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Results from a water-saving maintenance campaign at Cape Town schools in the run-up to Day Zero

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Abstract

Many South African schools struggle to maintain their water systems, particularly in the water-constrained Western Cape province, where the so-called "Day Zero" drought had intensified the urgency of saving water and increased the cost of supply. The problem is compounded by insufficient governmental funding, the lack of well-structured government policies, and a shortage of skilled maintenance staff at the schools. We evaluate the impact of a plumbing maintenance drive at 196 schools at the apex of the drought. Hypothesising that even the most basic maintenance could be a huge financial help to these schools, we gave plumbers a list of typical easy-gain repairs and restricted the budget to R5,000 per school, with some ad hoc exceptions. We then analysed the cost and benefit of these repairs, using data on the minimum night flow as recorded by smart water meters. We found an average of 28% reduction in MNF within five days of the reported maintenance date. The once-off R1,22 million spent on the 196 schools resulted in a monthly saving of R1,90 million – a saving that the schools could put to academic purposes.

Keywords: Minimum nightly flow (MNF); Dropula; SmartWaterMeterChallenge; School water system maintenance; Plumbing maintenance

1. Introduction

Supplying enough potable water is increasingly a threat to the sustainability of large cities. Although 70% of the planet is covered by water, only 3% of it is freshwater (Datta et al., 2015; C. Colvin, 2017). Despite the threat to water supply being particularly evident in cities in developing countries (e.g. São Paulo, Bangalore and Beijing), cities with water crises in developed countries often receive more media attention (e.g. San Francisco, Miami and Melbourne) (Quesnel and Ajami, 2017; Gurung et al., 2015). The threat in these developing cities is often compounded by ageing infrastructure, high levels of urbanisation and inadequate planning (Brick et al., 2018; BBC, 2018; Muller, 2018). One recent example is the city of Cape Town in

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South Africa, which on top of being a water-scarce region, recently experienced one of its worst droughts in a century (Turok, 2012; Datta et al., 2015; Cominola et al., 2015; Visser and Brühl, 2018). The severity of the drought necessitated the imposition of increasing levels of water restriction to curb usage, including some with heavy fines. As a whole, the City responded by slowly but steadily reducing usage (Visser and Brühl, 2018; Ziervogel, 2019; Enqvist and Ziervogel, 2019). The drought were so severe that the so-called "Day Zero" was introduced – when all taps in the City were predicted to run completely dry – to keep the City's water supply alive. With this vivid countdown in weeks and then days to the looming end, panic set in and household users responded by saving even more water (Booysen et al., 2019; Parks et al., 2019).

Our collaborative project was born in the middle of this storm, and attempted to help stave off a disaster through maintenance at governmental schools, which had still escaped the scrutiny of water-saving activists and had presented potentially significant and unexploited savings. The campaign, called the #SmartWaterMeterChallenge, comprised a maintenance drive and behavioural change drive, of which the results from the former is presented here. The campaign included two tertiary academic institutions, two provincial government departments, a radio station, and over 90 corporate sponsors. We evaluated the short-term gains of a demand management solution for maintaining water systems in schools to save water. A smart water meter called Dropula was installed at the schools, and minimum night flow (MNF) used to identify any abnormal water flow that might indicate leaks. We contracted plumbers to do basic "quick-and-dirty" emergency plumbing at a subsample of 196 of the schools, with a budget limited to R5,000 per school (US$350). Although all expenses were taken care of by the corporate sponsors, we present a cost-benefit analysis of the results, to assess the hypothetical expected payback period achieved through the savings as a guide to policy makers.

1.1. Literature survey

Similar to challenges in other developing environments, local and related contextual knowledge is paramount to understanding the scale and nature of plumbing maintenance challenges in South African schools, which may seem trivial when peering through a developed-country lens (Enqvist and Ziervogel, 2019). These challenges are often worsened by the financial constraints experienced by schools in developing countries.

The South African education system is beset by many problems, including how to manage its resources in the face of financial constraints (Xaba, 2012; Spaull, 2013; Hoosain, 2018; Spaull, 2019). Besides comprising the schools primary function of educating children, the financial difficulties also prevent proper management and maintenance of the infrastructure that supports the system. After the country's independence in 1994, the government designed and implemented several policies to combat these challenges. However, these policies, which relegate management of school facilities to the bottom of the list, were not able to fully eradicate these financial challenges (Engelbrecht and Harding, 2008; Lomofsky and Lazarus, 2010). As such, schools generally lose a tremendous amount of water and finances as a result of poor maintenance.

The first call for comments on the National Education Policy was made in 2008. This call was the first to prioritise the general maintenance of school environments in South Africa. At the time, only 12% of governmental finance for schools was allocated to facilities management as a whole (Nhlapo, 2009; Oliver, 2005). Interviewed about the 12% allocation, school principals said that it was insufficient to cover even the minimum costs of maintaining their facilities (Nhlapo, 2009). According to the 2018/19 Western Cape revenue and expenditure report, the province allocated R469,6 million to its schools for all maintenance and repairs. The report acknowledges, however, that there is a backlog in maintenance of education infrastructure and a shortage of school staff members with the skills to carry out the maintenance (Hoosain, 2018). Insufficient funding and shortage of skilled staff were fingered as the major contributors to this backlog. Moreover, the funding provided for maintaining school facilities has not produced the desired results, especially for schools in poorer neighbourhoods. This is particularly evident when it comes to maintenance of schools water systems, as we discovered when we investigated Western Cape schools during a drought period.

Water supply in South African schools is unreliable. For example, the Department of Basic Education Republic of South Africa (2015) reported that of the 23,589 schools in the country, 452 had no water supply and a further 4,773 had an unreliable supply – over 4,500 schools use pit latrines for ablution. In 2017 the City of Cape warned that should the water crisis continue it could mean closing some schools in the province (Hoosain, 2018; Department of Water and Sanitation, 2017). This makes it clear that water provision and the maintenance of water systems are part of the basic needs of every school and if not prioritised, can lead to major disruptions. Sources of accurate data on school water usage are thus urgently needed for research purposes. Although Gallego Sánchez-Torija et al. (2017) explored water usage in Spain (in the unrelated energy context), only one was study was found that attempted to quantify the amount of water used in schools within South Africa. In 2003, the Council for Scientific and Industrial Research estimated that South African urban schools were using 245 mega-litres a year in total. Of this, the CSIR estimated that 10 mega-litres were wasted yearly through inefficient management of school facilities. The estimates were based on data collected by the Green Buildings for Africa programme (Oliver, 2005). To date we do not know how maintenance affects schools water usage, as we do not have reliable data. Our study aimed to begin filling that gap.

Effective maintenance of school facilities has been noted to be an essential part of a successful education system. Numerous studies have demonstrated that children do better in well-maintained environments (South African National Norms, 1996; Oliver, 2005; Nhlapo, 2009). This means that maintenance of school facilities should be prioritised as an important element in building academic excellence, especially the water system, which is essential for good health. Plumbing is an essential part of the upkeep of the schools infrastructure: toilets, basins, showers, sinks, drinking fountains, irrigation systems for fields, fire extinguishing systems and so on all need constant attention (Whitehurst, 2003).

It was only in 2009 that schools started instituting policies and strategies for maintaining school facilities. A few studies have evaluated water-saving interventions and water awareness campaigns at schools in South Africa (Wilson, 2004; Still et al., 2008). Still et al. (2008) evaluated the status and use of water efficiency devices in the commercial and domestic environments in South Africa, including two schools. In the first, flushing urinals were replaced with flush-less equivalents. However, due to problems with odour, the urinals were reverted to flushing versions. The second school replaced toilets and urinals with flush-on-demand versions, and reduced their water usage by 75%. Although the report expands further on awareness campaigns, maintenance was not addressed. However, these studies did not evaluate maintenance at schools.

The topic remained largely unexplored within the South African context. As such, we reviewed the only two available South African studies that evaluated the condition of maintenance at school. These two qualitative studies covered four aspects: the current state of school maintenance, common practices, ideas for an effective school maintenance plan, and financial requirements. Although they are not about water system maintenance specifically, their general observations are relevant.

The first study, carried out by Nhlapo (2009) investigated maintenance plans and needs at a sample of 16 schools in the Gauteng province and suggested ways to incorporate maintenance into the schools' general management. The investigation showed that the current maintenance plans were reactive rather than proactive, consisting mainly of corrective and emergency plans, which suggested that maintenance was not considered a fundamental part of the educational system. The author further suggested that schools need intensive and strategic plans for maintaining their facilities. For example, most schools' maintenance was done by gardeners and groundsmen, as needed and through trial-and-error. Plumbing mainly focused on repairs, and major maintenance needs were contracted out. The author noted the low priority assigned to maintenance by the schools and their general lack of knowledge about how to do it. The author defines school maintenance, as a whole, as systematically using the available infrastructure for educational purposes.

The second study was a follow-up by Xaba (2012) to the study by Nhlapo. Principals and vice principals from 20 schools in Gauteng were interviewed regarding their practices for maintaining school facilities. Xaba argues that an effective school maintenance procedure needs three things: a maintenance plan that defines duties and responsibilities and establishes a committee solely responsible for maintenance; inspections that use check-lists (which can also be used for the planning phase); and a strategy for getting the maximum use out of the school facilities. Xaba sums up the whole school maintenance strategy as involving the following: organisational structure in the form of a committee, inspections, policies, a maintenance plan and funding.

Most of the schools in the study by Xaba were found to have some form of maintenance committee. These were made up mainly of cleaning staff and were responsible for the school's cleanliness and minor repairs. The lack of school staff who were qualified to carry out maintenance was similar to what was found by Nhlapo. Most of the schools in Xabas study said that inspection was usually done only after breakdown or damage had occurred. It was apparent from the study that schools had no standard maintenance procedures in place. Notably, most of the schools mentioned their need for staff members with maintenance skills.

Referring to the above general allocation of funds for school facilities maintenance in South Africa, it was noted that South African schools are prohibited by government from using funds allocated to other purposes for maintenance. All the schools interviewed by Nhlapo said the allocation was insufficient to sustain an efficient maintenance plan. Both these studies found that the biggest obstacle in maintaining school facilities in South Africa was financial constraints.

Schools are often left with the responsibility of augmenting this allocation. This is particularly difficult for public schools. Public schools are defined as schools in quintiles 1 to 3 and private schools as those in quintiles 4 and 5 (Hoosain, 2018). These categories are defined according to whether or not learners are expected pay school fees (Hoosain, 2018). A principal interviewed by Nhlapo said that their annual maintenance budget was in the range of R50,000 and that for 2009 this amount came partly from winning a competition. This shows how difficult it is for these schools to find extra sources of income for maintenance. Principals from two private schools said their maintenance fees come to R400,000 and R500,000 annually, indicating that private schools are better equipped to supplement their allocation than public schools. This meant that the private schools had better maintenance facilities than the public schools (Nhlapo, 2009).

The small samples in these two studies showed that upkeep of school facilities was commonly disregarded until the condition became bad enough to disrupt daily activities. Maintenance was not given the necessary priority. There was a disturbing lack of knowledge about the importance of maintenance plans. Effective maintenance strategies were not explored. The cost of maintenance was usually a mere estimate, based on little to no knowledge about how to make a good maintenance plan. Plumbing, was considered only a small part of maintenance and thus was often overlooked. The schools in the samples in both studies tended not to know either the cost or the benefit of maintenance, be it basic or extensive. Their main problems were insufficient funding, a lack of staff qualified to perform maintenance, and lack of strategic maintenance policies.

2. The maintenance project

In November 2017 it became clear that the dreaded "Day Zero" was approaching fast and the reality of 4 million users going without water looked increasingly certain (Booysen et al., 2019; Enqvist and Ziervogel,

(a) (b) (c)

Figure 1: General configuration of the Dropula. Figure (a) shows the generic configuration. The meter can be any meter that is able to generate pulses, for example the Honeywell/Elster/Kent meters, or Sensus meters (shown). Figure (b) shows the initial GPRS version attached to a bulk water meter, and figure (c) shows Sigfox version. For more information, refer to `www.bridgiot.co.za`

2019). This was when the #SmartWaterMeterChallenge was launched to reduce water usage at 100 Western Cape schools. Soon after going public, the project expanded to another 244 schools in the province as more parties got involved. The entities that came together to create the #SmartWaterMeterChallenge were The Shoprite Group, Cape Talk radio, Bridgiot, Stellenbosch University, the University of Cape Town, Pragma, the Office of the Premier of the Western Cape, the Western Cape Department of Education and 98 other corporate entities. Bridgiot, is a spin-off company from the University of Stellenbosch that specialises in water metering and smart controllers. Given their expertise, BridgIoT was responsible for managing the project and continuously assessing and reporting its results. The water metering was done using a Dropula device (see `www.schoolswater.co.za/` for further details). The plumbers were contracted through Pragma. The campaign comprised two parts: a maintenance part, to reduce the abundant losses at schools as a result of neglected maintenance, and a behaviour part, in which awareness was raised with staff and children to conserve water. Given the drought-induced increased water rates, the project was also expected to free up school finance commonly lost due to high water bills. This paper describes the former, in which local plumbing companies were contracted to carry out essential maintenance at the participating schools. The maintenance was carried out in two steps: basic maintenance (M1), where each plumber was given a checklist of allowed quick fixes and a budget restriction of R5,000; and an in-depth follow-up (M2), to assess the M1 work and consider the need for further work. The list of quick fixes can be found in Appendix A, and are based on a pilot study (Ripunda and Booysen, 2018). This paper describes the results of the first part of the maintenance project, M1, which started in November 2017 and was still running at the time of writing.

Description	Amount
Materials cost	R520,693
Transport cost	R144,131
Labour cost	R558,034
hline Total	R1,222,859

Table 1: Maintenance cost breakdown

3. Methods

3.1. Smart water meter data

Each school had a Dropula device installed on its main municipal meter, as shown in Figure 1. This device measures water usage in real-time. The device's circuit is made up of a pulse sensor and a communications protocol. The Dropula cost R1,500 (US$100), but the device, and online access, daily reporting and exceedance notifications were made available at R10,000 for the year, and paid for by the corporate and government funders. The pulse sensor records the number of pulses in a specific time period, each pulse representing 0.5, 10, or 100 litres, depending on the installed bulk meter. To communicate with the cloud server, it initially used the GPRS (General Packet Radio Service), which was later upgraded to Sigfox low-power communications. The device sends the data to an online platform for storage and processing. The processed data is then made available for downloading and analysis. The collected water usage data in the project was time-stamped for each school.

3.1.1. Limitations

We acknowledge some limitations in this study because parts of the water meter dataset was lost because of a technical problem that limited the battery life of some of the inital meters. Also, at several schools the municipal meter was outside the school grounds, which meant that the device was unprotected and we lost data due to vandalism. We had to replace stolen devices or move devices to a less visible place. To create the dataset that represented the schools water usage accurately, we thus had to omit some schools with large periods of missing data. If a days data were missing, or several hours were not recorded, we omitted that day from the analysis.

Of the three local plumbing companies hired for the project, only one had reliable maintenance cost data. Consequently, the maintenance cost dataset was made up only of schools whose maintenance was performed by this company. Table 1 shows that the bulk of the costs was for materials and labour.

Of the total 344 schools, 148 were excluded from the study because of unavailable data, reducing our sample of schools with reliable data to 196.

3.2. Metrics

The main aspects calculated were the following: aggregate MNF, reduction in MNF, total water and monetary savings, and rpayback period.

Since the maintenance of the schools was done as part of a staggered campaign over months, the schools' data sets of the the schools were re-alligend to centre on each school's reported maintenance day (M1), and all weekend days and school holidays were excluded.

Research has shown the minimum night flow (MNF) technique to be effective in detecting water leaks. Numerous studies have used it for this purpose (Oliver, 2005; Cheung et al., 2010; Peters and Ben-Ephraim, 2012; Candelieri et al., 2013; Loureiro et al., 2016; García et al., 2008; Alkasseh et al., 2013), we cite only a few examples here. Although the period for MNF was defined differently for some of those studies, all were in the range of 00:00 to 05:00 daily. For our study we defined, the MNF period as 01:00 to 04:00, with the MNF calculated as the average hourly water usage for this period. The MNF was calculated using the aggregate of each day for a six-day period before and after the reported M1 date. The MNF method was used to reveal the presence of water leaks at the schools. The percentage change in MNF was calculated using Equation 1,

$$\Delta Q = \frac{Q_{pre} - Q_{post}}{Q_{pre}} * 100\% \tag{1}$$

where Q_{pre} is the MNF pre-maintenance and Q_{post} is the MNF post-maintenance .

All water and monetary savings calculated and presented here were derived from water usage between 01:00 and 04:00 daily. The tariff was taken as R97.17/kL, from the Department of Water and Sanitation (2017) tariffs of 2018/19. This tariff was used to determine the monetary savings. These were then extrapolated to 24 hours for each day. The ROI (return on investment) period of the maintenance project was calculated based on the basis of extrapolated MNF water savings.

4. Results

Figure 2 depicts the mean and median of all schools' usage for the days preceding, including, and following the reported day of maintenance. Also shown are the means of the two sets before and after the reported day of maintenance. The results show that for some schools the maintenance date is likely to have occurred up to three days before the plumber eventually captured it on the reporting system, as evidenced by the steady decrease from M1-3 to M1 in the mean usage. Despite this inaccuracy, the weekly mean of the daily mean usage changes by 28%, or 55 L from the preceding to the following week. Moreover, the weekly mean of the median use is 34%, or 16 L, lower in the following week.

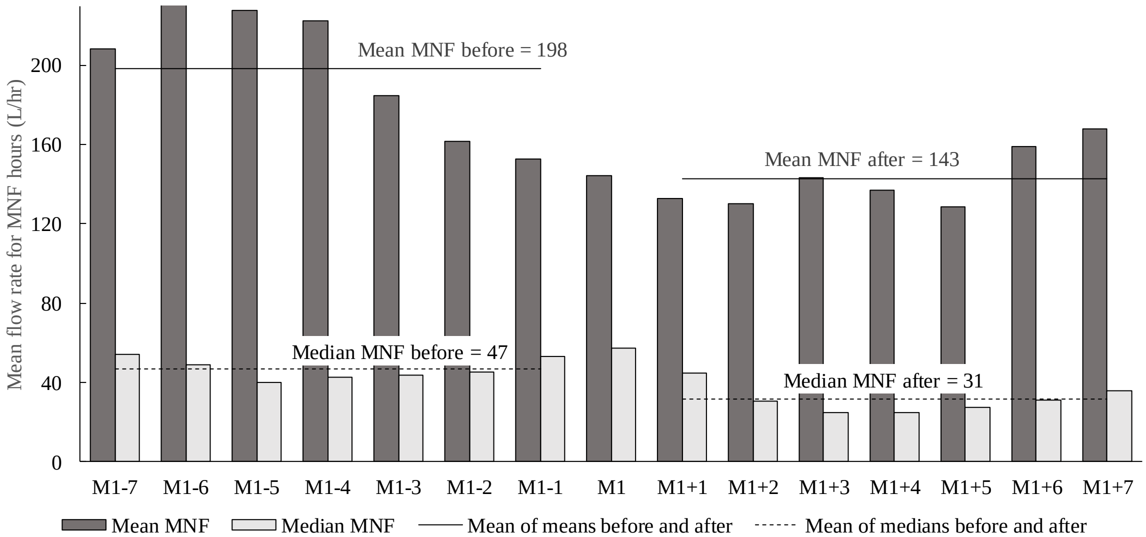


Figure 2: Median and mean of schools' MNF for each day relative to the reported day of maintenance, M1.

Given the high means relative to the medians, it can be concluded that the highest losses are contributed by a small number of errant schools. In fact, at day M1-7, the 75th percentile of schools had an MNF of 241 L/h, and on M1+7 the 75th percentile was at 136 L/h, close to the means for these times. To further illustrate this point, the distribution of MNF flow rates of a single day a week before M1 (M1-7) and a single day a week after M1 (M1+7) are given in Figure 3. This figure shows that the distribution of schools in terms of MNF improved most for schools with MNFs in the bracket of $(200, 500]$ L/h, followed by $(500, 1000]$ L/h, rather than for the lower volumes. Most of the schools appear to have shifted into the $= 0$ and $(50, 100]$ L/h brackets, as their MNFs reduced after maintenance.

Next, we evaluated the changes over the period by comparing the usage distributions per day across schools against a baseline made up of M1-8 to M1-6. The comparison expresses each day's usage as a percentage of the baseline and the results are shown in Figure 4.

We only included the 160 schools that did not start from a baseline of zero for the volumetric plot, Figure 4 (a). The figure shows that the median of the volume differential did not change much, while the 25th percentile of the ratios reduced substantially from M1, along with a substantial reduction in the average ratio for each day after M1-3. This further demonstrates that the bulk of the savings were achieved in a relatively small number of the participating schools. The average reduction per school at M1+5 was 97 L/h, while the median change at the same time was 25 L/h.

For the ratio plot, Figure 4 (b), we included only 103 schools that had a baseline of more than 42 L/h. This was done to ensure that schools with a small MNF and relatively small changes, did not skew the percentage change result. The medians make a drastic shift on the day before the reported maintenance,

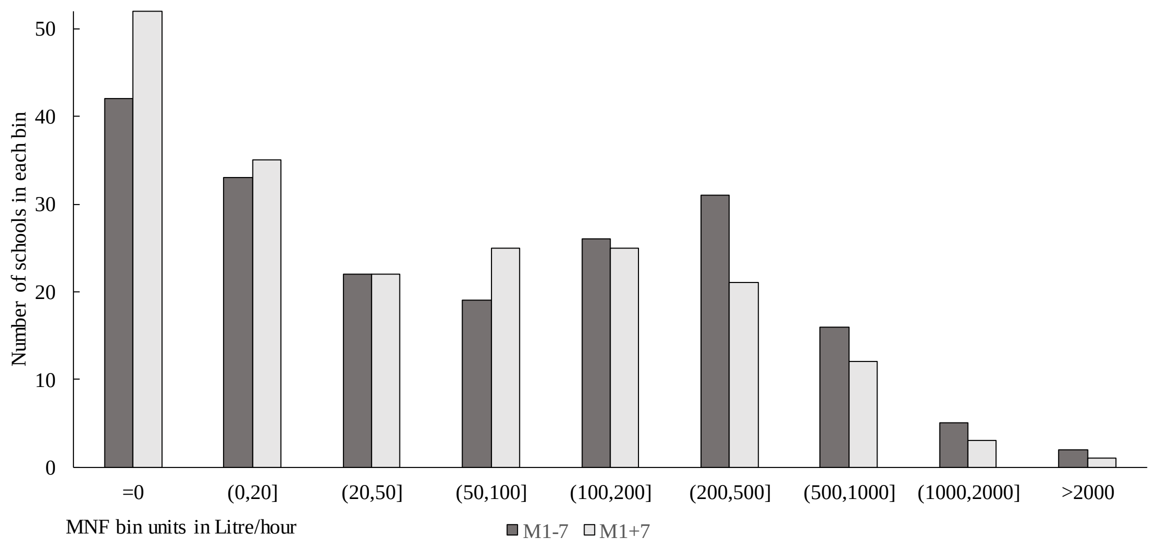
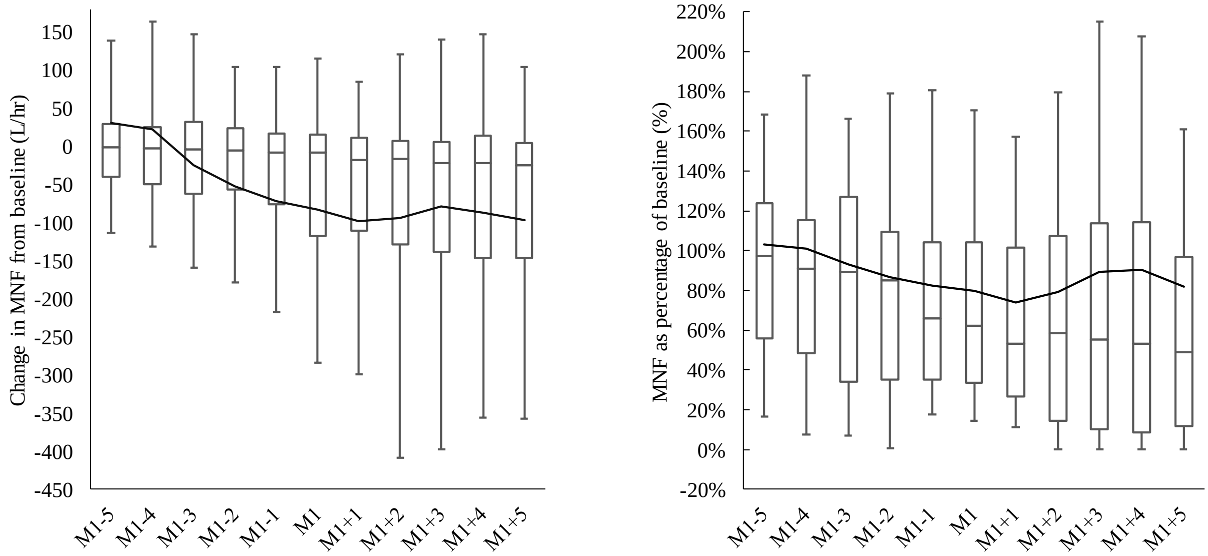


Figure 3: Histogram of the MNFs for all the schools for a week before (M1-7) and after (M1+7) the reported maintenance day, illustrating a shift from high MNFs to lower MNFs.

and after M1 a substantial and consistent reduction is visible in the 25th percentile. At M1+5, the MNF of the median school is only 45% of what it was before maintenance was performed. The large reduction in the medians of the ratio plot (b) relative to the small reductions in the volume plots (a), demonstrates a substantial reduction, as a percentage, even in schools with smaller MNFs, although their reductions may have had a smaller impact on the total savings.

Figure 5 gives another view on the MNF changes. For this comparison, the baseline was compared against the MNF for the week subsequent to the maintenance in a histogram to determine the changes for the whole school set. There was a 95% to 100% reduction in MNF for 54 schools and 67 schools lowered their MNF usage by 50 to 90%. For 37 schools, the MNF reduction was more than 0 and below 50%. For 38 of the schools, the MNF did not change (0% change) after the maintenance work. With hind-sight, we realise these schools should not have received maintenance, since the majority of them started off with zero MNF. Unfortunately, because of the panic caused by the drought and the threat of "Day Zero", when the pipes would run dry, there was no time to assess all the schools adequately before M1 was done. What we did not expect to see was 19 schools whose MNF reduction was negative – i.e. whose MNF actually increased. However, this perhaps should have been expected, as the quick fixes, i.e. the plumbing repairs that required the least amount of effort and expense, could not deal with all the plumbing problems that were already apparent and worsening at these schools. It is possible that in some cases the plumbing work caused new damage. This was not necessarily the plumbers fault – often when one fixes one thing, one causes a new problem. And it is in the nature of pipes and plumbing fixtures to deteriorate with time, and in the nature



(a) (b)

Figure 4: MNF change distributions of schools in the days preceding and following the reported maintenance date, M1. The solid black line represents the means. The volume of MNF change relative to the baseline of M1-8 to M1+7 is given in (a) for the 160 schools with a baseline of more than zero. The MNF as a percentage of the baseline is given in (b) for the 103 schools with an MNF of 42 L/h, equivalent to 1 L/d.

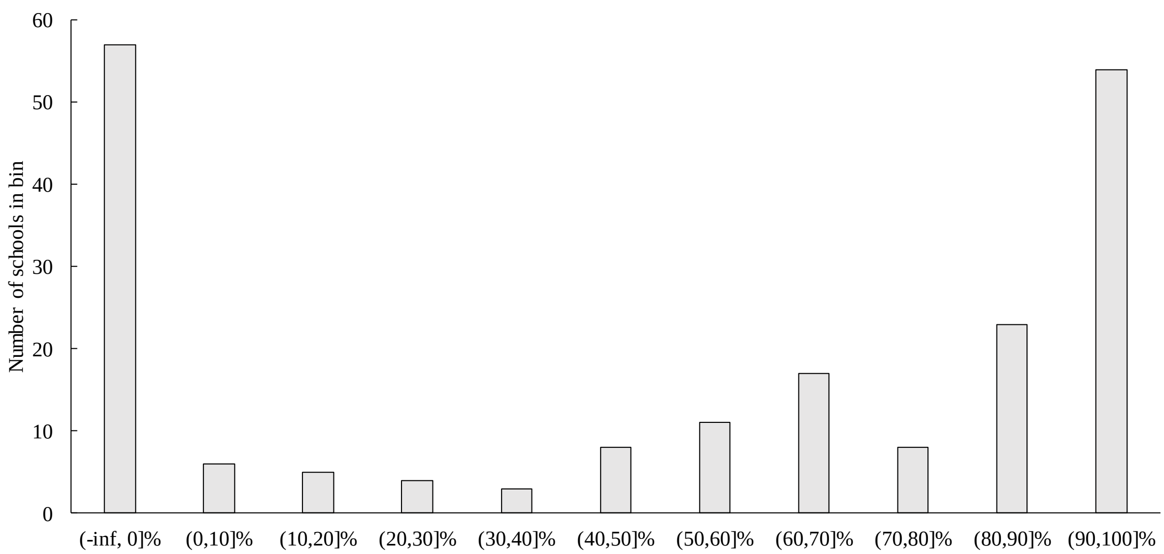


Figure 5: Percentage change in minimum night flow for 196 schools – before and after intervention.

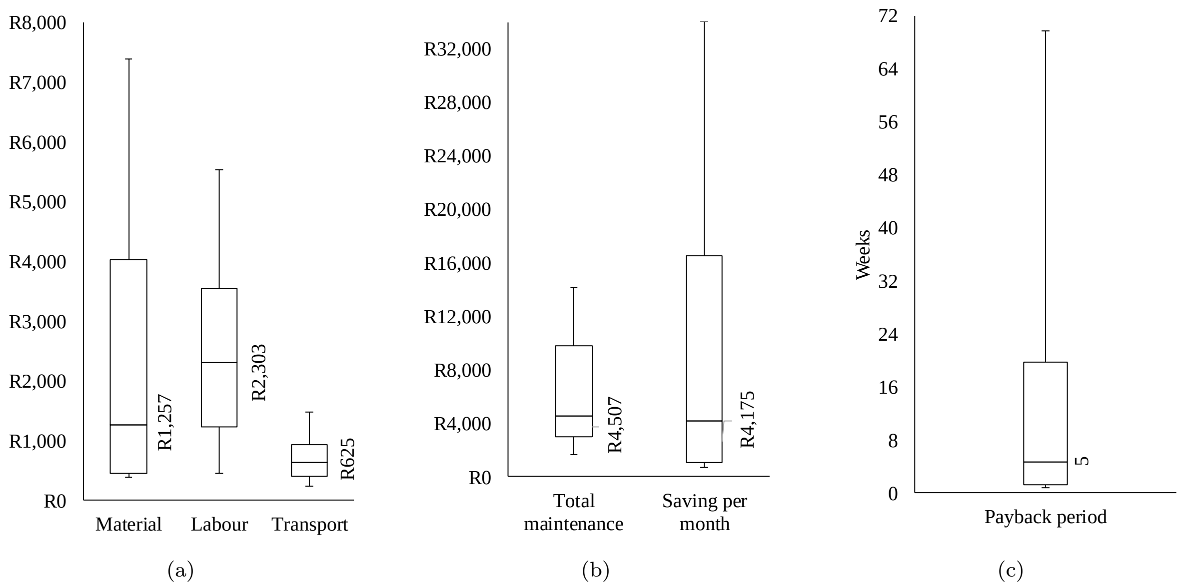


Figure 6: Distributions of expenses and savings. The cost of breakdown of maintenance done at all schools is shown in (a). The total cost of maintenance and savings distributions for 139 schools where actual savings were achieved are shown per month in (b). The return of investment distribution of the schools in (b) is shown in (c).

of pressurised water to come out when given the opportunity, hence the need for pro-active maintenance. It can therefore be considered normal that in certain cases the plumbing infrastructure would have failed in any event, which is another indication of the dire need for adequate and comprehensive maintenance at schools.

Finally, we evaluated the financial cost and benefit of the maintenance part of the project, which is depicted in Figure 6. Figure 6 (a) shows a statistical summary of the different expense types listed in Table 1. The plot in the figure shows that considering medians, labour cost is the main contributor to the expenses, but the variability and unpredictability of material costs result in more outliers. Transport cost is small and relatively constant, which is expected for schools in close proximity.

For the cost and savings plot in Figure 6 (b), we included only the schools that managed to reduce their consumption, which comprises total expenses of R912,658 and savings per month of R1,898,349 for the 139 schools. The median spent per school was R4,507, while the median saving per month was R4,175, but with a lot more variation than we see in the maintenance cost. We discovered towards the end of the M1 phase that the work at 74 schools was allowed to exceed the budget on an ad-hoc basis, and the average spent per school, for all the schools, was R6,284.

The hypothetical payback period for each of the 139 schools was calculated separately and the distribution is shown in Figure 6 (c): a median period of five weeks, and a 15 week period for the 75th percentile.

5. Conclusion

In this paper we evaluated the impact of performing "quick-and-easy" maintenance at 196 schools in the drought-stricken Western Cape. The limited available literature has shown that maintenance at schools in South Africa is often neglected and only performed reactively, leading to wastage of potable water and financial loss – a problem compounded by a shortage of skilled staff members and limited budgetary allocation. The maintenance campaign described in this paper was part of the #SmartWaterMeterChallenge, a corporate-funded campaign in the Western Cape in which plumbers were instructed to perform maintenance at a cost of initially no more than R5,000 (US$350) per school. We assessed the impact by evaluating minimum night flow (MNF) data for six days before and six days after the maintenance. Before the maintenance, losses were heavy – 198 L/h on average; after the maintenance, the MNF was reduced by an average of 28%. In total, R1,22 million was spent (on average, slighly more than the instructed R5,000 per school), and an immediate aggregate monthly saving of R1,90 million was achieved. The median return on investment for schools where savings were achieved was five weeks at the prevailing rate. These results make it abundantly clear that doing even a little maintenance makes financial sense, and that it should be done sooner rather than later. The project showed that investing in the upkeep of water systems could hugely reduce expenses, leaving money free to be used for the schools main purpose, namely to educate children. Nevertheless, without additional financial support, the overall maintenance in schools will not improve as much as it needs to. South Africa needs to find new ways to assist schools financially and to support principals with technical skills. The project was completed in the midst of Cape Town's worst drought in a century, with dams drying up and the terrifying prospect of a "Day Zero" becoming more realistic by the day. It is this crisis that gave impetus to the project and work presented here, but it also meant that funding partners demanded results from the outset and work was often done in a rush, especially since the number of schools tripled in a matter of weeks as more corporate funding partners jumped on board. As a result, opportunities were missed to keep tabs on all the plumbing contractors and to keep record of all their actions. We therefore recommend that future projects spend more time, if available, in setting up the finer detail of future projects before they commence. For example, assessing the state of each school's plumbing and monitoring their usage for a longer period before performing maintenance; setting up interaction with plumbers in which their payment is dependent on (i) detailed assessments and (ii) timely and detailed record keeping, preferably including photographic evidence, before and after any maintenance is performed. The accurate and reliable data we obtained will provide a valuable point of comparison for future studies on school water usage, and our findings contribute to the small but growing body of literature on maintenance at South African schools.

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Appendix A. Instructions to plumbers

DROPULA™
BY BRIDGIOT

School maintenance instructions:

Checklist of problem areas:

1. All bathrooms (Pupils and staff)
    a. Toilet cisterns
    b. Urinals
    c. Taps
2. Kitchen
    a. Taps
    b. Boiler
3. Geyser
4. Staff room
    a. Taps
    b. Boiler
5. Outside taps
6. Stop valve
    a. Confirm that stop-valve completely shuts off water supply

Pre-approved maintenance work:

1. Running toilet cisterns
2. Broken taps
3. Obvious leaks

Up to R 5 000 may be spent on these pre-approved items.

Scope of work to be quoted for:

1. Urinals with continues flushing to be replaced with push button flushing
2. Faulty mains stop valve to be replace or new one installed inline.
3. Obvious sources of water wastage.

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