Cluster 1 counties are strong in NRW, C_{omc}, C_w, H_s and weak in C_{wb}, Cluster 2 counties are strong in C_{omc}, C_w, H_s and WSP_p and weak in C_{wb}, Cluster 3 score average on most of the parameters, Cluster 4 is strong on WSP_p and weak in NRW, whereas cluster 5 is strong on C_{wp} and NRW and weak on C_s, WSP_p and C_{omc}. The correlation bi-plot (figure 4) shows a cluster plot of the WSB's in relation to the deal. The performance of the eight WSB's is far much different from the ideal situation. Tana and Coast WSB's show similarities in performance, they are weaker in C_{omc} and stronger in WSP_p. Other WSB's that cluster together include Lake Victoria South, Rift Valley and Northern WSB's. They are strong in C_{wb}, C_{omc}, and C_{wp} and weak in WSP_p. Tanathi WSB is the worst performer with a weak showing in NRW, H_s, C_w and C_s. Athi and Lake Victoria North WSB's though not similar in performance are the closest to the ideal situation. Athi WSB has a good WSP_p, while weak on C_{wb}, C_{oms}, C_{wp} whereas Lake Victoria North WSB has better C_{wb}, C_{oms}, and C_{wp}, while weak on WSP_p.

Looking at the performance in terms of technical performance, financial performance, and customer care and quality of service. It is clear that service providers that had weak technical performance (such as weak NRW, C_s, and C_w) generally performed poorly financially (weak C_{wb}, C_{oms} and C_{wp}) and also offered poor customer care and quality of service (weak H_s). However, there were instances where weak WSP_p and strong C_{wb}, C_{oms} and C_{wp} conditions were observed for some service providers. The technical performance of a service provider is closely associated to the availability of water, capacity and state of the infrastructure for production and distribution, and the system of operation and maintenance, therefore a strong WSP_p has to be accompanied by a strong technical performance. A higher service coverage (strong C_s, and C_w) is strongly associated to a weak H_s especially if the availability of water is limited as observed in dry counties.

5. Conclusion

In the present study, eight water services provision parameters were chosen for analysis of water services provision institutions in forty three counties and eight water services boards of Kenya. Water services utilities are facing substantial challenges as they endeavour to increase the quality and lower the cost of services to the consumers. The challenges may be technical, financial, or poor customer care and quality of service. Technical challenges are evident when the capacity to offer water and sewerage services is limited, whereas financial challenges arise as a result of utilities not being viable. On the other hand, utilities may also be faced with unsatisfied customers as a result of poor customer care and quality of service. Principle component analysis has shown the likenesses or non-similarities of counties and water services boards in Kenya with regards to water services provision. Clustering enables counties and water services boards to identify where they are performance wise and which county to look up to in terms of improvement. The addition of benchmarking conditions also helps in informing the best performing utilities on how much work is needed to realise ideal situation. This study therefore makes a significant contribution towards facilitating cross-utility comparisons, by clustering counties exhibiting similarity in performance.

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