Sanergy

Exploring the use of mobile-enabled sensors to optimise sanitation waste collection in Kenya

NOVEMBER 2017

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The **Mobile for Development Utilities Programme** improves access to basic energy, water and sanitation services in underserved communities using mobile technology and infrastructure. Our work encompasses any energy, water and sanitation service provided to a community, which includes a mobile component, whether it is voice, SMS, USSD, Machine-to-Machine, NFC, a mobile operator's agent network or tower infrastructure. We aim to seize the opportunity, leveraging mobile technology and infrastructure to enhance access to affordable and reliable energy, clean and safe water and sanitation services in underserved communities. The GSMA Mobile for Development Utilities Programme receives support from the UK Government.

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www.saner.gy

Sanergy designs and manufactures affordable sanitation facilities, called Fresh Life Toilets (FLTs), which are purchased and operated by a network of franchisees in urban informal settlements in Nairobi, Kenya. Launched in 2011, Sanergy has an active network of over 1,100 Fresh Life Toilets as of July 2017. The waste is safely collected by their logistics team on a regular basis, treated and converted into organic fertiliser, insect-based animal feed and renewable energy.

www.sweetsensors.com

SweetSense provides GSM cellular and satellite sensor technologies for water, energy and environmental projects and has deployed thousands of SweetSense units in 12 countries. Applications include water pumps, boreholes, water filters, cook stoves and latrines.

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GSMA Mobile for Development Utilities Seed Grant 2015-2017.

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Photography credit: Sanergy

USE OF MOBILE

M2M
connectivity

Mobile Services
Mobile App

Sanergy and SweetSense installed GSM and RFID enabled infrared sensors to record Fresh Life Toilet activity and estimate fill levels. Waste collectors and Fresh-Life Toilet Operators were able to use the sensors as well to record servicing events and request assistance by swiping RFID tags. A mobile app was also developed to capture waste weight data.

Sensor data was recorded from **40 Fresh Life Toilets** in informal settlements of Nairobi and used to dynamically predict the frequency of waste collection.

PROJECT OUTCOMES

"I prefer the sensor method [because] it saves time, cost and it is easier to monitor the toilet."
- Fresh-Life Toilet Operator.

"There are less complaints [from Fresh-Life Toilet Operators because] I am able to tell where there are problems and deal with them. It is very efficient."
- Sanergy staff member.

KEY PROJECT LESSONS

Initial hardware costs are only a fraction of overall costs as **sensor operation** and **maintenance costs** also have to be considered when implementing a new sensor system.

Sensors can be particularly useful to **learn about operations and customers**, rather than as a permanent tool for usage monitoring on all toilets.

Sanergy has operationalised some of these learnings, including recording waste collectors' servicing activities in real-time.

Overview of the grant project

Sanergy designs, manufactures and sells low-cost, high-quality sanitation facilities called Fresh Life Toilets (FLT) in Nairobi, Kenya. FLTs are owned and operated by Fresh Life Operators (FLOs), residents of informal settlements who run them as a business or as a value-added service to their customers. As part of its franchise agreement, Sanergy provides training, on-going marketing, business and maintenance support, empowering FLOs to provide clean and safe toilets to the residents of informal settlements. Sanergy ensures the waste is collected on a regular basis, charging an annual subscription fee for the collection service. The waste from all FLTs is collected, consolidated, and transported to a processing facility outside of Nairobi, where it is treated and converted into useful end products, such as fertiliser and insect-based animal feed, which are then sold to Kenyan farmers.

In 2015, Sanergy and SweetSense were awarded a grant from the GSMA Mobile for Development Utilities Programme to test how mobile-enabled sensors could be used to optimise the waste collection process. These sensors would provide information on exactly when a toilet was full and needed to be serviced. By using real-time information on toilet usage and fill levels, the objective was to dynamically schedule servicing and skip toilets that did not need it. A more efficient waste collection schedule would keep collection costs down while maintaining customer service levels, allowing collectors to service the growing number of FLTs in the Sanergy network.

Service design and use of mobile channels

Sanergy uses several mobile channels in its day-to-day operations:

- Mobile money is used by FLOs to pay their annual subscription fee and purchase their FLT in instalments, and by Sanergy to pay its suppliers.
- Mobile apps are also used by Sanergy field staff to capture data such as the sales of toilets and fertiliser.
- As part of the grant, and in partnership with Sanergy, SweetSense developed and installed sensors using machine-to-machine (M2M) connectivity to relay information on toilet usage in 40 FLTs to a dashboard. They also developed a mobile app for weighing waste.

Mobile app

To calibrate and compare the sensor data as an indicator of toilet fill levels, Sanergy hired a team of enumerators to count the number of toilet users over a day and weigh waste containers at each toilet. The enumerators were equipped with a smartphone and a "Sanergy Weight App" to record the weight of the collected cartridges, as well as two browser-based applications to record sensor installations and swaps, whether an FLT was serviced as scheduled and structured observations to count toilet users.

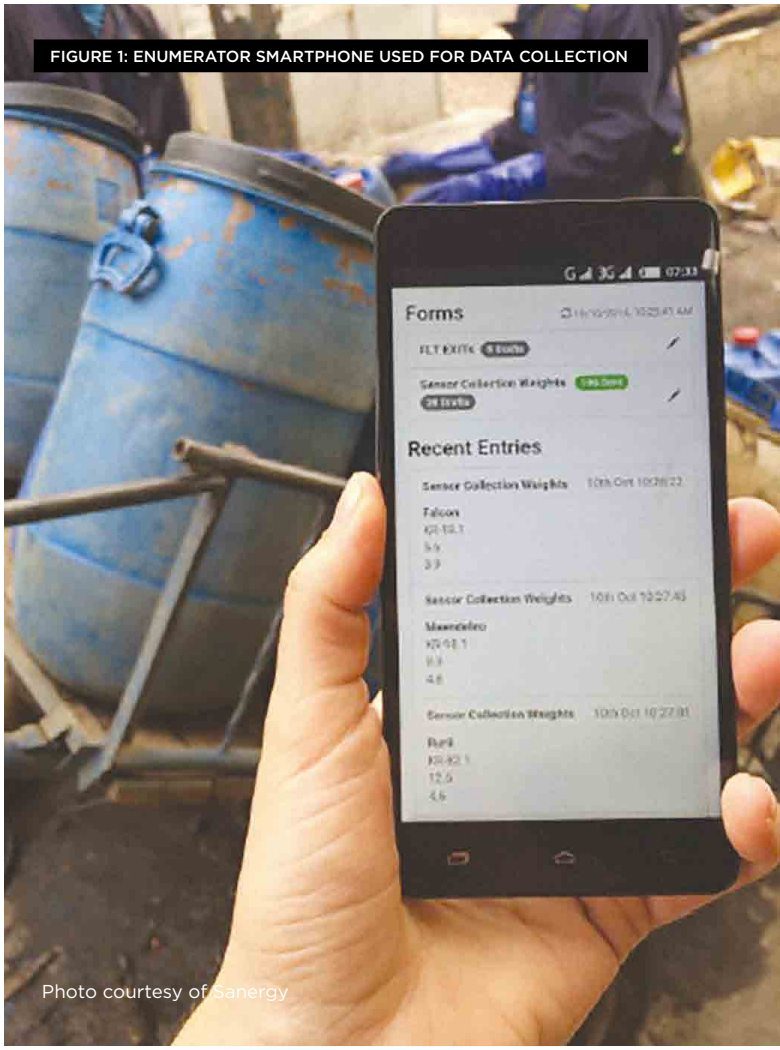


FIGURE 1: ENUMERATOR SMARTPHONE USED FOR DATA COLLECTION

Photo courtesy of Sanergy

Mobile-enabled sensors

In the first phase of the project, SweetSense developed three types of sensors to test and select the best device to use in the larger pilot study. These are summarised in Table 1.

The added advantage of the PIR sensor is that it is fixed inside the FLT and accessible to FLOs and logistics staff. SweetSense and Sanergy could therefore add functionality to the sensor: the ability to log events. The sensor was fitted with a Radio Frequency Identification (RFID) card reader, and FLOs were issued RFID tags to use if their FLT needed maintenance or collection.

When FLOs swiped their RFID tag, a case was automatically generated in Salesforce, one of Sanergy's back-end management systems, and an SMS was sent to the relevant Sanergy staff members. They then contacted the FLO to understand the reason for the request for assistance. While in most cases FLOs were worried that waste collectors had forgotten to service their FLT (the additional time needed to collect data while servicing toilets sometimes caused delays along the route), the RFID tag was also useful for requesting assistance with maintenance issues requiring a Sanergy repair team, such as a broken door or a damaged squat plate.

The logistics staff were issued two different RFID cards to swipe at the FLT sensor to indicate whether a toilet was serviced or not. If a toilet was not serviced, it was usually because it was too dirty or the containers were not full enough to warrant collection.

The sensors were equipped with Aeris[1] global SIM cards and relayed information over the GSM data network to the SweetSense server, which stored and processed the information and hosted the dashboard.

The dashboard aggregated the following real-time information for each sensor (see Figure 4):

1. Occupancy count and other associated information from the infrared sensor;
2. (a) Maintenance issues logged by FLOs (i.e. if the FLO's card had been swiped) and (b) the status of the associated Salesforce case, if any;
3. Servicing information logged by waste collectors swiping their cards;
4. Waste weighing information collected by enumerators; and
5. Sensor functionality if a sensor failed to report or had low battery.

Figure 5 shows the dashboard, which displays from the top:

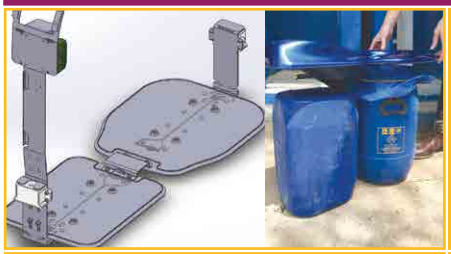
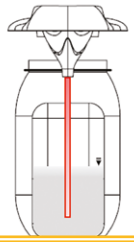
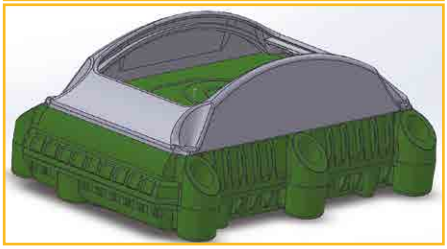
- Approximate number of uses for each FLT by day;
- Site status table that indicates sensor functionality, whether an FLT should be serviced or skipped, and whether the waste collector RFID card was scanned properly;
- Map indicating the location of each FLT and whether it has a pending Salesforce case;
- Record of Salesforce cases for each FLT;
- Record of RFID scans from waste collectors.

A machine learning algorithm developed by SweetSense was used to determine whether an FLT could be skipped for collection the following day.

1. http://www.aeris.com

TABLE 1

Summary of sensor selection tests

Sensor		Pros and cons	Selected / Not Selected
	A weight sensor placed below the solid waste cartridge underneath the squat plate.	While accurate, both were subject to a corrosive environment and would have required customised mounting and installation for each FLT.	Not selected
	A liquid transducer sensor placed inside the liquid waste cartridge to measure liquid pressure.		Not selected
	A passive infrared (PIR) sensor installed on the ceiling of the toilet structure to measure the occupancy of the toilet.	Easier to install and less expensive to produce. Provided an accurate estimate of waste levels based on FLT activity.	Selected for installation in all 40 FLTs for the second stage of the project.

Photos and diagrams courtesy of Sanergy, SweetSense

FIGURE 2: PIR SENSORS USED DURING THE GRANT PROJECT

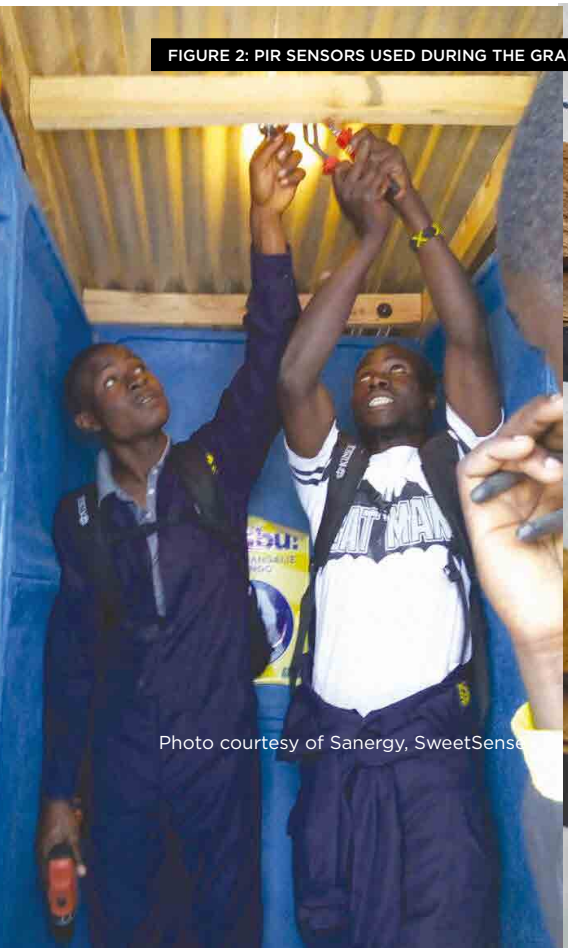


Photo courtesy of Sanergy, SweetSense

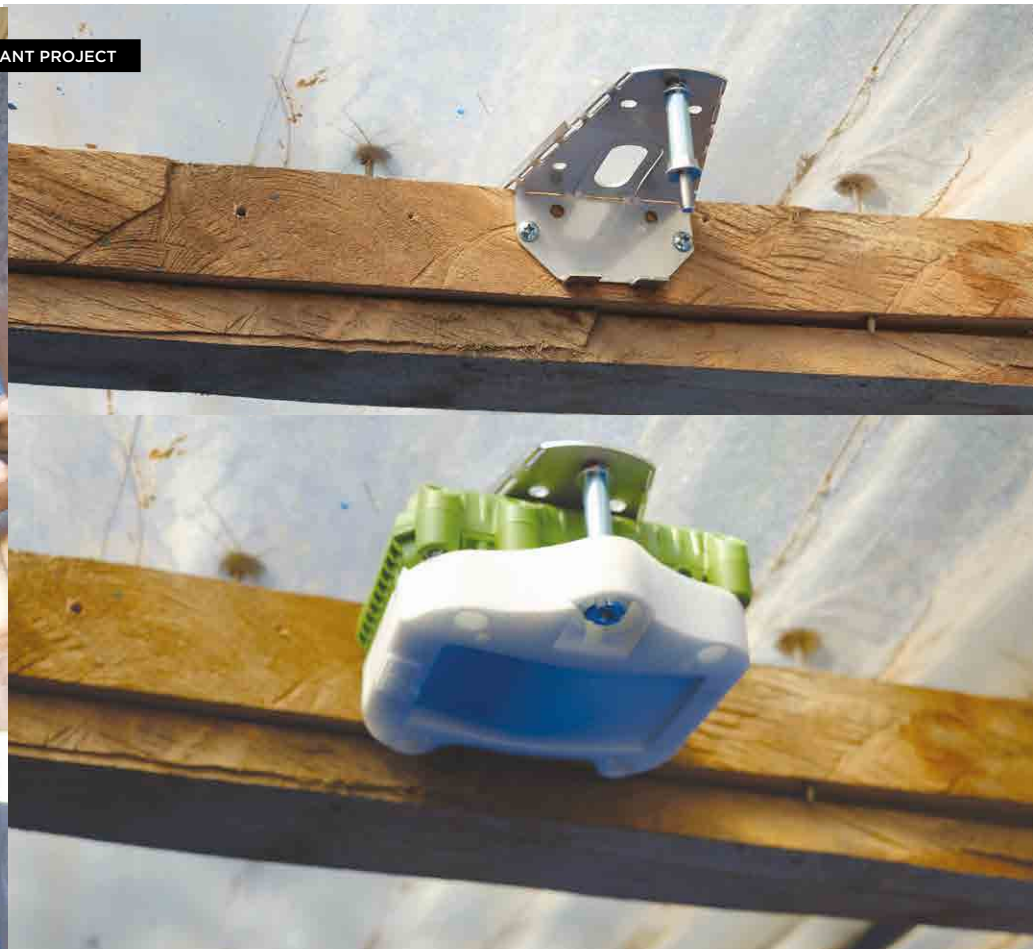


FIGURE 3: RFID CARDS FOR THE LOGISTICS TEAM AND SENSOR-CHARGING STATION

Photo courtesy of Sanergy

FIGURE 4

Information flowchart for Sanergy and SweetSense information systems

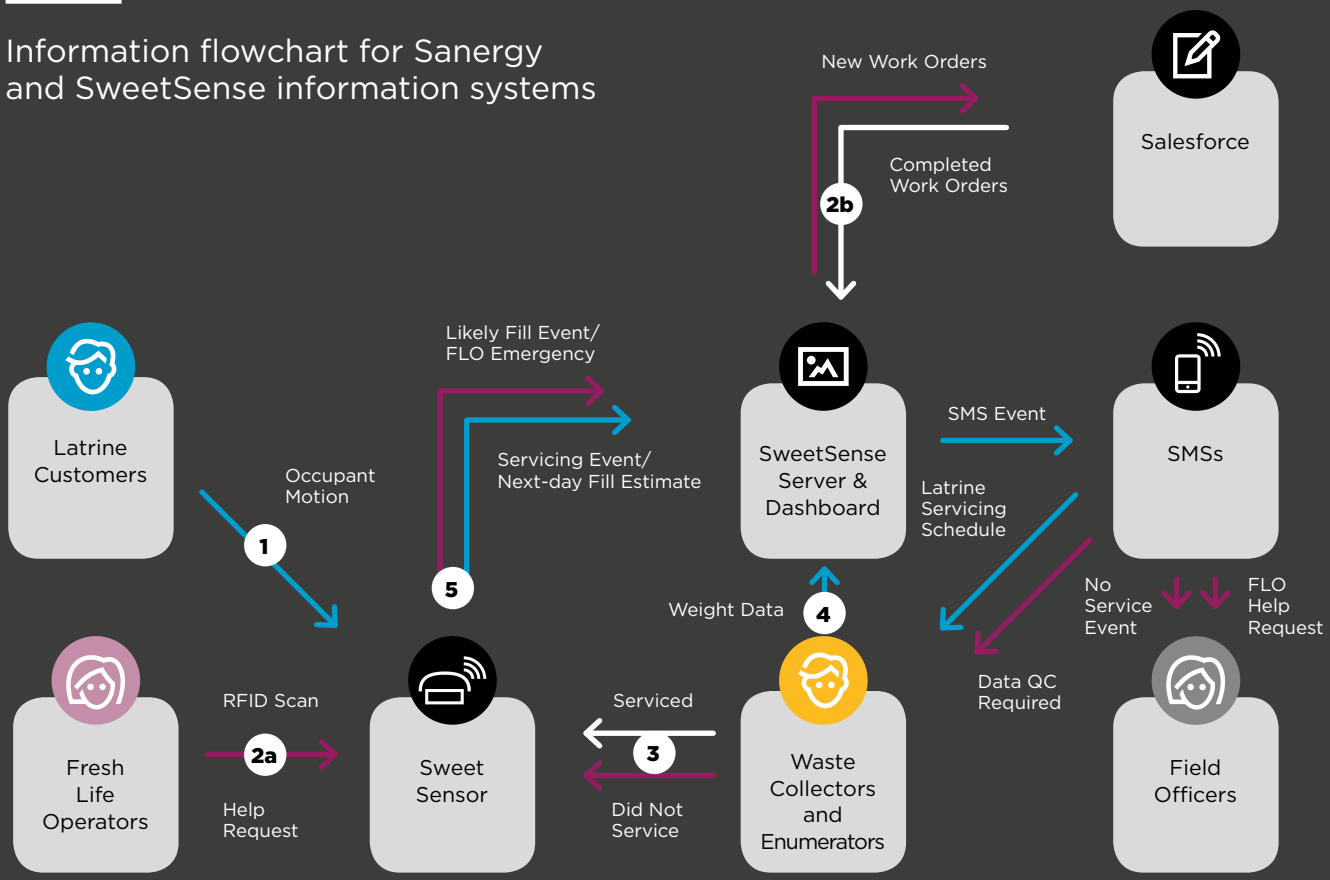


Diagram courtesy of Sanergy, SweetSense

FIGURE 5: SENSOR DASHBOARD DEVELOPED BY SWEETSENSE

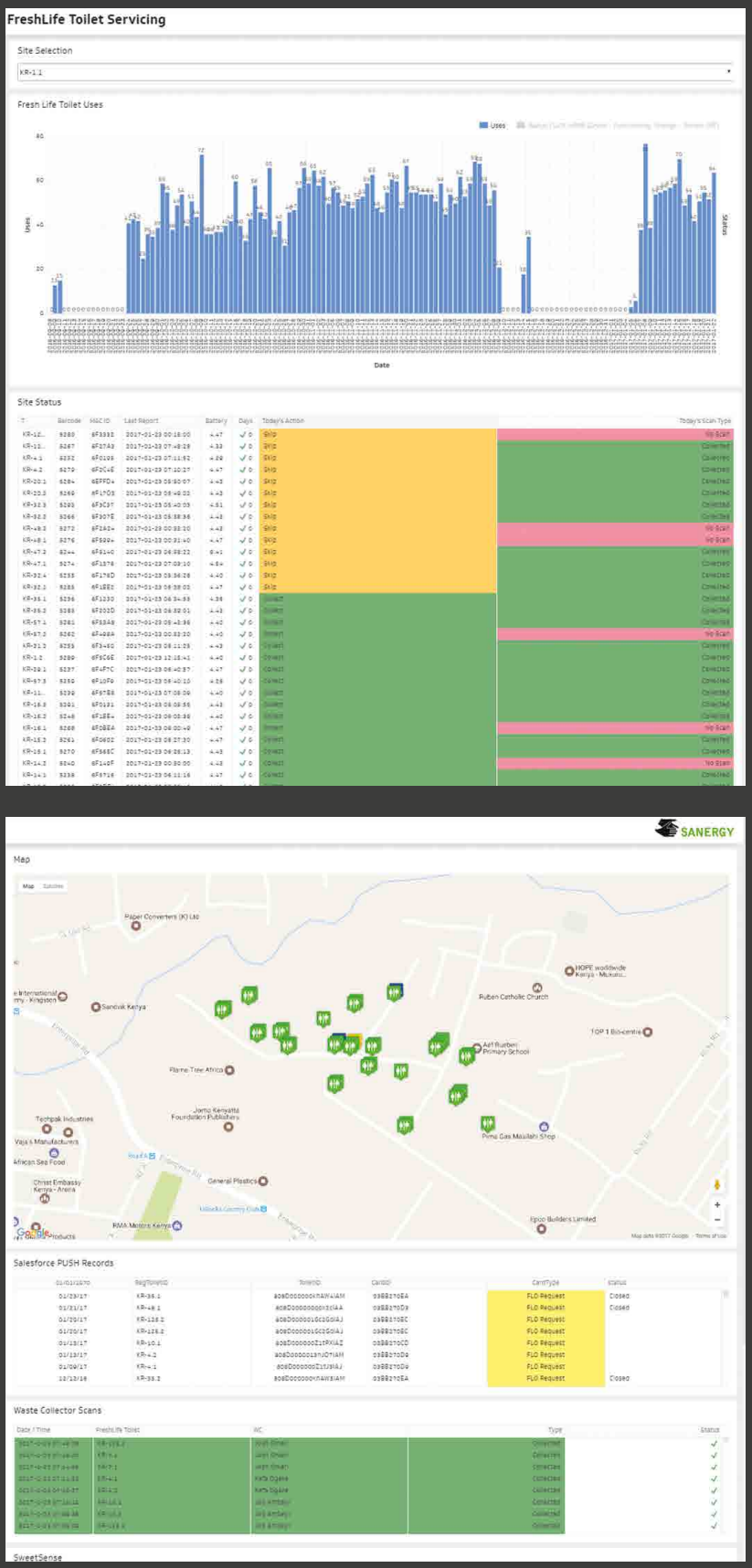


Figure courtesy of SweetSense

Lessons from the project

1 Using sensors for status reporting and dynamic scheduling is complex and requires consistent feedback from various stakeholders (FLOs, waste collectors, logistics staff, FLT users)

It was originally assumed that knowing the fill levels in each FLT would be sufficient for predicting when collection could be skipped. The reality, however, was more complex. While data from the sensors and on-site weighing could be used to accurately estimate the weight of accumulated waste each day (with a mean average error of 2.5 kg), this was not the best predictor of whether the latrine needed to be serviced the next day (see Figure 6).

First, waste weights and fill levels varied depending on the amount of consumables that were used each day, such as the amount of sawdust and toilet paper in the solid waste cartridge, and the capacity of each waste cartridge, as not all cartridges in the FLTs were the same size. Second, FLT servicing depended not only on the estimated fill level from that day's FLT activity, but also on the waste that would be added the next day if service was skipped.

To summarise, although there was a strong correlation between FLT activity from the PIR sensor and actual solid and liquid waste levels, SweetSense determined that historical average waste weights for individual FLTs were better predictors of the need for service than the PIR sensor data for a given day. For example, knowing the average solid waste weight for Mondays was more useful for predicting the need for servicing on a particular Monday than the toilet activity logged by the PIR sensor for the previous day. This is because the FLTs had stable usage patterns that varied primarily by day of the week.

Finally, even when it was determined that an FLT needed to be serviced, there was no guarantee the waste collector would service it. Sometimes waste collectors were not able to access FLTs when FLOs had closed them, and sometimes waste collectors used their own judgement based on a visual inspection of the fill level and their experience with the route to determine whether the FLT needed servicing. Waste collectors also indicated that they were more likely to service some FLTs based on FLO preferences, often creating a tension between Sanergy's desire for more efficient servicing and the FLOs' desire for more frequent servicing.

As a result, it was determined that using sensors for dynamic scheduling would be most useful on new routes where FLT usage patterns were still being established, on existing routes where FLT use was more variable, or on routes where FLTs were used less frequently. In the case of this pilot, dynamic scheduling facilitated four more servicing skips per day on average for the 40 FLTs compared to Sanergy's static skip schedule (see Figure 7). However, average FLT fill levels at collection only increased from 50% to 55% over the course of three months. This small improvement is likely because the majority of FLTs on the route were high-use latrines that required daily servicing (i.e. there

were limited opportunities for skipping when FLTs were already half-full on average). Also, the skip algorithm was tuned conservatively to minimise inaccurate skip predictions that could have resulted in overflow events or toilet closures. Finally, the algorithm automatically scheduled a collection when a sensor did not report. While sensor uptime averaged 91%, there were regular incidences when the battery had to be recharged.

FIGURE 6

Information needed to facilitate dynamic FLT servicing

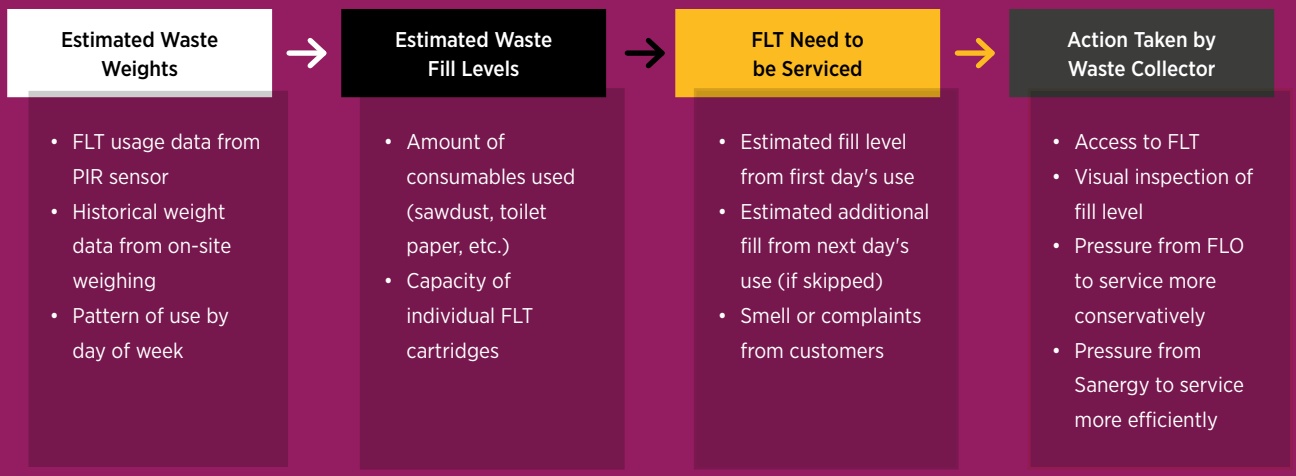


Figure courtesy of SweetSense

FIGURE 7

Number of skipped collections per day

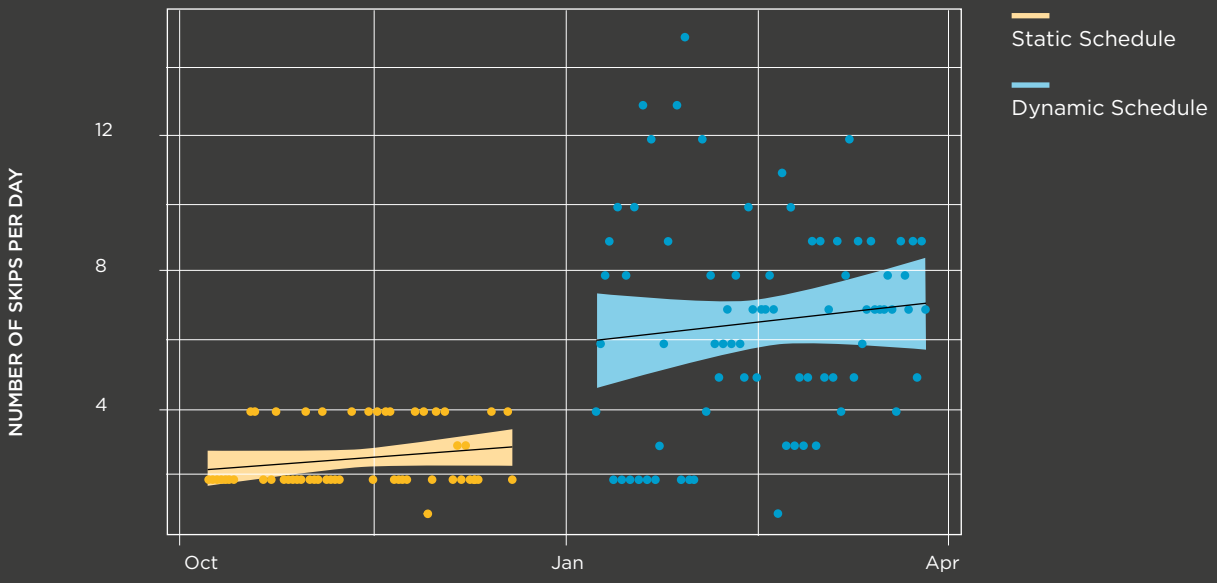


Figure courtesy of SweetSense

2 Data availability, visibility, and transparency provide value for customer care and logistics processes

While the value of using sensor occupancy data for dynamic scheduling was limited in this pilot, having data on collections and logistics was a significant asset and has proven to be the most useful feature. RFID tags provided accountability that FLTs were indeed being serviced. Sanergy's Logistics Manager was able to follow collectors' work on the dashboard (timing and routes) to better understand route dynamics in real time and adjust collections planning and labour distribution. This feature was very useful for Sanergy to gather more insights on collection process optimisation.

Swiping RFID cards also proved popular with the FLOs, as they felt this direct, responsive, and open line of communication with Sanergy's Customer Service team improved the level of customer service. Some FLOs who owned several FLTs even wished they could have access to the sensor usage data to better understand toilet utilisation rates and cross-check it with their actual income.

"I prefer the sensor method [because] it saves time, cost and it is easier to monitor the toilet."

"The sensor makes work easier – as long as you swipe, there's communication between the company and me. [This] makes work easier since I can leave someone else to run the toilet."

"Have a method to capture everything, [for example], to detect how many people used the toilets [so that I can] tally with my own calculations and payments; have a tool [...] to retrieve data; also have CCTV cameras to capture everything happening in the surroundings. Have swipe cards that classify the specific problem with the toilet or different bar codes to help identify the specific task to handle. Toilets could also be fitted with coin-operated locks so that users open doors [themselves] by inserting their payments."

FEEDBACK FROM FLOs ON TOILETS EQUIPPED WITH SENSORS

Photo courtesy of Havis Research Company

This feedback from FLOs was echoed by Sanergy's customer support staff, who found it faster and easier to deal with FLO issues. After receiving an SMS, staff would follow up with a call to the FLO. In most cases, the FLO wanted to register a missed collection. Staff would then check the dashboard for the status of the waste collectors, who had been swiping their cards at FLTs along the route. The dashboard therefore provided a smoother and more transparent way for the customer support and logistics teams to communicate. One planned improvement is to create a mobile app for collectors to closely monitor their work and collection trends.

In cases where an FLT needed maintenance, the office staff would open a Salesforce case, the status of which would then be displayed and tracked on the dashboard. Overall, this event-driven process was much more efficient than the periodic bi-monthly visits and weekly calls made previously. Timely and faster follow-up with each FLO allows more FLOs to be assigned to each support staff and a higher level of satisfaction for FLOs.

The key contribution from this pilot was the information captured in the dashboard on toilet use, cartridge weight, and the timing of waste collectors, which provided valuable insights for Sanergy on its waste collection processes. Sanergy's logistics manager was able to see and understand collection dynamics in real time instead of relying on collection and fill level information recorded manually by lead collectors at the end of each day. In addition, the software automatically generated the collection schedule and sent it out via SMS to the logistics manager and the waste collectors, also saving time.

"There has been an improvement with the [swipe] cards … there are less complaints [from FLOs because] I am able to tell where there are problems and deal with them. It is very efficient."

"Supervision is easier and complaints easily sorted."

FEEDBACK FROM SANERGY OFFICE STAFF

Photo courtesy of Havis Research Company

FIGURE 8

Results of FLO satisfaction surveys before and after the sensor pilot conducted in December 2016 and March 2017, respectively (n=19)

Figure courtesy of SweetSense

3 Sensor hardware costs are just the beginning; total lifecycle costs must also be considered

Since the pilot size was small, the unit cost for the sensors was USD 750, which is more expensive than an FLT. While it is expected that the unit cost would decrease as production volume increases, Sanergy found that several other associated costs for the sensors had to be taken into account when evaluating their cost effectiveness, including:

- **Cost of installation**
  SweetSense designed the sensor to be easily fitted and removed. Moreover, its engineers travelled to Nairobi to train Sanergy staff, which resulted in straightforward installations.

- **Cost of calibration**
  The PIR sensor had to be calibrated with structured observations, which required a team of enumerators to be hired as Sanergy wanted to avoid having their logistics team service toilets and handle a mobile device at the same time. Furthermore, the prediction algorithm relied heavily on weight data, which was also measured by the same team of enumerators.

- **Cost of data analysis and algorithm development**
  As noted above, the calibration and prediction algorithms proved to be more complex than anticipated and required additional time and resources from SweetSense.

- **Cost of operation and maintenance**
  The sensor batteries had to be recharged monthly. Sanergy estimates that its Customer Support Field Officer spent five to seven hours a week on average on the maintenance and logistics of sensors for various tasks, such as:

  - Reviewing the dashboard daily;
  - Following up on battery and maintenance issues;
  - Managing enumerators to swap sensors and charge their batteries; and
  - Liaising with SweetSense on technical issues.

- **Cost of change management**
  Sanergy's IT team had to integrate its internal systems with the new dashboard. Moreover, Sanergy staff and FLOs had to be trained on the new functionalities introduced during the pilot. Sanergy further implemented a voucher reward programme for FLOs to ensure that the sensors were returned intact at the end of the pilot. This was introduced after one incident of theft from a curious child.

4 Sensors have proven valuable in identifying where processes can be improved

At the end of the pilot in March 2017, after considering all the costs listed above, Sanergy concluded that the sensors were more valuable as learning methods than as scalable operational tools. Sanergy gleaned several lessons on where they could improve their operations, and have opted to develop some of the sensor functionalities in-house. For example, Sanergy is now incorporating the waste collector RFID card feature.

Several cards will be placed at each FLT, and the logistics team will use Famoco[2] devices to scan the appropriate card to indicate whether the toilet was serviced, was not full enough to warrant collection, or whether the FLT was closed. Sanergy is also exploring how to continue to provide a free and direct line of communication for its FLOs, as that feature was highly valued.

2. Famoco devices are Android-based and can use Wi-Fi or mobile data. They are used by enterprises to equip their field workers and are dedicated to a single application. https://www.famoco.com

Recommendations

FOR MOBILE NETWORK OPERATORS

Be aware of the many ways mobile technology can be leveraged in the sanitation value chain. While Sanergy does not work directly with mobile operators, its extensive use of mobile technology from mobile data, bulk SMS, M2M connectivity, and mobile money payments highlights that sanitation service providers are good-value consumers of B2B services.

FOR SERVICE PROVIDERS

Consider the total lifecycle costs of new technology. Hardware costs only constitute a fraction of the overall costs, especially for projects employing radically new technology and processes.

Consider sensors a learning tool for your existing processes. Use sensors to gather data and make existing operations more visible and transparent. Especially in cases where cost-effectiveness is in doubt from the start, sensors should be used to shine a light on where processes can be fixed or improved. Sanergy is now considering using their existing pool of sensors for ad-hoc research.

Start with simpler functionality for feedback and communication. The sensors were originally expected to be used to measure and predict toilet fill levels but, in the end, the most useful feature turned out to be a communication tool for waste collectors and FLOs.

Appendix

Methodology

Monitoring and evaluation methodology and design was provided by Alexandra Tyers of Tyers Consulting.[3]

All data used in this case study is primary data, and data sources include:

- A baseline survey conducted by Sanergy on 29 November and 1 December 2016, and an endline survey on 21 March 2017 with 19 Fresh Life Operators.
- Operational monitoring data from October 2016 to March 2017, using data from SweetSense Sanergy dashboard.
- An independent third-party qualitative evaluation, conducted by Havis Research Company,[4] based in Kenya, and consisting of six in-depth interviews with users and Sanergy staff, as well as participant observations of four FLOs and Sanergy waste collectors.

The research methods and data gathered are as robust as possible, but are not intended to be part of an exhaustive, academic study. Rather, we have taken a pragmatic approach to recording the impact of the mobile service on beneficiaries, capturing early-stage data and insights to help GSMA grantees improve their business performance, and generating knowledge for GSMA and the wider mobile ecosystem on the business case for using mobile innovations for energy, water, and sanitation services. With this, we recognise some limitations of the data: capacity and budget restraints means that most field data relies on primarily self-reported responses by users / beneficiaries; the sample sizes are statistically significant where possible, but statistical analysis has not been applied.

3. http://www.alexandratyers.com/
4. https://www.linkedin.com/in/havis-research-company-25444045/?ppe=1

For more information on the Mobile for Development Utilities programme visit:
www.gsma.com/mobilefordevelopment/programmes/m4dutilities

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