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**Research Paper**

# Developing formal pit-latrine emptying businesses for hard-to-serve customers: resources, methods, and pricing structures

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## ABSTRACT

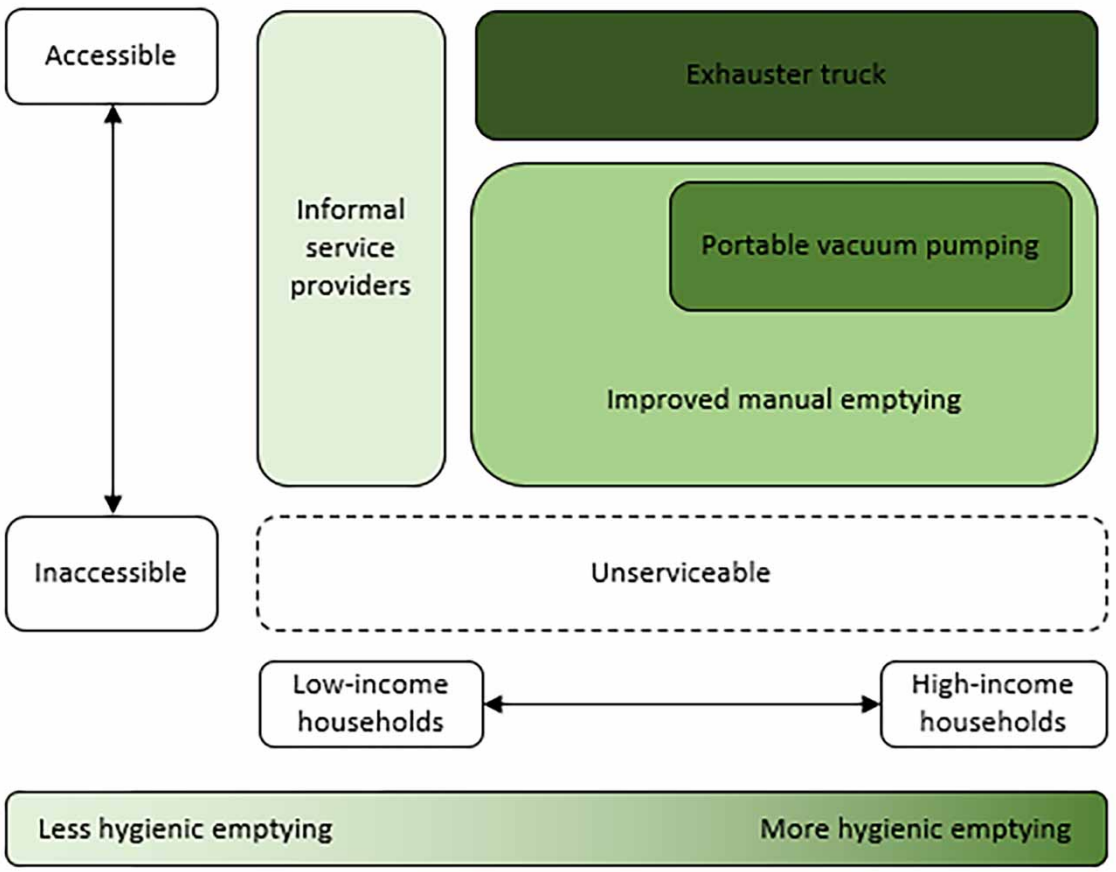
Rapidly increasing populations in informal settlements commonly use pit-latrines that require regular emptying. This study compares two emptying businesses from Kampala, Uganda and Kigali, Rwanda and identifies developments in formal services for hard-to-serve customers that are not accessible to large vehicles. Using observational and operational data shared by both businesses, we analyse the resources, methods, and tariffs used. Results indicate that although portable vacuum pumps are able to empty some facilities, fully manual methods are still required to empty thick sludge, deep pits, and weak structures in hard-to-serve areas. Manual emptying in Kampala which uses no mechanical equipment has the same overall duration as emptying using a portable vacuum pump in Kigali due to the additional time required to prepare, pack, and clean equipment. Effective municipal solid-waste management makes pit emptying faster at a lower cost. Some hard-to-serve customers require manual methods but increased costs are not affordable or equitable. This study highlights the opportunity for government and city authorities to support sanitation businesses by managing the tension between affordability, formalising services, and increasing uptake by recognising that manual emptying is required for some customers, and such higher regulatory standards can increase prices and prevent some customers from accessing formal services.

**Key words:** desludging, faecal sludge management, on-site sanitation, pit-latrine emptying, solid waste

## HIGHLIGHTS

- Portable vacuum pumps are able to empty some pit-latrines that are inaccessible to exhauster trucks.
- Fully manual methods are required to empty pit-latrines that cannot be pumped in hard-to-serve areas.
- Formalising services increases costs that are unaffordable to some hard-to-serve customers.
- Governments and city authorities have opportunities to make services more equitable.
- Municipal solid-waste management makes pit-latrine emptying faster at a lower cost.

## GRAPHICAL ABSTRACT




## INTRODUCTION

In East African countries, rapidly increasing informal urban populations urgently require sanitation services (Tsinda *et al.* 2015). The majority of households use unlined pit-latrines that typically contain sludge which is partly dewatered and consequently cannot be pumped by exhauster trucks (Mikhael *et al.* 2014; Gurski *et al.* 2022). Many live in informal settlements that are inaccessible to large vehicles (Ross & Pinfold 2017; Greene *et al.* 2021; Semiyaga *et al.* 2022). Therefore, emptying pit-latrines for hard-to-serve customers relies on manual methods (Mikhael *et al.* 2014; Gurski *et al.* 2022). However, manual methods are often unhygienic, presenting risks to both operators and customers, and are often done by by emptiers working informally (Capone *et al.* 2020).

Some cities have worked with manual emptiers to formalise services (Peletz *et al.* 2020). Personal protective equipment (PPE) and hygienic emptying methods are often introduced to minimise the exposure of emptiers to diseases (Chumo *et al.* 2021; Sklar *et al.* 2021). In addition, vehicles are used to transport sludge to treatment or to a safe disposal site (Jenkins *et al.* 2015). Generally, these measures allow services to be formally recognised. But these service improvements increase costs, and the full cost is transferred to the customers through increased tariff rates that may be unaffordable for most hard-to-serve customers (Burt *et al.* 2019; Peletz *et al.* 2020). Consequently, most households continue to use informal manual emptiers in hard-to-serve areas (Burt *et al.* 2019; Semiyaga *et al.* 2022).

City authorities and businesses have not identified suitable methods for all hard-to-serve customers that are safe, hygienic, and affordable if the full cost is transferred to the household. In Uganda and Rwanda, some businesses have formalised and have experience which can inform city and business planning. An estimated 600,000 urban facilities require manual emptying in Uganda and 160,000 in Rwanda (Greene *et al.* 2021). Previous studies have compared businesses in the same country (Peletz *et al.* 2020; Semiyaga *et al.* 2022; Singh *et al.* 2022) but not between countries which excludes contextual comparative analysis.

The purpose of this research is to identify developments in delivering hygienic and formal emptying and transport services in informal and low-income communities. This study compares two established businesses from Uganda and Rwanda. Primary data collected from observation of emptying jobs and a time-and-motion survey, and secondary data from the operational records are combined and analysed to identify emptying methods and resources, task durations, and emptying tariffs and prices.

## METHODS

### Study context

This study compares two faecal sludge emptying and transport businesses in nearby cities in different countries that collaborated with each other to share professional best practices on pit-latrine emptying: Forever Sanitation[i] in Kampala, Uganda, and Pit Vidura[ii] in Kigali, Rwanda. Data production and analysis were conducted by Pit Vidura staff.

Kampala has 1.5 million residents, over 60% of people live in informal settlements, 90% of households use on-site sanitation facilities, and there are 140 mechanical emptying businesses using exhauster trucks and 15 manual emptying businesses using a manually operated mechanical pump (Gulper[iii]) (Nkurunziza *et al.* 2017; Singh *et al.* 2022). Kigali has 1.6 million residents, over 72% living in informal settlements, everyone uses on-site sanitation facilities, and there are seven licensed exhauster trucks and no licensed manual emptying businesses (Akumuntu *et al.* 2017; Ross & Pinfold 2017).

Both businesses have developed emptying services for customers in planned and informal neighbourhoods, for commercial and household customers, for pit-latrines and septic tanks, and facilities that are inaccessible to conventional exhauster trucks or far from a formal road network. An interesting feature of both businesses is the use of a technical evaluator: after receiving an emptying request they complete an in-person assessment to determine whether the facility is serviceable and the optimum emptying and transport method. Pit Vidura also operates a call centre to screen emptying requests, organise evaluations, and coordinate emptying teams.

The focus of this study is hard-to-serve customers: households in informal neighbourhoods using pit-latrines that are inaccessible to large exhauster trucks.

### Data production

Forever Sanitation was observed by Pit Vidura staff under normal operating conditions in June 2022 to identify the emptying and transport resources and methods used. The authors' operational experience was used to identify the emptying and transport resources and methods used by Pit Vidura.

Enumerators were recruited and trained in both cities to observe and record emptying jobs between June and November 2022. Enumerators used the smartphone software Kobo on Android-enabled phones to record the facility type, emptying method, the distance between facility and vehicle parking, removed sludge volume, removed trash volume, and the duration of individual tasks during emptying jobs. A time-and-motion survey (Barnes 1963) tracked task duration and was divided into: job preparation, trash removal, sludge emptying, facility repair, and cleaning (Rutayisire *et al.* 2021). The task tracking started and ended with the pit emptying service team's arrival and departure from the household. Task tracking does not include transporting sludge to treatment or disposal as this is a separate activity from emptying. Ninety-nine jobs were tracked by Forever Sanitation in Kampala and 102 jobs were tracked by Pit Vidura in Kigali.

Both businesses shared operational records as secondary data: Forever Sanitation for 979 jobs between January 2021 and November 2022 and Pit Vidura for 103 jobs between April 2021 and March 2023. These data included the emptying method, the number of sludge and trash barrels removed, the number of emptiers, and the price charged for each job. Pit Vidura also shared secondary data regarding pit evaluations from December 2021 to October 2022 detailing latrine type, and evaluation outcome and reason.

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[i] Forever Sanitation – see https://toiletemptying.com/

[ii] Pit Vidura – see https://www.pitvidura.com/

[iii] Gulper – see Gurski et al. (2022, p. 21).

### Data analysis

Observational data were used to inductively identify qualitative categories for emptying methods: emptying technology, intermediate storage (immediately after emptying before transfer to transport), intermediate transfer (transfer from emptying to transport), and vehicle transport storage.

Time-and-motion survey data were organised according to the emptying method and descriptive statistics were calculated. Manual handling loads were determined by combining the number of barrels removed per job, reported barrel volume, and number of emptiers per job.

Emptying tariffs and the price charged to each household were directly converted to United States dollars (USD) using 2021 official exchange rates (World Bank 2023). The volumetric tariff and price were calculated by dividing the price of each emptying job by the sludge volume removed. Price variability was calculated as the percentage point difference between the expected price based on the reported tariff structure for each business and the actual price based on operational records.

## RESULTS

### Development of emptying and transport methods and resources

Different emptying and transport methods have been developed by Forever Sanitation and Pit Vidura. Wherever possible both use large exhauster trucks (at least 10 $m^3$) to empty accessible facilities. Both have also purchased small exhauster trucks (4 and 5 $m^3$, respectively) for use in areas inaccessible to larger exhauster trucks. When facilities are not accessible to any size exhauster truck, the businesses use different technologies to empty latrines but both use manual barrel-based methods to transport sludge from the facility to a vehicle parked at the closest accessible road. For hard-to-serve customers not accessible to large exhauster trucks, Forever Sanitation completed 68% using barrel-based methods and 32% with a small exhauster truck. In comparison, Pit Vidura completed a lower proportion with the barrel-based method (28%) than with their small exhauster truck (72%).

Both businesses also decline jobs for practical and economic reasons: the latrine cannot be safely emptied because it is at risk of collapse during sludge removal; the latrine cannot be accessed by any acceptable means; the sludge is too thick to remove by any acceptable means; or the distance between the latrine and vehicle parking is too far for sludge to be economically transferred either by mechanical pumping or manual carrying. Pit Vidura's evaluator assessed 13% of pit-latrines as being unserviceable, including 7% assessed as sludge being too thick to pump and 4% as being at risk of collapse during emptying. This excludes an unknown proportion of emptying requests screened and declined by the call centre.

In areas that are inaccessible to the smaller exhauster trucks but where the evaluator assesses emptying to be possible, Forever Sanitation use the 'scooping' method where a 5- or 10-litre jerrican on a rope is lowered into the latrine, submerged using a long stick, removed, and emptied into a 20-litre jerrican for carrying to a flatbed truck where sludge is stored in 160-litre barrels.

Pit Vidura uses three methods for customers that are inaccessible to smaller exhauster trucks, all using a portable petrol vacuum pump (Pitvaq[iv]) that discharges sludge into a barrel. Firstly, when an exhauster truck can be parked at 100 m and at the same elevation as the facility, a fully mechanised double vacuum (DoVac) pumping system is established. This consists of a portable pump discharging into a 200-litre barrel used as a balance tank that is pumped by the exhauster truck. Secondly, when the exhauster truck cannot park nearby or at the same elevation, 50-litre barrels are used to carry the sludge to a suitable location for them to be pumped by the exhauster truck. Thirdly, when a suitable exhauster truck is not available or there is no suitable location for pumping transfer to an exhauster truck, a flatbed truck is rented and sludge is carried from the facility to the truck and transported in 50-litre barrels.

Table 1 shows the resources and methods used by both businesses that use barrels as part of the intermediate transfer task. Each method consists of several tasks that have different combined overall levels of mechanisation, varying between being fully manual (scooping), semi-mechanised (portable pump and carrying to flatbed truck), and fully mechanical (DoVac).

The scooping method is suitable for more latrines than the portable pump because it can manage thicker sludge and some latrine substructures that would be damaged by the vacuum suction force, risking collapse. Forever Sanitation uses two

[iv] Pitvaq – see Gurski et al. (2022, p. 37).

**Table 1** | Resources used for barrel-based pit-latrine emptying and transport methods by Forever Sanitation, Kampala and Pit Vidura, Kigali

| **Business** | Forever Sanitation | | Pit Vidura | | |
|---|---|---|---|---|---|
| **Location** | Kampala, Uganda | | Kigali, Rwanda | | |
| **Method name** | Scooping and flatbed | Manual pumping and flatbed | Portable vacuum pump and flatbed | Portable vacuum pump and exhauster | DoVac |
| **Mechanisation level** | Fully manual | Semi-mechanised | | | Fully mechanised |
| **Sludge emptying method** | Scooping | Manually-operated mechanical pumping | Portable mechanical vacuum pumping | | |
| **Sludge emptying equipment** | 5 or 10 litre jerricans, cord and long wooden stick | Gulper | Pitvaq | | |
| **Intermediate storage equipment** | 4no 20 litre jerricans and 10no 160 litre barrels | | 40no 50 litre barrel | 10no to 20no 50 litre barrels | 1no 200 litre barrel |
| **Intermediate transfer method** | Manually carrying to vehicle | | Manually carrying to vehicle | Manually carrying to a suitable location and mechanically pumping to vehicle | Exhauster truck |
| **Transport vehicle** | Flatbed truck | | Flatbed truck | Exhauster truck | |
| **Workforce** | One driver and two emptiers | | One driver and five emptiers | | One driver and two emptiers |

emptiers compared to Pit Vidura's five because of the lower average distance and elevation gain between the facility and the vehicle. In addition, Pit Vidura aims to schedule two portable vacuum pump jobs per day and seeks to manage emptiers' physical capacity.

Both businesses own a manually operated mechanical pump (Gulper) and Forever Sanitation uses it on request but no jobs were recorded using this method. It was reported to be more laborious to use, unable to empty pits as deep as the scooping or portable pump, and scooping could remove thicker sludge. Pit Vidura did not use the DoVac system during the data recording period because no jobs had suitable topographical conditions.

### Time-and-motion assessment

Several factors were observed to influence the overall duration of both businesses' emptying methods: trash, technology and workforce, latrine opening size and potential slab removal, sludge thickness, and requirement for liquefying.

Figure 1 shows the average durations of emptying tasks and the average volume of sludge and trash removed. Jobs completed with small exhauster trucks were both faster and higher in volume in both cities than barrel-based methods. Data from the time-and-motion study show both businesses emptied on average about 2 $m^3$ per job using barrel-based methods (scooping and portable vacuum pumping). The barrel-based methods were similar in overall duration after accounting for duration differences attributable to trash removal. Directly comparing in isolation scooping in Kampala and pumping in Kigali from other tasks finds that scooping takes longer than pumping but overall is faster to prepare, clean and pack. Portable vacuum pumping jobs were lower duration when combined with the flatbed than an exhauster truck because the barrels are carried straight to the transport vehicle without the need for cleaning and packing up the secondary pumping station, but would take longer to dispose at the disposal or treatment site.

Overall Forever Sanitation removed more trash (0.57 $m^3$) during barrel-based jobs than Pit Vidura (0.16 $m^3$). Forever Sanitation emptiers carried a larger sludge volume per job (1.1 $m^3$ per emptier) than Pit Vidura (0.36 $m^3$ per emptier) as fewer emptiers are used to empty a similar sludge volume.

### Tariff structures

For hard-to-serve customers, Forever Sanitation and Pit Vidura use different tariff structures. Forever Sanitation charges 8 USD per 160-litre barrel emptied (sludge or trash), has a four barrel minimum, and varies the barrel tariff on average $\pm$10% depending on the distance between the facility and the vehicle, and sludge and facility characteristics. Forever

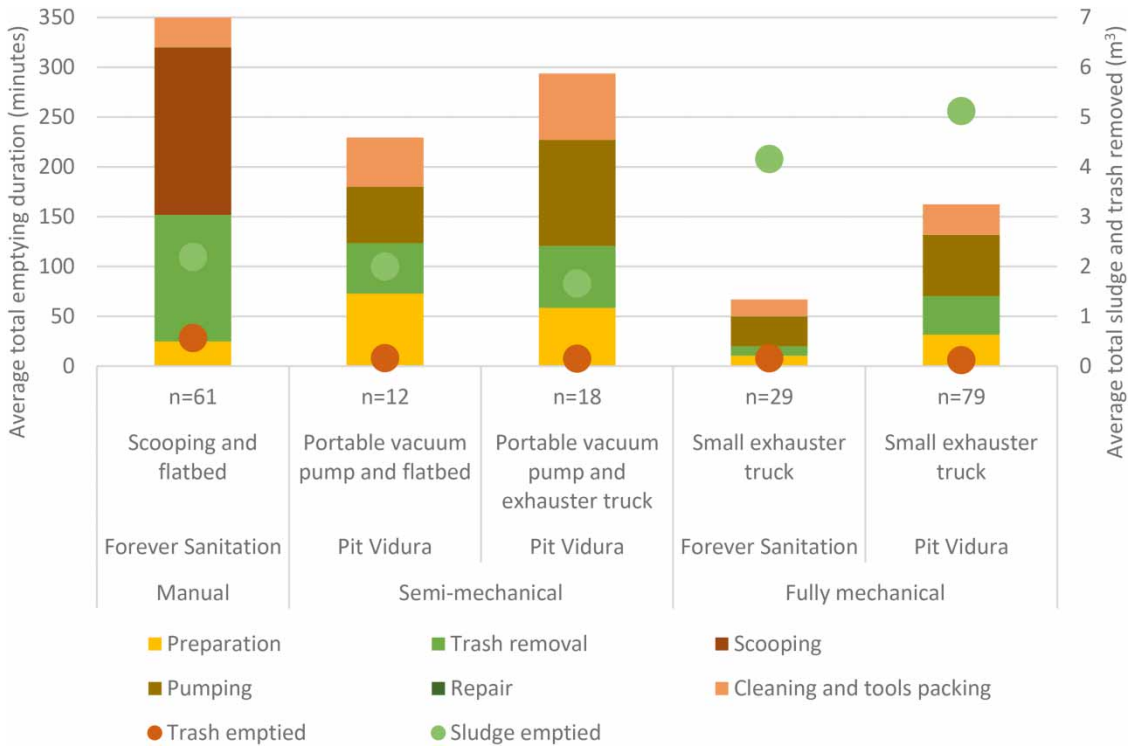


**Figure 1** | Task durations (bars and left-hand side vertical axis), and trash and sludge emptied (dots and right-hand side vertical axis) for emptying and transport methods used by Forever Sanitation in Kampala, Uganda and Pit Vidura in Kigali, Rwanda for hard-to-serve customers. Emptying methods ordered left-to-right on horizontal axis with increasing mechanisation.

Sanitation had a low minimum volume (0.64 $m^3$) but after the observation period introduced a ten-barrel minimum (1.6 $m^3$) that could be shared between neighbouring customers. This increase in minimum volume was introduced because Forever Sanitation wanted to prioritise higher volume and more profitable emptying requests.

Table 2 shows the tariff structures used by both businesses for barrel-based and small exhauster truck jobs. Both businesses have lower volumetric tariffs for jobs completed using small exhauster trucks than the barrel-based method. This was reported to be due to the increased duration and resources required for barrel-based methods compared to exhauster truck emptying.

Pit Vidura charges 81 USD per 40 barrels of 50 l emptied, a 3 USD per barrel penalty tariff if more than four barrels of trash are emptied, and emptier discretion is used to empty more sludge at no additional charge if it completely empties the facility with a small number of additional barrels. Pit Vidura has a high minimum volume (2 $m^3$) because of the time and associated cost of preparing, cleaning and packing the portable vacuum pump. The 40-barrel minimum is used to optimise vehicle capacity (80 barrels total) to complete two jobs per trip to disposal.

Figure 2 shows the distribution of barrel-based emptying volumes. Forever Sanitation customers generally have lower sludge volumes removed than Pit Vidura, although Forever Sanitation also has a small number of high-volume customers (up to 21 $m^3$). Forever Sanitation has a large proportion (85%) of customers that empty 1.6 $m^3$ or less. In comparison, 70% of Pit Vidura customers emptying between 1.6 and 2.1 $m^3$. The data suggest that a combination of Forever Sanitation's

**Table 2** | Tariff structures for emptying jobs completed by barrel-based and small exhauster truck methods by Forever Sanitation in Kampala, Uganda and Pit Vidura in Kigali, Rwanda

| **Business** | Forever Sanitation | | Pit Vidura | |
|---|---|---|---|---|
| **Emptying method** | Scooping | Small exhauster truck | Portable vacuum pump | Small exhauster truck |
| **Emptying volume increments ($m^3$)** | 0.16 | 4 | 2 | 5 |
| **Tariff (USD)** | 8 | 42 | 81 | 81 |
| **Volumetric tariff (USD/$m^3$)** | 50 | 10.5 | 40.5 | 16.2 |

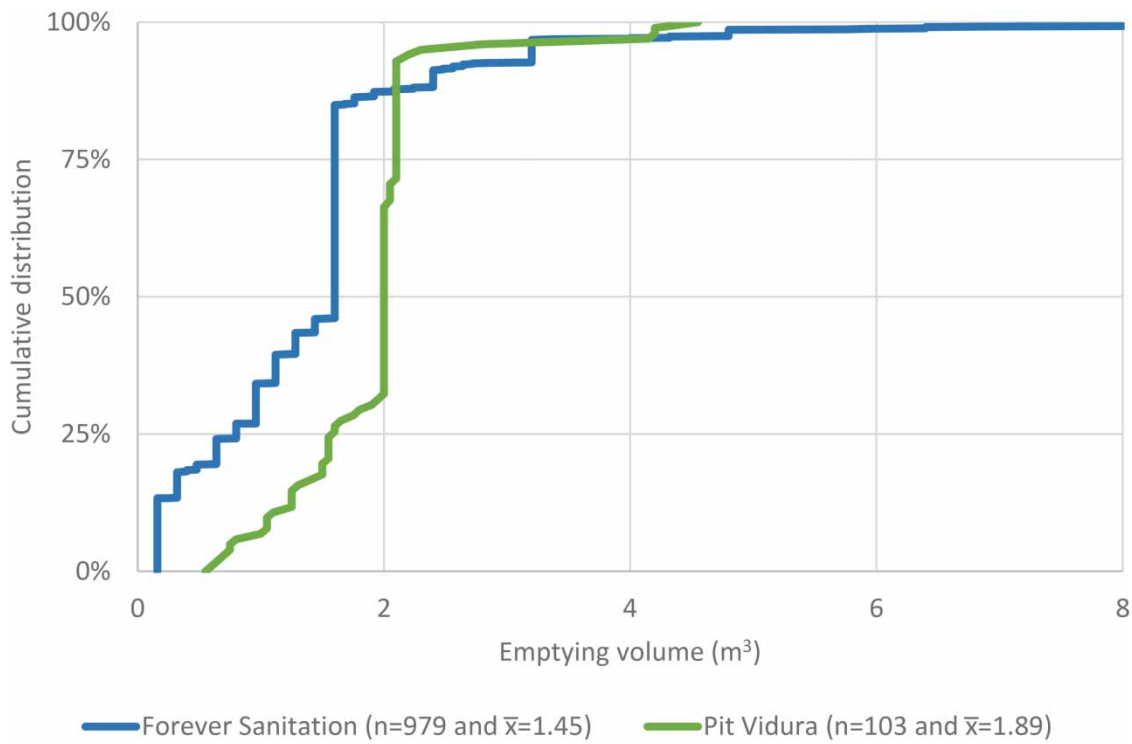


**Figure 2** | Distribution of emptying volumes for jobs completed using barrel-based pit-latrine emptying and transport methods by Forever Sanitation in Kampala, Uganda and Pit Vidura in Kigali, Rwanda for hard-to-serve customers.

lower minimum volume (0.64 $m^3$) and smaller tariff increments (0.16 $m^3$) allows customers to request smaller emptying volumes compared to Pit Vidura customers (2 $m^3$ minimum volume and 2 $m^3$ tariff increments).

Forever Sanitation effectively has a fixed volumetric tariff (52 USD per $m^3$) as customers can choose to empty volumes with more precision at 160-litre increments. In contrast, Pit Vidura effectively has a variable volumetric tariff because the tariff increment (2 $m^3$) does not align with the emptying volume increments (0.05 $m^3$). For the 40% of Pit Vidura customers emptying 2 $m^3$ the effective volumetric tariff is 40 USD per $m^3$ but for the 5% of Pit Vidura customers that empty less than 1 $m^3$ the effective volumetric tariff is more than 80 USD per $m^3$.

## DISCUSSION

### Portable mechanical methods can empty some pits but manual methods are still required

Unlined pit-latrines are the most common household sanitation system in both cities and across the region (Greene *et al.* 2021). This type of latrine typically contains thick sludge rather than dilute wastewater because some of the liquid fraction passes through unlined walls (Ross & Pinfold 2017; Semiyaga *et al.* 2022). Pit Vidura's experience shows that portable vacuum technologies are a suitable emptying technology for some of these facilities. But Pit Vidura is unable to serve some households because facilities are too deep for the vacuum pumps, the sludge is too viscous, or has too low a moisture content to pump (Greene *et al.* 2021; Gurski *et al.* 2022). As demonstrated by the technical evaluator declining 14% of customer pit-latrine emptying requests after call-centre screening.

Forever Sanitation's scooping methods are suitable for some of the facilities that Pit Vidura declined. The scooping method allows them to empty sludge from deeper and by not using a pump Forever Sanitation is able to empty sludge which is thicker and more viscous. The scooping method also removes the need for emptiers to enter the pit, increasing safety and hygiene in comparison to methods typically used by informal emptiers.

Different manual and mechanical tasks can combine to produce an emptying method that is suitable for hard-to-serve customers. For example, using a portable mechanical pump and manually carrying barrels to a transport vehicle is suitable for customers that have pumpable sludge but that cannot be accessed by an exhauster truck. Recognising the existence of this spectrum from fully manual to fully mechanical is important: a variety of emptying methods are required to ensure hygienic services are available for hard-to-serve customers.

At the other end of the spectrum, small exhauster trucks are a useful technology for businesses to serve customers that cannot be accessed by large exhauster trucks. This is consistent with a study which found that 50% of exhauster trucks in Kampala had a volume of 4 $m^3$ or less (Semiyaga *et al.* 2022).

### Accepting fully manual emptying methods can increase transition to formal services

Forever Sanitation has developed its manual method using PPE and locally available equipment to be able to extend formal services to hard-to-serve customers, in a similar way to formal manual services in other cities (Peletz *et al.* 2020). In Kampala, emptiers are required by regulation to use a semi-mechanised method but fully manual emptying is common because it is faster and less laborious (Semiyaga *et al.* 2022). This contrasts with Kigali where regulation also requires mechanical emptying but there are no formal businesses using fully manual methods (RURA 2016). This prevents Pit Vidura from using fully manual methods.

Higher regulatory requirements in Kigali lead to fewer customers benefiting from formal services than in Kampala whilst more hard-to-serve customers have to use completely unregulated highly informal services which may be of much lower quality. Allowing manual emptying from facilities in hard-to-serve areas could increase the transition to formal services across the city (Semiyaga *et al.* 2022). At the same time higher service quality can be an affordability challenge in hard-to-serve areas as it can result in higher costs (Jenkins *et al.* 2015).

Local authorities have a policy and regulatory opportunity to increase the transition to formal services by recognising the tension around formalisation between affordability, available methods and service quality. This highlights the need to involve emptiers where their experience can be used to develop regulation (Lerebours *et al.* 2021) that does not exclude some customers from accessing formal services.

### Municipal solid-waste management reduces emptying duration and price

Forever Sanitation removes more and spends longer removing trash in Kampala than Pit Vidura in Kigali. The recorded proportion of trash to faecal sludge removed during manual emptying in Kampala is consistent with other studies (Semiyaga *et al.* 2022). The additional trash removed in Kampala increases the average price charged to Forever Sanitation customers by 20

USD compared to Pit Vidura customers in Kigali. This finding is consistent with Kampala having a less effective municipal solid-waste management system than Kigali (Kabera *et al.* 2019) and extends previous studies suggesting that the absence of effective municipal solid-waste management systems leads to trash disposal in latrines and that this increases emptying duration (Portiolli *et al.* 2021). Promoting behaviour change around depositing trash in latrines could reduce the duration of the trash removal task, reduce customer prices and increase the proportion of jobs that could be completed by mechanical pumping (Semiyaga *et al.* 2022).

### Hard-to-serve customers take longer to empty which limits commercial viability

The time-and-motion study indicates that each individual task takes longer both for manual emptying and portable mechanical emptying jobs than using an exhauster truck. As a result, both businesses have higher volumetric prices for barrel-based jobs than exhauster truck jobs to manage commercial viability. In addition, completing more than one job per day has been linked to being profitable (Rao *et al.* 2016) but this is challenging when hard-to-serve customers take on average four hours to empty and if dumping sites do not have extended opening hours (Semiyaga *et al.* 2022).

Using portable vacuum pumping technology does reduce the pumping or scooping duration compared to manual methods. However, after accounting for differences between cities in trash removal duration, the overall duration for the scooping method is similar to the duration for portable vacuum pump methods because whilst the scooping task takes longer than pumping, the setup, cleaning and packing time is shorter. It is important to consider the overall emptying and transport method and consider efficiency opportunities beyond the pumping task (Sugden 2013). Improving facilities to make them easier to empty has been found to increase the use of formal services (Capone *et al.* 2020).

### Minimum emptying volumes exclude hard-to-serve customers but are commercially necessary

Operational records and the emptying volume distribution data suggest that Pit Vidura exclude customers who cannot afford the 80 USD minimum price. In comparison Forever Sanitation completes both a larger proportion of jobs with hard-to-serve customers and a larger proportion of lower volume and lower price jobs. This is consistent with research that suggests affordability is a constraint for low-income, hard-to-serve customers (Peletz *et al.* 2020) and that there is a general preference for lower volume, more frequent and lower price emptying (Jenkins *et al.* 2015).

In Kigali, the 80 USD minimum price means that 85% of potential customers will not use Pit Vidura and opt for an informal service (Burt *et al.* 2019). The 40 barrel minimum is required for the job to be cost-effective for Pit Vidura because of the time associated with setting up the portable vacuum pump. One option is to cluster multiple nearby smaller-volume jobs to share the minimum volume between multiple customers (Burt *et al.* 2019). Other similar options to reduce cost and the minimum tariff include delegated management (Peletz *et al.* 2020) and scheduled emptying (Mehta *et al.* 2019).

In 2023, Forever Sanitation increased their minimum volume and associated price to 1.6 $m^3$ and 84 USD after recognising that low-volume emptying was not cost-effective or profitable. About 50% of Forever Sanitation customers emptied less than 1.6 $m^3$ and while the original minimum price was low, a higher proportion of emptying jobs were barrel-based than is the case for Pit Vidura. It is expected that this increased minimum price will reduce barrel-based emptying requests from hard-to-serve customers.

### Lifting demands of manual emptying could exceed recommended limits

Mechanisation reduces manual lifting and is more hygienic than manual emptying. Removing the need for physical entry to the pit and reducing the risk of direct contact between the emptiers and the sludge is desirable. However mechanical emptying is not viable for all facilities.

If businesses increase the number of jobs and volume of sludge emptied per day or per year then barrel carrying will exceed recommended guidelines for manual handling and there is a safety risk to emptiers (Mital 1997). Pit Vidura already uses more manual emptiers than Forever Sanitation to manage physical loading but also because they carry sludge greater distances and over greater elevations. A further consideration is required to consider cumulative lifting loads along with the other occupational hazards associated with manual emptying methods (Chumo *et al.* 2021; Sklar *et al.* 2021).

### Limitations

This study is based on normal operating conditions, which prevents direct comparison between emptying methods. No additional data were collected to assess other factors that may have influenced results and account for differences between emptying methods, e.g. sludge thickness. All emptying methods are assumed to be of a comparable quality and no assessment

was made of customer satisfaction. Both limit generalisability to other contexts. No data were collected about informal emptying methods which limits comparison. No data were collected or reviewed about the different regulatory approaches taken by city authorities. Data production and analysis were conducted by Pit Vidura with the potential for reporting bias.

## CONCLUSION

This study reveals the developments made by two service providers in different countries in delivering formal services. The comparison shows the influence of context and highlights city authorities' crucial role in supporting businesses to extend formal emptying services in hard-to-serve areas.

Formal pit emptying services are not always suitable for all households and the tariffs resulting from formalisation can be inequitable. Portable vacuum pumping is a suitable method to empty some pit-latrines but improved fully manual methods are required when sludge cannot be pumped because pits are too deep or sludge too thick. Municipal solid-waste collection makes pit emptying faster and saves customers 20 USD for every pit empty. Facilities that are easier to empty are charged lower prices to remove the same sludge volume, and the minimum emptying volume and price for many hard-to-serve customers is unaffordable.

Regulators should require service levels that are suitable and affordable for households to allow them to access safe and hygienic services. Higher volumetric tariffs for households in hard-to-serve areas are inequitable and authorities should consider their options to lower prices. City authorities should involve service providers in developing appropriate regulations.

Government and city authorities have the opportunity to increase coverage of safely-managed sanitation by managing the tension between affordability, formalising services and increasing coverage by recognising that manual emptying is required for some customers and that regulating for a higher service quality can increase prices and excluding some customers from accessing formal services.

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## AUTHOR CONTRIBUTIONS

Funding acquisition was done by R.S., N.K., and B.R.; study design was performed by J.W., B.R., N.K., and R,S,; data collection was done by B.R. and N.K.; data analysis by B.R. and J.W.; manuscript writing by J.W. and B.R.; reviewing and editing by J.W., B.R., N.K., B.E., J.B., and R.S.

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## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information. The following supplementary materials are available: volumetric tariff structure description, price variability distribution, time and motion summary statistics, pit evaluation results, time and motion box plots.

## CONFLICTS OF INTEREST

B.R. and N.K. are employed by Pit Vidura. R.S. is on Pit Vidura's Advisory Board. J.W. is an independent consultant for Pit Vidura. The remaining authors declare no conflict of interest (financial or other) that might be construed to have influenced the content of this paper.

## REFERENCES


Akumuntu, J. B., Wehn, U., Mulenga, M. & Brdjanovic, D. 2017 Enabling the sustainable faecal sludge management service delivery chain-A case study of dense settlements in Kigali, Rwanda. *International Journal of Hygiene and Environmental Health* **220** (6), 960–973.

Barnes, R. M. 1963 *Motion and Time Study : Design and Measurement of Work*, 5th edn. John Wiley & Sons Inc, London and New York.

Burt, Z., Sklar, R. & Murray, A. 2019 Costs and willingness to pay for pit latrine emptying services in Kigali, Rwanda. *International Journal of Environmental Research and Public Health* **16** (23), 4738.

Capone, D., Buxton, H., Cumming, O., Dreibelbis, R., Knee, J., Nalá, R., Ross, I. & Brown, J. 2020 Impact of an intervention to improve pit latrine emptying practices in low income urban neighborhoods of Maputo, Mozambique. *International Journal of Hygiene and Environmental Health* **226**, 113480.

Chumo, I., Simiyu, S., Gitau, H., Kisiangani, I., Muindi, C. K. K. & Mberu, B. 2021 Manual pit emptiers and their heath: Profiles, determinants and interventions. *International Journal of Medical and Health Sciences* **15** (6), 207–213.

Greene, N., Hennessy, S., Rogers, T. W., Tsai, J. & de los Reyes Iii, F. L. 2021 The role of emptying services in provision of safely managed sanitation: A classification and quantification of the needs of LMICs. *Journal of Environmental Management* **290**, 112612.

Gurski, T., Hennessy, S., Rogers, T. & Shaw, J. 2022 *A Practical Guide to Available Pit-Emptying Technologies.* Faecal Sludge Management Alliance. Available from: https://fsm-alliance.org/resources/ (accessed 15 May 2023).

Jenkins, M. W., Cumming, O. & Cairncross, S. 2015 Pit latrine emptying behavior and demand for sanitation services in Dar Es Salaam, Tanzania. *International Journal of Environmental Research and Public Health* **12** (3), 2588–2611.

Kabera, T., Wilson, D. C. & Nishimwe, H. 2019 Benchmarking performance of solid waste management and recycling systems in East Africa: Comparing Kigali Rwanda with other major cities. *Waste Management & Research* **37** (1_suppl), 58–72.

Lerebours, A., Scott, R., Sansom, K. & Kayaga, S. 2021 Regulating sanitation services in sub-saharan africa: An overview of the regulation of emptying and transport of faecal sludge in 20 cities and its implementation. *Utilities Policy* **73**, 101315.

Mehta, M., Mehta, D. & Yadav, U. 2019 Citywide inclusive sanitation through scheduled desludging services: Emerging experience from India. *Frontiers in Environmental Science* **7**, 188.

Mikhael, G., Robbins, D., Ramsay, J. & Mbeguere, M., 2014 Methods and means for collection and transport of faecal sludge. In: *Faecal Sludge Management – Systems Approach for Implementation and Operation* (Strande, L. *et al.*, ed.). IWA Publishing, London, pp. 67–96.

Mital, A. 1997 *Guide to Manual Materials Handling*. CRC Press, London, UK.

Nkurunziza, A., Bateganya, N., Byansi, J., Rokob, J., Busingye, J., 2017 Leveraging FSM to close the urban sanitation loop in Kampala. In: *FSM Innovation Case Studies – Case Studies on the Business, Policy and Technology of Faecal Sludge Management*, 2nd edn. (Blackett, I. & Hawkins, P., eds). Bill & Melinda Gates Foundation, Seattle, USA, pp. 132–144.

Peletz, R., Feng, A., MacLeod, C., Vernon, D., Wang, T., Kones, J., Delaire, C., Haji, S. & Khush, R. 2020 Expanding safe fecal sludge management in Kisumu, Kenya: An experimental comparison of latrine pit-emptying services. *Journal of Water, Sanitation and Hygiene for Development* **10** (4), 744–755.

Portiolli, G. F., Rogers, T. W., Beckwith, W., Tsai, J., Wilson, N. & de los Reyes, F. L. 2021 Development of trash exclusion for mechanized pit latrine emptying. *Environmental Science: Water Research & Technology* **7** (10), 1714–1722.

Rao, K. C., Kvarnström, E., Di Mario, L. & Dreschel, P. 2016 *Business Models for Fecal Sludge Management*. International Water Management Institute (IWMI), Colombo, Sri Lanka.

Ross, I. & Pinfold, J. 2017 *Kigali Urban Sanitation Study – Synthesis Report*. Oxford Policy Management, UK.

RURA 2016 *Regulations Governing Liquid Waste Collection and Transportation*. Rwanda Utilities Regulatory Authority, Kigali. Available from: https://www.rura.rw/fileadmin/Documents/Water/RegulationsGuidelines/Regulations_Governing__liquid_waste_collection_and_transportation.pdf

Rutayisire, B., Wolter, D., Kuria, N. & Sklar, R. 2021 Time and motion assessment of pit-emptying operations in Kigali, Rwanda. *Journal of Water, Sanitation and Hygiene for Development* **12** (1), 16–22.

Semiyaga, S., Bamuhimbise, G., Apio, S. C., Kinobe, J. R., Nkurunziza, A., Lukooya, N. B. & Kulabako, R. 2022 Adequacy of vacuum and non-vacuum technologies for emptying faecal sludge from informal settlements of Kampala City. *Habitat International* **125**, 102596.

Singh, S., Laker, F., Bateganya, N. L., Nkurunziza, A. G., Semiyaga, S. & Brdjanovic, D. 2022 Evaluation of business models for fecal sludge emptying and transport in informal settlements of Kampala, Uganda. *Water* **14** (18), 2914.

Sklar, R., Zhou, Z., Ndayisaba, W., Muspratt, A., Fuhrmeister, E. R., Nelson, K. & Katharine Hammond, S. 2021 Risk of adenovirus and Cryptosporidium ingestion to sanitation workers in a municipal scale non-sewered sanitation process: A case study from Kigali, Rwanda. *Journal of Water, Sanitation and Hygiene for Development* **11** (4), 570–578.

Sugden, S. 2013 The importance of understanding the market when designing pit-emptying devices. *Waterlines* **32** (3), 200–212.

Tsinda, A., Abbott, P. & Chenoweth, J. 2015 Sanitation markets in urban informal settlements of East Africa. *Habitat International* **49**, 21–29.

World Bank 2023 *4.16 World Development Indicators: Exchange Rates and Prices*. Available from: https://wdi.worldbank.org/table/4.16 (accessed 25 May 2023).


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