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Fees and governance: Towards sustainability in water resources management at schools in post-apartheid South Africa

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Abstract: Water scarcity is increasingly staking a claim next to energy as a threat to the sustainability of large cities, especially in developing countries with limited resources. The recent crisis brought on by Cape Town's "Day Zero" drought created the impetus to expand on existing research on water demand management to include analysis of school usage patterns and key determinants thereof. With the effects of apartheid still visible in society and in school infrastructure coupled with the high water usage rates at schools, this paper evaluates the impact of school affluence (whether it is fee-paying or not, and self-governing or not) on water usage. We find that poor schools use substantially more water, partially because of poor maintenance, with mean water efficiencies of poor schools around 50% and 80% for affluent schools. Bayesian models were used to further determine which characteristics of a school are good proxies for the higher usage to help administrators and policy makers in the resource constrained educational environment. In addition to the obvious impact of maintenance, the results point an incriminatory finger at early morning-school usage, early afternoon usage, and Saturday usage.

Keywords: Community affluence; Schools water usage; Sustainable water management; Water demand modelling; Water equity, Water Scarcity

1.0 Introduction

Water shortages are increasingly reported compromising the sustainability of several large cities and regions worldwide. The unpredictability and extremity of climate change have further intensified the gravity of limited water supplies (McDonald et al., 2014; Srinivasan et al., 2017; Wagener et al., 2010). This problem is particularly salient in developing countries that are characterised by rapid population growth, high rates of urbanisation, and management challenges (Muller, 2018; Ziervogel, 2019). For example, Cape Town recently experienced its worst drought in over 100 years and was declared a disaster area with the so-called "Day Zero" an imminent threat (Enqvist and Ziervogel, 2019).

It is known that service providers and users require accurate and timely usage of information and billing to influence prudent user behaviour and to effectively predict and manage demand. Despite this need, municipalities in developing countries struggle to capture and report on water usage, often relying on estimates of water usage for the billing process (Booysen et al., 2019a; Booysen et al., 2019b; Parks et al., 2019). The result is that users often receive actual billing information two months or more after usage, resulting in undetected leaks and broken feedback information loops. Moreover, in some cases this is further exacerbated by four separate entities, respectively, with responsibility for using the water, maintaining the infrastructure, sourcing the money, and paying the bill. This paper expects to contribute by addressing the issue of reliable water usage data.

There has been a substantial amount of research dedicated to urban water demand management, which is particularly essential in developing countries as they often suffer from high rates of urbanisation. The majority of existing research on urban water demand management have focused on the residential sector, for example, demand forecasting (Adamowski et al., 2012; Bougadis et al., 2005; Donkor et al., 2012; Ghiassi et al., 2017; Ren and Li, 2016), demand modelling (Gurung et al., 2014; Jacobs and Haarhoff, 2004), general demand management (Kenney et al., 2008), and water usage management interventions (Datta et al., 2015; Dernoncourt and Lee, 2016; Fielding et al., 2012). There is limited research on the water demand in the non-residential or educational sectors despite the fact that these sectors can be high water consumers (Sánchez-Torija et al., 2017). Moreover, although historic water usage data has been used in several studies to model water usage patterns, there are several influential factors including socio-economic, political and climatic variables that have not been specifically taken into consideration (Botai et al., 2017; Donkor et al., 2012; Enqvist and Ziervogel, 2019; Muller, 2018; Scheba and Millington, 2018).

In light of Cape Town's "Day Zero" threat, the Western Cape Education Department (WCED) stated that schools are of primary importance as the Province struggled with the drought and to keep schools from closing due to the water shortage (WCG, 2017). Since the schools are responsible for their own water bills, albeit indirectly in some cases, any money that is unnecessarily spent on water reduces the already constrained resources available for education-related expenses. A study by Ripunda and Booysen (2018) highlighted the severity of water wastages in the Province's schools, by showing that a single primary school used as much as 35 kL per day, the equivalent of more than 100 households (Booysen et al., 2019b). The study further demonstrated that significant savings are possible through raising awareness and influencing water usage behaviour. A follow-on maintenance campaign by Booysen et al. (2019a) further demonstrated that even greater savings could be achieved through "quick-and-dirty" inexpensive maintenance at these schools. However, with more than 1,600 schools in the province (more than 23,000 in the country), and with the limited budgetary and managerial resources available, knowing where to focus attention remains a challenge without reliable higher frequency metering data.

Accordingly, we explored the non-residential sector of urban water demand in a developing city context. Specifically, we identified the general trends in water usage by schools in Cape Town, South Africa. Given the scars left by apartheid and severe inequality, we evaluated the influence of a school's affluence, revenue stream, and governance locus of control on their water usage, and in order to identify key drivers in relation to water usage. The results are expected to empower policy makers to focus their attention on the critical areas that drive high usage. Moreover, the results can be used to improve sustainable water management by reducing water usage and the related expenses.

2.0 Materials and Methods

2.1 Case study description

2.1.1 Education system in South Africa

The South African education system prior to the country's first democratic election in 1994 was both, unjust and biased, and the political system was one of totalitarianism with regards to school management. Because of this, after the end of the apartheid regime, the Education Department established several policies aimed at transforming the education system to be just and fair to all South Africans (Dalgleish et al., 2007; Engelbrecht and Harding, 2008; Government_Gazette, 1996; Longueira, 2016). Considering this, the Education Department created two main policies. The first was the SASA (South African Schools Act), which was created to establish committees that would be responsible for the general management of schools. The second was the NNSSF (National Norms and Standards for School Funding), which stipulated the governmental funding for each school according to its socio-economic status.

The SASA of 1996 (Government_Gazette, 1996) aimed to involve communities and relevant stakeholders in the day-to-day management of schools. This was achieved by establishing committees that are responsible for the overall governance of schools. These committees are referred to as School Governing Boards (SGBs) and are made up of educators, parents and learners in the case of secondary/high schools. Thus, the introduction of SGBs brought about shared responsibilities in terms of school governance in South Africa, by involving communities in their own upliftment through improved education. In the name of a fair and just system, the SASA defined the responsibilities of SGBs based on the socio-economic status (SES) of each school. Consequently, two types of schools were defined; termed Section 20 (S20) and Section 21 (S21) schools. For S20 schools, those with lower SES, the government is responsible for buying school material, paying utility bills, and performing maintenance. Section 21 schools on the other hand are allocated funding, from which the SGBs purchase all school materials, pays utility bills and perform their own maintenance. Therefore, SGBs of S21 schools have added responsibility and directly control school fund expenditure. Moreover, SGBs are mandated to augment state funding by implementing either school fees, in the case of some schools, or undertaking fund-raising programmes. These fund-raising programmes include renting out the school grounds to churches and other community groups for a fee. These fund-raising programmes indicate that the allocated governmental funding is not sufficient to sustain general school operations.

The National Norms and Standards for School Funding (NNSSF), which was established in 1998, stipulates how much governmental funding each school receives (Swartz, 2009).

Governmental funding is allocated to schools based on their quintile ranking, which divides schools into five groups according to their socio-economic status (Engelbrecht and Harding, 2008; Motala, 2015). Schools in quintiles 1 to 3 are classified as less affluent schools based on their SES. These schools receive higher governmental funding than schools in quintiles 4 and 5 and do not charge fees. For quintile 4 and 5 schools, governmental funding is significantly less and schools can charge school fees to augment their funding. The aim of the system is to remedy the inequality and inequity caused by the apartheid system, by increasing governmental funding to schools with a lower SESs in order to provide better opportunities to previously disadvantaged learners through a better education (Longueira, 2016). Therefore, this policy is expected to create better opportunities for learners that were previously disadvantaged by the old regime.

2.1.2 Water supply and use in South African schools

Water supply within South African schools is unreliable, especially for schools in poorer communities. Currently, South Africa has a total of 23,589 schools. From these, 452 schools were recorded as not having water supply, while another 4,773 have unreliable supply and more than 4,500 still use pit latrines (DBE, 2015).

Western Cape Education Department (WCED) water usage database indicates that four methods are used for recording a school's monthly water usage reading: physical readings by the school; readings by the municipality; automatic estimation; and re-estimation if over estimation occurred. From these, the two commonly used methods are automatic estimation and collection by municipality. The issue was particularly evident in the database of the WCED on schools' water usage data, a snapshot of which can be found in the Supplementary Information. The majority of schools in the Western Cape had several months with no recorded water meter readings in the database, of which the worst case was a school that had no recorded data for 10 months in 2017.

Furthermore, several schools reported that water bills are only issued every two months despite the fact that several of these are responsible for directly settling their own water bills. Consequently, schools are unable to effectively monitor or track their water use patterns. This delayed feedback also makes it difficult for schools to detect and deal with maintenance issues, such as leaks, in a timely manner.

2.2 Data collection

Accurate water usage data is essential for building water demand models that can generate reliable water usage estimates to be used for planning by utilities companies (Bakker et al., 2013; Ferraro and Price, 2013; Ghiassi et al., 2008). Although past studies have utilised several data sources, for example, municipal data, they are known for being inaccurate and unreliable (Datta et al., 2015; Ferraro and Price, 2013). Another data source frequently employed is smart water meters (Fielding et al., 2012; Gurung et al., 2014; Liu et al., 2016). However, smart water meters have only recently been introduced in South Africa, and not yet for schools. Therefore, there is limited or no access to high frequency and accurate long-term water usage data.

This study employed data sets from two different sources. One was a data set of 242 schools located in the Western Cape, obtained from the database emanating from a water-saving campaign of approximately 350 schools during Cape Town's drought, run as a private-public partnership with universities, government, and almost 100 corporate entities (www.schoolswater.co.za/) (Booysen et al., 2019a). Using a smart water meter called a Dropula, water flow was reported in real time to an online platform.

The second dataset was from the WCED, which had details of all the schools within the province. Among the variables were the number of students and educators in each school, whether the school is S20 or S21, and fee-paying or not. These are the variables used in this study.

2.3 Data analysis

2.3.1 Data pre-processing

The data set from the Dropula device was made up of minutely water usage data for each participating school. This data set of 242 schools was first screened based on the continuity of water usage. As such, water usage over a continuous period of at least 720 hours (30 days) or more was considered. This reduced the data set to 163 schools, of which the schools that had zero water usage were eliminated. Accordingly, the final data set included 156 schools.

From this data set of 156 schools, several variables were identified and used for the data analysis. The temporal identifiers were chosen based on observed and anecdotal evidence of school water usage patterns. Some examples are: (1) it was observed that some schools double as church buildings on Sundays, which will affect their Sunday usage; (2) some poorer schools seemed to have maintenance problems, which was linked to nightly flow; (3) some schools have feeding schemes, which will affect the lunch-time water usage; (4) some affluent schools have sporting activities on Saturdays, which will increase Saturday usage; (5) some schools have people living on the property or community members who do not have water supply, may use water from the school's supply during evening and early morning periods; (6) some affluent schools have after school hour music and drama lessons; and (7) some poorer schools have adult education programs in the evenings.

Table 1 captures the data types and classification. Daily usage for each school was separated into weekday, Saturday and Sunday usage. The weekday usage was further divided into different times of the day, which were chosen based on school operating times and activities. These were before school hours, during school hours, extra mural activity hours in the afternoon, after school early evening hours and midnight hours.

Table 1. Data types and classification.

Variable	Data type	Classification	
		Primary	**Secondary**
Water usage	Quantity (L/hour)	V_w: Weekdays	V_{0508}: 05:00 – 08:00
			V_{0814}: 08:00 – 14:00
			V_{1417}: 14:00 – 17:00
			V_{1722}: 17:00 – 22:00
			V_{2205}: 22:00 – 05:00
		V_{sa}: Saturdays	
		V_{su}: Sundays	
		V_t: Total	
St: Number of students	Quantity		
Edu: Number of educators	Quantity		
Fees: Fees charged	Yes/No		
S21: Self-governance	Yes/No		

2.3.2 Selection of analytical technique

The main imperative in selecting the appropriate analytical technique was the integration of both, quantitative and qualitative variables (see Table 1 above), which were identified to influence schools' water usage. In this context, Bayesian Networks (BNs) modelling has proven to be effective in relation to a range of environmental systems/processes modelling (Bonotto et al., 2018; Borsuk et al., 2004; Liu et al., 2018; Maeda et al., 2017; Martín de Santa Olalla et al., 2007; Rigosi et al., 2015; Ticehurst et al., 2007; Wijesiri et al., 2018). In fact, Bayesian statistical methods have gained relatively little attention, although they have been used for scenario-based water demand modelling. These methods combine the theory of probability and deductive reasoning to manage uncertainty in data.

The BNs modelling facilitates developing interdependencies between variables using the current knowledge of the problem, and their *Markov Property* (i.e. each variable depends only on its immediate parent variables) and overcomes the *curse of dimensionality* when dealing with small data sets (Scutari, 2009). A detailed discussion on BNs modelling is provided in the Supplementary Information. Accordingly, BNs modelling was employed in the current study to understand the interdependencies between influential factors of water demand in the schools. The modelling outcomes were then used to assess the significance of the state of affluence of schools compared to other factors.

3.0 Results and Discussion

3.1 General trends in water usage by schools

Table 2 summarises the data captured for different scenarios, and summarises the number of schools in each scenario. From the 156 schools investigated, 27 are in Scenario 1, 44 in Scenario 2, 12 in Scenario 3, and 73 in Scenario 4. In summary, this translates to 73 affluent schools and 83 less affluent schools in the dataset.

Table 2. Summary of schools in the dataset.

Scenario			**Number of Schools (%)**	**Description**
No.	Fees	S21		
1	No	No	27 (17)	Parents don't pay, school not self-governing
2	No	Yes	44 (28)	Parents don't pay, school self-governing
3	Yes	No	12 (8)	Parents pay, school not self-governing
4	Yes	Yes	73 (47)	Parents pay, school self-governing

The results in Fig. 1(a) show a drastic difference in flow rate for each school over all hours (V_t) from Scenarios 1 – 4. The medians and means are incrementally less for each scenario, with the Scenario 4 mean, 189 L/hr, only 40% of the Scenario 1 mean at 468 L/hr. We then investigated the source of the difference between the groups by individually evaluating the periods in Fig. 1(b) to Fig. 1(f).

As expected, the highest flow rate for each scenario occurs during school hours (8:00 to 14:00), with disparate means of 709 L/hr, 536 L/hr, 331 L/hr and 364 L/hr, respectively, for the four scenarios. There is large variance in the flow rates of the two non-fee-paying schools, with the fee-paying S21 scenario (Scenario 3) using similar amounts of water as the fee-paying S21 schools (Scenario 4), but with substantially less variance, which may be because of the small number of schools in Scenario 2.