REFLECTIONS ON BUSINESS MODELS AND TECHNOLOGY DESIGNS FOR PIT EMPTYING SERVICES

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INTRODUCTION

The development of new, low cost pit emptying devices such as the Gulper has catalyzed interest in creating much needed new pit emptying services for the unplanned slum areas in cities of the developing world. Whilst improving the technology is a good first step, it is not the total solution and much work and innovation is still needed to achieve sustainable pit emptying service. This document reflects on the factors and constraints that impact on the creation of sustainable private sector operated pit emptying services and is based on the work undertaken in Dar es Salaam, India, Blantyre and Kampala.

One of the major errors in the past when designing equipment for the urban sanitation chain has been the lack of consideration for anything other than the technical engineering based aspects of a proposed device. The Vacutug developed in the 1990's is a 500 litre self-propelled mini- sludge tanker and is technically, a very well designed and robust machine. However, its design fails to take into consideration market-based factors which should govern the design process and it is basically to too slow and too expensive to survive in the market place without some form of external donor subsidy. This brings to mind the sentiments of Paul Polak, formally of IDE, a person well known for his work in the area of technical innovation for the developing world, when he poses the question,

> *"Question: If you build a better mousetrap will the world beat a path to your door?*
> *Answer: Without superb marketing and distribution nobody beats a path to your door"*

Paul Polak then goes on to describe one of his main lessons,

> *"In my work with a multitude of affordable technologies over the past 30 years, one key feature has become abundantly clear: If you have met the challenge of designing a transformative, radically affordable technology, you've successfully solved no more than 10-20% of the problem. The critical other 80% of the solution lies in designing an* ***effective marketing****, distribution, and profitable business strategy that can be brought to scale. Of these, perhaps the most important is designing an effective scale strategy.*

In Paul Polak's terms the Vacutug is just a better mousetrap that has been designed with a lack of understanding about the market place and without proper marketing. The world did not beat a path to the Vacutug manufactures door and the machine has faded into pit-latrine-emptying obscurity.

Marketing has many definitions, but most are along the lines of

> "The management process through which goods and services move from concept to the customer. As a practice, it consists in coordination of four elements called 4P's: (1) identification, selection, and development of a product, (2) determination of its price, (3) selection of a distribution channel to reach the customers place, and (4) development and implementation of a promotional strategy" (business directory.com)

Marketing is a wide subject in which there are interconnections between each of the 4 P's. This paper focuses on how the engineering aspects of new sanitation products have to be designed in relation to the market and business in which they operate.

The document is divided into two parts. The first considers the existing pit emptying profession and the business models which could be used to formalize the profession and improve the quality of the service. The second part considers how the nature of the sector and the entrepreneurs impose constraints on the market which limit the options for improving urban sanitation chain technologies. It attempts to give some context and direction to people wanting to develop new technologies.

PART ONE - THE PIT EMPTYING PROFESSION AND BUSINESS MODELS

<u>The existing pit emptying profession</u>

The fundamental constraint within the pit emptying profession is the nature of the work and no matter how decorative the language, it cannot disguise the fact that taking shit out of a pit is not pleasant and never will be. Better pit emptying devices and the liberal use of disinfectant can make the work less disgusting, but it will never be considered either a desirable or high status job. Children will never aspire to be pit emptiers in the same way they do to become doctors or computer programmers.

Pit emptying is currently a profession people start practicing with a view to it being a temporary job whilst something better comes along. It's an occupational cul-de-sac in which most would prefer not to get stuck as opposed to being a career of choice with glittering prospects. The social costs of being a pit emptier can be heavy. 'Mr Clean' the charismatic owner of a septic tank emptying business in Mzuzu, Malawi, likes to explain how his wife left him after she was pressurized by her father not to be married to a man making a living from shit. "I got her back after I bought him a new three-piece-suite and he could see the money," he says with a mischievous smile in his eyes.

After years of practice, pit emptiers tend to become hardened professional whose senses have become muted to the disgusting nature of their work, have realized that pit emptying is reasonably lucrative and that its just about the best job they are going to get. In Bangalore, India, the unskilled manual pit emptiers are paid twice as much as unskilled labourers on a building site for work which is comparatively easy and only involves lifting a bucket from ground level and tipping its contents into a large drum. Not exactly arduous and the hardened profession emptier accepts it as his (because it always is a 'his' and not a 'her') lot in life. It's not glamorous or even socially acceptable, but it's better than the alternatives and not particularly difficult. With their main comparative advantage being the ability to handle shit and smile at the same time, pit emptiers can be keen to maximize the benefits these skills can bring by making the work appear to be more disgusting than it actually needs to be. The pit emptying process in Bangalore is truly disgusting to watch and with a little ingenuity it could be made more pleasant and cleaner. Ingenuity is not in short supply in India, but the emptiers know that if they improved the process by making it more hygienic they would have less of a negative impression on the householder who would then argue for lower charges. It is in the best interests of the emptiers to keep the process as dirty as possible. Mr Clean, who normally drives his vehicles around in a sharp suit says he occasionally walks about town dressed in his dirty overalls just to 'put people off' entering the business.

Hardened professional emptiers who manually empty pits using a bucket and spade have a near perfect business model and it is difficult to see why they would want to change. The capital cost of their equipment is very low (a shovel, a bucket and a piece of rope) and they do not need bank loans or credit to purchase the equipment. They do not need expensive vehicles to transport the pit sludge to the treatment plant as they simply dig a hole near the latrine and bury the waste or throw it in the nearest drain or area of waste ground. Good for profit margins, not good for public health. Manual pit emptiers are well known throughout the community and do not need to promote or advertise their services. Ask any householder in an unplanned area where the pit emptier lives and they will always point in the direction of their house. The work is very profitable, they pay no taxes, they a have no real competition or 'Do-it-Yourself' alternative, and their services are needed by their loyal customers on a steady and repeated basis; people in densely populated slum areas produce a lot of shit. The only possible threat is the Municipality Environmental Health Officers, but these usually turn a blind eye to the process. As one manual pit emptier stated in Dar es Salaam, "We used to only empty pits at night, but now we do it during the day and the health officers do not care". It is only a perfect from a business model perspective, but not from a public health perspective. As one lady living in an unplanned area in Dar es Salaam stated,

> *"Rainy seasons are a double tragedy to us. You see we are at risk with stagnant water, and worse even is that this water is mixed with latrine sludge. You can imagine how children love water and now they have to play with contaminated water. It is really very disgusting and yet it happens almost all the time." (WSP)*

Or perhaps more poetically expressed by another resident,

> *"What's the point of having a clean house when you have next door's shit running through your kitchen?"*

Manual pit emptiers can be regarded as the main competitor to more hygienic mechanized pit emptying businesses. Attempts were made in Dar es Salaam in the 1990s to mechanize the process using simple hand-powered vacuum tankers which were given to the manual emptiers. These rapidly failed and three years after the end of project implementation, none could be found operating. Why would they be interested in developing a more hygienic pit emptying business, particularly if involved buying expensive capital cost equipment? Why change when their existing approach has minimal costs and good profit margins? Mechanizing the process would mean having to be registered and crossing over into the formal sector, regulation leads to control and worse of all, paying taxes.

From an outsiders perspective one of the biggest reasons to stop manual emptying is to make the process more hygienic and to protect the health of the operator. Manual emptying is indeed hazardous. The emptiers in Dar es Salaam complain that their biggest hazard is being cut by broken bottles or needles dumped in the pit which they fear could become infected. Pit emptiers in Bangalore reported that their biggest occupational hazard was alcoholism, but whether they drank to allow themselves to empty pits or whether they emptied pits to allow themselves to drink was unclear. The hazards both sets reported were not the expected ones of diarrheal disease, vomiting, or worm infection which in theory should be high given the nature of their work and the ease at which faecal- oral transmitted pathogens can be spread. Perhaps these diseases were so common that they considered them as normal or perhaps they simply did not have any major disease problems. It is virtually impossible to avoid the faecal-oral disease transmission routes when digging out a pit. Research undertaken on the masks worn by manual emptiers in Durban, South Africa, found the masks they wore to be so grossly contaminated with large numbers of Ascaris Lumbercoides (round worm) eggs that they had to introduce mandatory regular de-worming treatments for all operators.

Although many cities have a cohort of hardened and long established professional manual pit emptiers, there are also people who empty pits as a way of earning a bit of money until a better job opportunity arises. These can be considered to be temporary pit emptiers. They tend to have no skills that distinguish them from the mass of other people seeking casual work and solely seek a good rate of pay, prompt payment, no expenses, and no long hours. Such people are not likely to have a particularly good education, likely to be poor, and likely to lack entrepreneurial drive. If they had any entrepreneurial drive they would not be emptying pits. They tend to suffer from short term thinking regarding their careers and are not ambitious in growing an emptying business.

If an existing pit emptier became interested in developing their business it is likely they would need a bank loan to purchase equipment. Opportunity International bank reports "Less than 10 percent of households in most sub-Saharan African countries, including Malawi, Mozambique and Uganda, have a bank or savings accounts" and pit emptiers are firmly in the category of those without bank accounts. Banks are risk averse when it comes to lending their money and an entrepreneur operating in the informal sector, with no collateral, no existing bank account, no credit history, no recognized business skills, and no formal business plan or financial projection, does not represent an attractive prospect for a bank.

In summary, it is going to be difficult developing a replicable business model that can be taken to scale based on the type of people currently making a living from emptying pits. The 'temporary' pit emptiers have low educational levels, no business acumen or entrepreneurial drive and are looking for a way out, rather than a way further in. The 'harden' professional pit emptiers already have a good business model and are comfortable with the way they operate; its profitable, they pay no tax, its cash in hand, their services are in high demand, and their business cost are low to none existent.

<u>Who is going to buy and use any newly developed urban based sanitation technologies?</u>

If the 'temporary' pit emptiers or the 'harden' professional pit emptiers are not going to purchase a new improved pit emptying device, who is? This is a key question for the designer which should always be at the fore front of their minds.

Designing with the belief that NGOs or donors will be the customers is a common mistake. The scale of the problem is so huge that where NGOs have tried to intervene over the last 30 years, they have only had a miniscule impact. On a visit to Dar es Salaam in 2005 it was found that CARE were planning to build 75 heavily subsidized latrines in the unplanned areas over a two year period. 70% of Dar es Salaam 3.2 million population use pit latrines giving an estimated 448,000 pit latrines. CAREs well intentioned contribution will reach just 0.02% of the pit latrine users in Dar es Salaam. The other INGOs were even less active than CARE.

If improved pit emptying practices are to be available at scale it has to be driven by private sector entrepreneurs wanting to make a profit from offering better quality services and continually expanding their businesses to find new customers. The customer for any new device or technology has to be a new breed of entrepreneur who enters the pit emptying market to make a profit and who operates in the formal sector on more professional lines. Water for People is working to pull such entrepreneurs into the market, but there are still only a few of them in existence on which to base an understanding of their needs and attitudes. Improving sanitation in slum areas in developing country cities could be regarded as been doubly hard; not only is it about developing new technologies, it is also about developing a whole new sanitation industry.

<u>Business based constraints and business model options</u>

There are currently only a few private sector operators at which to target any new devices and to some extent the designer has to work from best 'guestimates' based on the knowledge and experience gleaned from supporting a private sector operators in Dar es Salaam and Blantyre and the experiences gained from developing other emptying devices such as the Gulper and the Vacutug.

The best people to develop successful business models for sanitation businesses in developing countries are not NGO staff, government officials, academics, engineers or sanitation experts, but rather the actual entrepreneurs themselves trying to make a living from the process. The following is therefore not an exhaustive list of possible business models for emptying businesses, rather a reflection on the experiences to date and some the business based hazards which better designed pit emptying technology can help mitigate and control.

When thinking about which business model to adopt an entrepreneur should firstly decide how to manage the person whose job it is to actually empty the pit. This is arduous physical work which requires little training, no formal qualifications and the ability to withstand an environment which other people find disgusting. A typical operator would be male, young, strong, poorly educated and poor. They become pits emptiers because of their economic circumstances and the need to earn money. Being financially stressed they are prone to falling to temptation should the opportunity arise, such as when a customer requests additional work, doing undeclared 'private work 'or falsifying receipts. The common solution to this in Africa seems to be for the entrepreneur to only employ relatives in the belief that stealing from a family member is a social crime and a stronger deterrent than that of being caught and prosecuted by the police. This may be true, but it is not a guarantee and the employer of an operator needs to develop a system which prevents such tempting opportunities arising.

The usual method of controlling employees is to employ a manager to monitor and coordinate the operators work and to act as the interface between the company and the house owner. Such a person would need to be better educated and would have higher earnings expectations than the people they manage, and this could be a significant drain on profits. Such a person would also require transport, petrol money, telephone and possibly a desk in an office. The impact of employing a manager is to escalate running costs which in turn requires more pits to be emptied by employing more emptying operators and the purchase of more emptying devices. If setting up a new team of pit-emptying operators costs $500 this may be manageable, but if it costs $5000 then this could represent a major barrier to expansion. As the number of teams increase, so do the difficulties and efficiency at which they can be monitored and greater the number of opportunities the operator has to embezzle money.

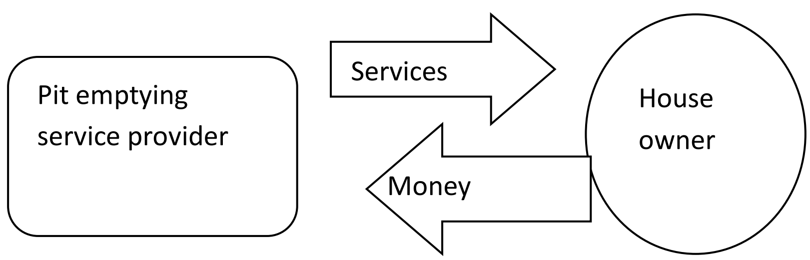
One of the great advantages the manual pit emptiers have is that they are easy to find and easy to contract to undertake the work. This ease of contracting access has to be matched by any new pit emptying business and they will need some form of office or agent who can promote the improved pit emptying services within each slum area. A business should resist setting up an office in each area as this will escalate costs, but instead should consider using the local government area offices or local hardware shops as contact points.

The business also needs to ensure that the pit emptying operators are incentivized to promote the services. The best way of achieving this is to pay the operators on a 'per latrine emptied basis', as opposed to paying a weekly salary.

The main lesson from Dar es Salaam would seem to be that the entrepreneur must assume that the operator will steal money, perform private work and generally cheat the company, if given the opportunity. Rather than employing additional people to monitor and manage the operators, an entrepreneur may be better accepting the inevitable and instead use a business models which mitigates the risks by using the principle that people cannot steal from themselves. The following are three business models which achieve this,

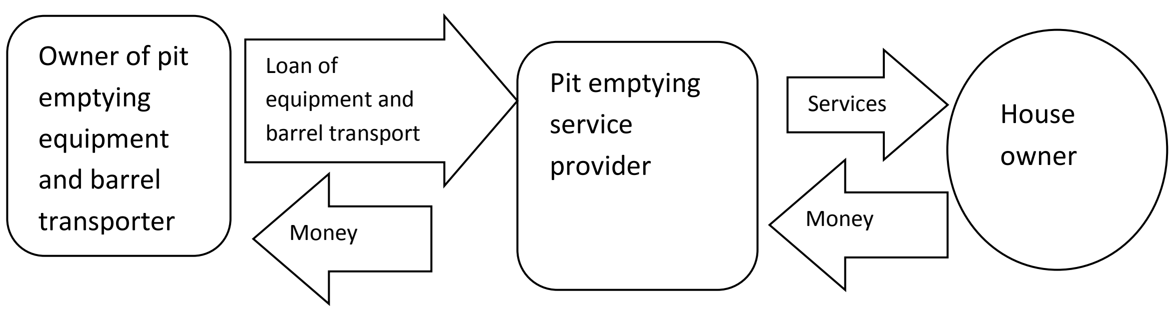
Owner operator model

This is where the emptying equipment is owned, used and managed by a single entrepreneur. This model is used in Blantyre and has the advantage that it is impossible to embezzle from yourself and it is very simple to manage. The disadvantage is the quality of entrepreneur is limited by the disgusting nature of the work and growth in market penetration will be slow and piecemeal. If a successful owner operator wanted to expand by employing more operators / teams, it automatically means that the business model changes. Such entrepreneurs are also likely to be 'lifestyle' entrepreneurs and not be hungry for expansion once a certain income level has been achieved.



Equipment rental and independent operator model

This model is where the emptying equipment is owned by one business and rented to an operator on a daily or job basis. This model is used for solid waste collectors in Dar es Salaam and could be easily adopted for the pit emptying process.

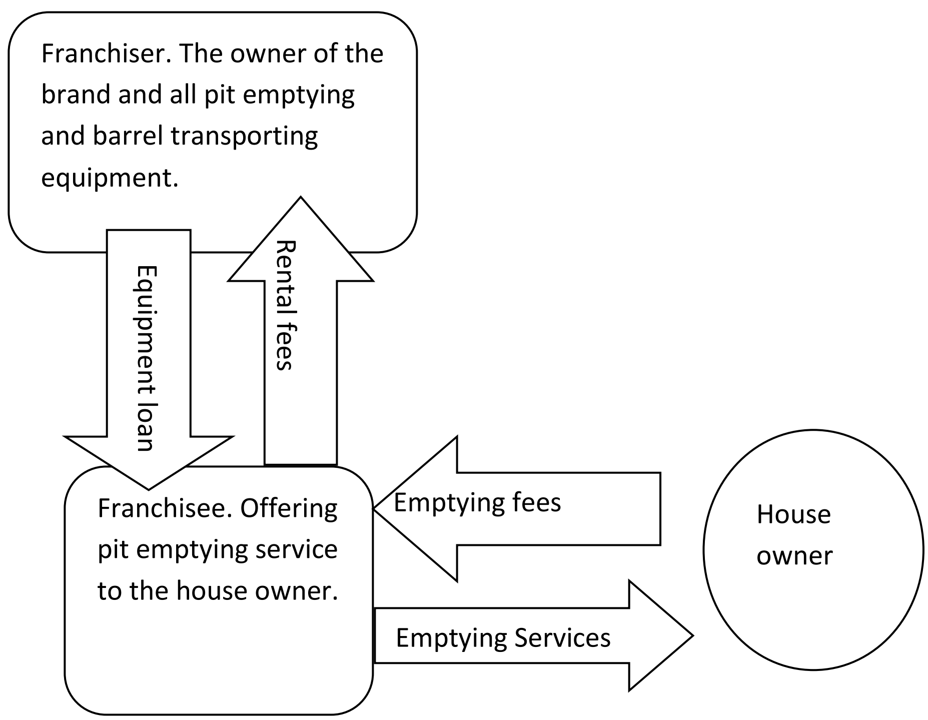


When the operator finds a customer with a full pit they hire the pit empting equipment and some 200 litre barrels. The operator empties the pit, gets paid, and leaves the barrels at the road side for collection. The owner of the equipment collects the barrels and takes them to the dumping site and collects a hire fee from the operator.

The advantage of this model is that the operator requires no capital start-up costs, that more than one operator can be served by one barrel transporter (the high capital cost item), and there will be a relatively large number of operators trying to promote pit emptying services. The transaction between the equipment owner and the operators is easy to manage with no opportunities for embezzlement. If one operator drops out, they can easily be replaced by another.

Franchising model

This is where the emptying equipment and barrel transporter are owned by a franchiser and loaned to a franchisee operator on a long term basis for the payment of a monthly rental fee. The franchiser brands and promotes the service at a city level and the franchisee finds customers and promotes the service at a local level.



The franchisee would be given a geographical area in which to operate and would essentially operate as an owner/operator. The monthly rental fee removes the need for the operator to have any capital start-up costs and should he fail to make the repayments, the equipment can be repossessed and issued to another operator. After three years, or when a transporter reaches the end of its useful life, it will be replaced by the franchiser who would sell the used transporter on the second hand market. The rental fee would cover contributions to the city wide promotion process and servicing and maintenance of the transporter. A rough spreadsheet calculation shows that the rental fee would be less than if the operator was to apply for his own bank loan. The franchiser could be regarded as a vehicle fleet manager that makes a profit from what is fundamentally a financial deal for transporter leasing. The longer serving operators could be offered shares in the franchiser company to tie them into the brand and to generate more income.

The advantages are that emptying services can be taken to scale relatively easily, poor performing operators can be easily replaced, there is limited room for embezzlement, and the bank loan and business plan is with one large company, the franchisor, and not with multiple geographically spread, small companies. The main concern is regulating the franchisees, maintaining a high quality of service and preventing the franchisee selling the equipment and disappearing over a convenient international boarder.

PART TWO – DESIGN CONSIDERATION FOR PIT EMPTYING DEVICES AND URBAN SANITATION TECHNOLOGIES

Customer feedback on existing empting services

It is difficult for a new entrant to break into the pit emptying market, particularly when they have to attract customers away from their usual tried, trusted and local manual pit emptier. The new entrant has to offer better value to the householder and to achieve this, it is important to understand what customers value and what they dislike about the manual pit emptying service. By interviewing household in Dar es Salaam who have used manual emptiers it is possible to gain insights into their likes and dislikes about the process.

Likes with manual emptying service

- The ease at which they can contact the emptier
- The quality of their removal work. The manual pit emptiers remove all the pit contents, no matter how old or how dense the sludge within the pit. At the bottom of an old pit the sludge can become clay-like and virtually impossible to remove by any of the low cost mechanical devices currently being developed.

Dislikes with manual emptying service

- The disgusting nature of the process with piles of sludge visibly accumulating in their compound
- The dirty mess the manual emptiers usually leave behind.
- Manual emptiers have to remove the cover slab in order to gain access to the pit, and this usually means breaking open the slab with a hammer. After the work has been completed householders have the additional cost and effort of contracting a mason to construct a new slab which is an expensive and time consuming process.
- The high cost of emptying, usually around $90 for the complete pit.
- The time taken to complete the work. It can take a team of two, three days to empty a large latrine, during which time the latrine is out of action and the family have to tolerate a filthy emptying process.
- Socially objectionable. Although all the householders have to have their pits emptied, it is regarded as anti-social behavior mainly due to the smell and filthy nature of the process.
- Drunkenness. Many manual pit emptiers need alcohol before entering the pit and this can result in drunken behavior.

The development of the Gulper (a simple direct action hand pump) based emptying services in Dar es Salaam and Blantyre has led to the following customer insights,

Likes with Gulper emptying service

- It clean and hygienic in comparison to the manual emptiers. There are no piles of sludge or dirty or mess within the compound.
- The operators were smart, sober, clean and wore protective clothing, such as overalls, masks and gloves.
- They did not need to break open the slab so it did not need to be replaced.
- It was quick and completed within two hours so there is little social disruption.
- The latrine was clean when the operators left. (The operators have the practice of washing down the latrine after emptying so there is no fecal matter visible. They also put disinfectant on the slab which makes it ‘smell clean’)

- There was no burying of the sludge on site and it was taken away for proper disposal (socially acceptable)

Dislikes with the Gulper emptying service

- It does not empty the whole of the latrine, just the top one meter section, which usually mainly comprises of watery sludge.
- When the service started in Blantyre there were arguments over payment. The households believed the price was for emptying the whole pit, whilst the operator had a volumetric tariff based on the number of 200 litre drums of sludge removed. The operators have learnt to carefully explain the charges to the householder before they start.
- An experiment was tried in Dar es Salaam using handcarts to transport the waste to the treatment site. This proved to be slow and extended the pit emptying process over the whole day. The householders complained indicating that the speed of the process which causes minimal disruption is a key attribute to a good emptying service.

The main competitive advantage the Gulper operators have over the manual emptiers is the clean, hygienic nature of their emptying process, not destroying the slab and the fact that they take the waste to a treatment plant for disposal. The main disadvantage is that their emptying equipment only removes the top section of waste within the pit and they are not regarded as doing a more efficient emptying job.

<u>Designing a device that provides customer satisfaction</u>

Pit emptying is a *service* and *service quality* can be hard to objectively assess. When a person buys a product, such as a car, they can see, touch, smell, and even take the car for a test drive. They use all their senses to make a judgment about the car. When a person buys a service, such as an internet connection from a service provider, a mechanic for repairing a car, or a restyling from a hairdresser, it is not possible to use these same senses to assess *quality* and the customer has to make subjective judgments based on factors which can be unrelated to the actual quality of the service received. A competent and diligent mechanic can have an untidy workshop, but tidiness is one of the few outwardly visible indicators on which his competency can be judged. Marketing a service is therefore difficult and often relies heavily on word of mouth ("Joe's a good mechanic, he will do a good job on your car and won't over charge"). It is important that an emptying business understands how it is assessed and that the designer of new emptying technology develops a device which enables the operator to provide high levels of customer satisfaction. The insight of the manual emptying and Gulper based processes leads to the following key attributes for a pit emptying service,

1) Quick service - in and out as fast as possible
2) Clean service – No shit being spilt in the compound and the latrine looking cleaner after then emptying that it did before. A small amount of disinfectant or bleach helps reinforce this perception.
3) Service which can empty a pit without removing or breaking the slab
4) Service that is capable of removing all the pit contents and not just the top section. This requires a device that can remove thick sludge at the bottom of the pit and not just the watery sludge layer at the top of the pit.
5) Uses easy to measure volumetric tariff system e.g. number of drums, as disputes can occur over payment. It is hard to assess how much sludge has been removed from a pit by looking down the squat hole.
6) Service which does not add large quantities of water to the pit to fluidize the sludge. Householders feel cheated if the operator tips twenty litres of water into a pit and then charges the householder for taking the same twenty litres away.

<u>Designing technologies that will pay for themselves within the first six months.</u>

No matter what a technologies function, it has to be designed and built to a price, and pit emptying technology is no exception. It is worth putting a few hypothetical figures into the design equation. Say, an entrepreneur needs $600 to buy pit emptying equipment for which they gain a bank loan where the interest rate is 25% per annum repayable over a 12 month period. This equates to an average monthly repayment of around $55. If each household pays an average of $18 for their latrine to be emptied, they would need to be empting 3 pits a month to repay the loan, 7 pits to breakeven and 11 to make it worth their while. Emptying 11 pits a month is realistic figure for a new company offering a new form of emptying service.

If the same interest rates and loan periods are applied to capital equipment costing $2,000, the average monthly repayment would rise to $189, and the entrepreneur would need to empty 10.5 pits a month to pay off the loan, 17 pits to breakeven and 21 to make it worth their while. Emptying 21 pits a month, around one per working day, is high for a new business to achieve within the first six months of operation, but achievable for a well-established business. Increasing the loan repayment period and reducing the interest rates can alleviate loan repayment pressures, but it would still be a challenge for a new business to achieve these outputs.

If the same loan conditions were applied to capital equipment costing $7,000, the average monthly repayment would rise to $662 and the entrepreneur would need empty 37 pits just to pay off the loan; highly unlikely.
An established pit emptying business may be tempted to take out a $2,000 loan and may have accumulated some of their own capital to re-invest in the business, but temporary pit emptiers, with their hand to mouth existence would not even consider taking out a $600 loan for a pit emptying device and becoming locked into an anti-social professional cul-de-sac.

It is possible to envisage that better and more expensive pit emptying devices will be needed as a pit emptying business grows. However, the starting point on the technology ladder has to be a simple low cost manually powered device which enables them to get a foot on the ladder and to grow a customer base. As their confidence and understanding of their business grows they may want to upgrade their equipment, but this is a value judgment the entrepreneur has to make and could include one or more of the following factors,

1) If the demand for their services has outstripped their ability to supply the service, and new equipment allows them to increase their output for the same or slightly increased operating costs, then upgrading is a logical decision. The basis for the calculation may be as simple as, if a new device is capable of emptying latrines as twice as fast, will this result in twice as many customers being served and double the profits? In practice the answer to this question is usually ‘no’ as the relationship between the capital cost of equipment and profit margins are not linear. There are many other factors which contribute to overall profitability.
2) Improved emptying performance e.g. new equipment goes deeper and removes thicker sludge.
3) The owner / operator is tired of handling shit and wants a cleaner device
4) The customers and market forces increase the expectation for cleaner, higher quality services and the entrepreneur has to upgrade to keep their market share.

Whatever the reason the operator will make a value judgment based on his own motivations. The designers role is to develop a machine that meets the needs of a pit emptying business at every stage of its development. Cost will always be a prime consideration and to follow Paul Polak’s principle, ‘If it cannot pay for itself in 6 months, don’t bother’.

<u>Power source considerations</u>
There is a series of interrelated factors and decisions regarding the design of urban sanitation chain technologies which have the tendency to escalate the capital and revenue costs of a device. If not controlled, a device will soon go beyond the limit of affordability and practicality.

One of the early key questions most designers have to tackle is the source of power for their device. The options are a petrol engine, an electric motor or human power. Up to the development of the Mapet, human power was regarded as being insufficient to pump sludge and was rejected. The electricity supply to slum areas was generally considered to be sporadic and grounds for rejecting it as a power source. This only left the petrol engine with its many inherent advantages and flaws which seriously limit its practicality and commercial viability. Small five horse power petrol engines are available in all major cities in Africa and their small size, the readily availability of fuel and the simplicity in incorporating them into a design made it the power source of choice. It provides an instant independent power source with a lot of power for its size. The drawbacks relate to the same factors which makes them advantageous. Engines are very 'pinchable' and therefore need to be protected from theft which entails employing a guard or paying for nightly safe storage. These extra costs can be quite high and impact on the profit margin and force changes in the business model. Having a guard is no guarantee that the asset will be protected as such guards are usually poorly paid and can act as the 'insider' for a larger gang of thieves. Petrol is also very 'pinchable' and it is easy, as the experience in Dar es Salaam has shown, for an operator either to siphon off and sell the petrol or to have an arrangement with the petrol pump attendant to obtain false inflated receipts. It is very difficult for the owner of a business to monitor and control such behavior. Engines also require care in their operation and simple checks need to be carried out every day to ensure oil levels are satisfactory and belts and bolts are properly tensioned. Although these are simple tasks, it does require an operator with a basic understanding of engines and such people tend to be better educated and have higher salary expectations. Paying extra for such staff eats into margins, which in turn means more pits need to be emptied to breakeven. Petrol engines, no matter how well they are cared for, eventually wear out and need repairing or replacing. Repairing an engine is another opportunity for an operator to supplement their income and minor problems can be easily inflated into major repairs ("The rings have gone" being the old favorite) and receipts are easily falsified. It is hard for an inexperienced person to tell whether the engine oil has actually been replaced and whether repair work has been undertaken in a competent manner. (Who checks whether a garage has actually replaced the oil in your car or do you simply trust them?) Replacing an engine can often be the simplest and cheapest-in-the-long-run solution, but this requires a few hundred dollars in cash which a typical pit emptier is unlikely to have. Although they know it is a false economy, it is usually cheaper to carry out a 'patching up' repair job to keep an engine going for a few more weeks, than it is to buy a replacement. The business man may know the repair will not last, but at least they can keep on trading and earning.

Basing a pit emptying device around a petrol engine automatically leads to an increase in the capital and revenue costs of the machine. The cost of the actual engine will always be a significant portion of the total cost of petrol driven vehicles, but on top of this, the power the engine generates needs to be harnessed and controlled to make the device safe to operate. Petrol engine driven devices require a substantial framework or chassis on which to mount the engine which in turn pushes up the costs, makes them heavier to move and more difficult to construct. The weight of such machines is possibly the largest drawback as the operator will not be able to push or carry the device to the household and a vehicle will have to be hired or bought for transportation. This additional cost, once again, eats into profit margins.

In summary, the decision to select petrol as a source of power for a pit emptying device has consequences far beyond the design of the device itself. If they are to be the basis of a pit emptying business, more innovative business and financing models will have to be developed.

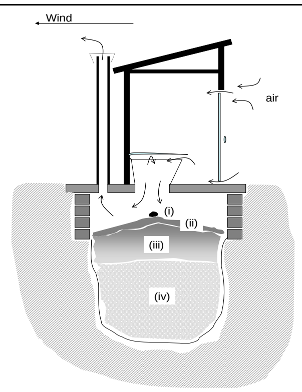
It is worth re-considering the initial assumptions which rejected electricity and human powered devices. The Gulper (a design based on a direct lift water hand pump) has shown that it is possible to empty pits using human power and that its low cost, light weight construction, robustness, and lack of need for maintenance lend themselves readily to the business models outlined in part one. It may not remove sludge as quickly or as cleanly as some petrol engine powered devices, but the trade-off has allowed for the creation of several small owner operated commercially viable pit emptying businesses in Blantyre.

It may be a mistake to rule out using an electric motor as a power source. An electric supply is usually one of the first services to be placed in a slum area and now the majority have a rudimentary electricity supply network. These are often ramshackle and not always legal, however it does mean that a device based on the electric motors could be viable. Motors, new and second hand, can be purchased in all African cities and there are normally several traders specializing in there repair. An electric motor is smaller than an equivalently powered petrol engine, is less vulnerable to poor maintenance, less likely to be pinched, and provides fewer opportunities for embezzlement.

<u>Design consideration based on the nature of pit contents</u>

There have been few studies on the decomposition processes occurring within latrines and only anecdotal insights into factors which can slow or speed up the processes. Research is currently being undertaken by London School of Hygiene and Tropical Medicine into the degradation processes and the factors that determine the performance of a pit, but nothing conclusive has come to light at the time of writing. Jamie Radford, an EWB member from the UK, has developed a Ball Penetrometer which measures the sheer strength of the sludge whilst in the pit. The initial results of testing 30 pit latrines in Kampala will be available shortly. Both studies will enable the better design of emptying devices, but until the time when the results are available, the following section contains the most up to date information available.

A publication from the KwaZulu-Natal group put forward the hypothesis summarised below on the type of decomposition which occurs at different layers within VIP pit latrines. This was based on measurements of Chemical Oxygen Demand (COD) and organic solids at different depths in a number of pits in comparison with fresh faeces.



First Layer (i) New faeces where readily biodegradable components are still present, wherein rapid aerobic degradation occurs. This layer is negligibly small and is not measurable in practice.

Second Layer (ii) Made up of the top aerobic section of the pit. In this layer, aerobic degradation of hydrolysable organic material occurs at a rate limited by the aerobic hydrolysis of complex organic molecules to simpler compounds.

Third Layer (iii) Anaerobic due to the occlusion of oxygen by covering material.

Fourth Layer (iv)Deeper in the pit where anaerobic digestion proceeds at a significantly slower rate than in the layer above, and is controlled by the rate of anaerobic hydrolysis of complex organic molecules to simpler molecules.

Variations within the different layers are due to a number of possible causes: including water ingress; inhibition and user behaviour (lack of maintenance and use of the pit for waste disposal).

Figure 1. Diagram of a pit latrine showing the different theoretical layers.

Previous studies on the biodegradability of organic matter present in fresh faeces show that 80% of human faeces comprises slowly biodegradable organic matter, while 20% is inert material. The slowly biodegradable portion cannot be utilized directly by micro-organisms found in the pit and has to be made accessible through cell external enzymatic reactions.

Pit fill-up rates based on anecdotal evidence are variable. Some might fill up within 18 months while others have a seemingly indefinite lifespan. In practice sludge accumulation rates vary from as little as 10 litres per user per year to as much as 100 litres per user per year, with the median rate being in the 25-30 litres range. Pit lifetime is likely to depend on a variety of factors, the most important of which are the number of users, the size of the pit, the degree to which the pit or tank is drained, and the degree to which the pit is used for disposal of other household waste.

Experience of pumping and digging out latrine pits has shown that not all pits degrade in the same way and the above diagram showing distinct layers is somewhat idealized perception. In practice there is huge variability and it is common to find both pits that seem to comprise mainly of a watery sludge that is easy to pump and other where the sludge is very dense and is un-pumpable with a vacuum pump after only a few inches. The reasons for the differences are unclear and further investigations are been carried out by London School of Hygiene and Tropic Medicine with funding from the Gates Foundation. Pits that routinely flood with the rise in groundwater seem to last longer than most, possibly because the permeability of the pit walls is maintained by the regular flushing.

As a general rule, the longer the excreta stays in the pit, the greater its density will become and the harder it will be to remove. When tested, sludge densities in Dar es Salaam were found to increase from 1.1 kg/dm^3 in year one to 1.34 kg/dm^3 after 5 years. From a removal point of view the yield stress (a measure of the applied stress that must be exceeded in order to make a structured fluid flow) of the sludge is important. In the Dar es Salaam experiments this was found to increase from 58 Pascal in year one to 163 Pascal in year seven. By way of comparison the table below shows typical yield stresses for a range of common products:

Ketchup	15 Pa
Salad Dressing	30 Pa
Lithographic Ink	40 Pa
Mayonnaise	100 Pa
Skin Cream	110 Pa
Hair Gel	135 Pa

Over the course of time the nature of sludge in a properly performing anaerobic pit changes from being like thin mayonnaise to thick hair gel. The energy needed to pump thick hair gel is obviously far greater than that needed to pump thin mayonnaise and this characteristic has a huge impact on the capital cost and power requirement of an emptying device. Any designer of a new pit emptying device must aim at removing the dense waste at the bottom of a pit and not just the watery layer at the top.

According to Hawkins (1982), the hardest part of emptying is getting the sludge to move, after which it remains fluid, generally due to yield stress, shear thinning and thixotropy. A decrease in organic content also leads to a reduction of sludge fluidity. This implies that the fluidity of sludge decreases with time. Therefore the age of the pit contents may give an indication of sludge properties. One way to regain fluidity is to vigorously agitate the sludge either by mechanical means by rapidly pushing and extracting the pit contents under pressure. This second method is usually employed by vacuum tank owners and can cause pit collapse, particularly with unlined or poorly lined pits. When this does occur an argument usually follows about who is responsible for the collapse and who is going to pay for building a replacement latrine. Some tanker operators simply refuse to empty pit latrines. One area of current research is based on fluidising dense sludge using low pressure, high volume air water mix which, if successful, may lead to improved emptying devices.

One way of preventing sludge becoming too dense is to limit the time it spends in the pit by decreasing pit volumes and increasing the emptying frequencies. This reduces the capital cost of the latrine, but increases its annual operational cost. It is particularly difficult to achieve as the sludge accumulation rates are dependent on the number of users and diet. The aim in designing a pit emptying service would be to achieve a balance between pit size, emptying frequencies and capital and operational costs of the emptying devices. Smaller pits may be difficult to introduce within a community as they associate a larger pit with permanence and longevity, both key attributes for latrine designs.

The whole process of designing a pit emptying device is complicated by the fact that households use, in varying degrees, the latrine pit to dispose of solid waste. The four most commonly found items of solid waste are pieces of cloth used by women as sanitary towels, hair, condoms, and pieces of discarded plastic bag. All these have a tendency to wrap themselves around any moving part and cause the device to jam. Removal can be a very messy business.

There are local variations as to what is dumped down a pit latrine. In Dar es Salaam some pits fill with sand thought to have entered either through rain washing in sandy soil or women putting the result of sweeping the compound into the latrine. Sand is difficult to remove using mechanical means as it does not flow and is abrasive. In eThekwini in South Africa the amount of solid waste found down pits sometimes beggers belief with emptiers pulling out car tyres, scrap metal, prams, etc. and to date only manual emptiers seem capable of performing this task.

The usual method emptiers use to remove solid waste is to stir the sludge with a length of iron reinforcement bar with hooks attached. The hooks catch hold of the pieces of cloth and plastic and dragged up out of the pit through the squat hole. This removes much of the debris, but not all, and emptying devices need to be designed to cope with smaller pieces of solid waste.

<u>Hygiene considerations</u>
There are three elements to the hygienic removal of sludge from a pit; community health, family health and operator health.

The manual pit emptiers are known to tip the pit contents straight into the nearest drain or on to a piece of wasteland, indeed one form of manual emptying involves diverting flood waters at a time of heavy rain into the pit and using the water to flush out the pit contents. These practices are usually technically illegal under some public health regulation, although health officials rarely, if ever prosecute. Having pathogenic waste dumped in the middle of high density communities should be discouraged and in places like Vingunguti in Dar es Salaam, it is a practice probably contributing the presence of endemic cholera. The designers of urban sanitation technology chains should therefore only consider removing the pit waste from site to a place for treatment or transfer, even though this automatically means an increase in both the capital and running costs of the emptying equipment as some form of bulk transport system will be required. In Durban, South Africa in the lower density areas, the municipalities bury drier ecological waste on-site, but this is done in controlled circumstances and drier waste is easier to handle than wet sludge.

Family health is mainly related to spillage of pit waste during the emptying process and the cleanliness of the latrine after the latrine has been emptied. Spillage of waste in the compound must be avoided which means that the waste must be completely contained as it is transferred to the bulk transporter. The current methods used are either to carry the pit waste in 50 litre drums with tight fitting lids or transfer through a pressurized delivery hose. The operators in Dar es Salaam have learnt that cleaning the latrine after emptying is critical as to how the householder assesses the quality of the service. They have learnt to leave the latrine cleaner than when they started and to leave the strong of smell disinfectant. Smell is one of the key senses people use to assess cleanliness.

The process of emptying a pit always involves pushing a suction hose or a ridged plastic pipe into a pit. When these are withdrawn they will be covered in sludge and fresh feaces; it is unavoidable. The best method of protecting the operator in such circumstances is good personal protective equipment such as gloves, masks, overalls, and wellington boots. As with most PPE it tends to restrict movement and be uncomfortable to wear, particularly when it is 30°C in the shade. On a surprise visit to a pit empting site in Durban, all the operators who had been issued with good quality PPE, were found to have their masks perched on their foreheads, their overall tops tied around their waists and their gloves were nowhere to be seen. When recently emptying a pit latrine in Kampala using the Gulper, the sweat was dripping off the authors chin and his gloves and mask were quickly abandoned. It was not even hot outside and he is well aware of the health risks.

The messiest times which present the greatest health risks to the operator are during the actual pumping and cleaning processes when sludge can accidently leave the empting equipment. Most tanker operators can describe an incident where the tanker was put on 'blow' rather than 'suck', or when a coupling broke, resulting in pit waste being blown across the compound and covering the operator from head to foot. Such stories are usually told to loud roars of laughter. The more basic pit emptying devices, such as the Gulper, have a tendency to splash when sludge leaves the exit pipe and falls into the drum. Designers need to be aware of these problems and build solutions into their design.

Cleaning equipment after use is made messier by having to remove the sludge still present within the device. The best way is to allow the sludge to run back into the pit land the equipment should be designed so as to allow this to occur with minimum operator contact to the contaminated parts of the device.

The designer can assist the overall cleanliness of the process by avoiding the use of little screws or nuts and bolts which are virtually impossible to find under a layer of sludge and even harder to insert or remove. They are easily lost when laid down to rest on dirty latrine floors and screw threads tend to get clogged with particles of grit contained within the sludge. A better solution is to use bayonet fixing or simple locking devices. If anybody ever says "Don't worry, it will never unscrewed down the pit", do not believe them, it will and retrieval of important parts that have become mysteriously unattached down full pits is one of the most disgusting tasks of any profession anywhere.

Beyond these measures, the best defense again disease is simple good personal hygiene and regular hand washing with soap and water.

<u>Transporting the waste from the latrine to bulk transporter</u>
The designer should aim to keep pit waste covered and contained at all times whilst it is being transferred from the pit latrine to the bulk transporter. The two ways of doing this are either in a pipe where the waste is pushed to the bulk transporter under pressure or by hand carrying it in a fifty litre drum with a tight fitting lid. From a health perspective the risks are about the same, but from a 'disgust' perspective the piped approach will be considered to be more 'modern' and of higher quality.

Forcing waste through a pipe does how power implications and will escalate the cost of the emptying equipment. From a practical point of view drums are more labour intensive, but can be carried further and manually handled through narrower passageway and up steeper paths. The limit for a large tanker for pulling waste through a pipe from a pit latrine is around 60m, any further and problems occur with sludge settling and blocking the pipe. Cleaning and manual handling such a long pipe is problematic.

<u>Improving emptying efficiency by better design</u>
Engineers can become obsessed by the rate of discharge of a pit emptying device, but in most cases this only becomes an important factor when the demand for the service outstrips the capacity of the operator to provide the service. The most time consuming aspects of the pit emptying process are usually the time it takes to,

- transport the waste to the treatment plant
- travel to and find a customer's house
- set up the equipment before emptying
- clean the latrine after emptying

Whether it takes five minutes or fifty minutes to remove 500 litres of pit sludge does not usually impact on the number of households that can be served in one day. If the operators are on a fixed output rate for each pit emptied (which is advisable from a motivation point of view), faster emptying speeds do not reduce the overall labour costs and as many of the other costs are also fixed (such as fuel costs for transport and dumping charges) the difference made by decreasing actual pumping time is insignificant.

When a designer of a pit emptying device focuses on pumping capacity it tends to reinforce the decision to use a petrol engine as the power source. Designers should instead be concentrating on the overall pit emptying efficiency, which is the time taken to remove, transport and safely dispose of 1,000 litres of sludge from a pit latrine. When considering pit emptying in such a way it is found that efficiency is closely collated to haul distances pointing to the best way to improve efficiency is through optimizing unit transport costs, which in turn is related to the capital and revenue costs of the transportation vehicle.

A major decision the designer of a pit emptying device needs to make is whether to combine the pit emptying device and the sludge transport system into one inseparable system and create a miniature version of a larger vacuum tanker or whether the emptying device should be capable of working in dependently of the transport system. In the past, engineers have tended keep them together and to utilize the same power source for both the emptying device and drive power to the vehicle. The Vacutug and Dung buster in Ghana are examples of this type of design. By making this decision the designer automatically commits themselves to using a petrol engine as the power source and all the inherent problems and additional costs that petrol engines bring. By combining, the designer is placing a major financial hurdle to small scale entrepreneurs entering the pit emptying market.

The designer of the Vacutug tried to reduce capital costs by the ingenious use of a small Honda-type engine which he rightly argues are comparatively cheap and readily available in most cities. Such small engines have a limited power output and this resulted in the Vacutug only being able to travel at 5 km/hour. Whilst it could take the Vacutug ten minutes to remove sludge from a pit, it could take over an hour to take the sludge to the dumping site, which from a total emptying efficiency (see above) perspective, is poor.

<u>Transporting the waste to a treatment plants:</u>

Providing transport to move sludge from the pit latrine to a safe dumpsite is the greatest expense associated with any pit emptying business. It is the main area that a business needs to maximize when developing its business model as it can easily make the difference between profit and loss.

The capital and revenues costs of the transport are related to their carrying capacities, the haul distances and the speeds at which the vehicles can travel. The table below gives approximations of these factors for various types of sludge tankers in African cities.

	Capacity (litres)	Speed (km/hour)	Maximum range (kilometers)	Capital cost (S/H second hand)
Large tanker	10,000	60	100	$55, 000 (S/H)
Medium tanker	3,000	60	100	$40, 000 (S/H)
Small tanker	1,500	50	50	$30, 000 (S/H)
Motorbike tricycle	400	50	10	$3, 000 (new)
Hand Cart	130	2.5	1	$250 (new)

The best vehicle for any haulage business depends on the tasks involved and the demand for its services. If a business buys a vacuum tanker for emptying septic tanks and the average septic tank has a capacity of 3,000 litres, there would be little point in the business spending an additional $15,000 on buying a large tanker when its extra capacity would be rarely needed or used. If the emptying business obtained work to empty a 5000 litre tank, a medium sized tanker would simply have to make two trips and trade-off the extra fuel and maintenance costs against the savings in capital costs.

The fixed costs of running large and medium sized tankers are not significantly different with the only real differences being higher fuel consumption and spare part costs. The same principle applies to small engine powered tankers and running cost are not ten times cheaper for a 400 litre tanker than a 4000 litre tanker e.g. the drivers wages and tyre wear are roughly the same. This results in the unit costs of transporting one meter cube of sludge per mile (m^3/mile) being significantly lower for larger tankers than for smaller tankers. This is unfortunate as most pit latrine owners usually want relatively small quantities of sludge removing.

A major constraint when designing transporting sludge vehicle is the physical size of the vehicle. The passage ways and streets of some slum areas can be narrow, steep and full of obstructions making it impossible for a large or even a medium sized tanker to access the pit. Smaller vehicles have fewer problems than larger ones and it has been found in Dar es Salaam that a 1.2 m wide motorbike tricycle has no difficultly in parking relatively close to all the customers houses in the unplanned area of Temeke. In extreme cases such as the Central Urban Area of Antananarivo in Madagascar, or the slum areas of Jimma in Ethiopia where most of the houses can only be accessed on foot, any form of vehicle access is impossible. Sometimes the nearest road access can be 100 m up a steep narrow muddy path and even gaining access by walking can be awkward in the wet season.

It is worth mentioning here that the best way to reduce sludge transport cost is to bury the sludge on-site or at a place close to the household. This is the method used in Durban, South Africa and represents major savings in pit emptying costs. The main drawback with this approach is that suitable land within or around the house is not always available, it is hard to control and easy for operators to take short cuts and dump the waste into a nearby drainage channel. In addition, the surface of the dumping pit after it has been filled and covered with earth, tends to be very soft and a hazardous for anyone who walks across it.

In Dar es Salaam, the human powered Gulper provided the emptying capacity whilst a second hand Chinese motor-tricycle load carrier with a fixed 500 litre tank (locally called the Piki-piki) provided the means of getting the sludge to the dump site. The tricycle could travel at 50 km/h when fully laden which had the impact of more than making up for the losses in efficiency caused by the slow pumping speeds of the Gulper.

Such Chinese tricycles are now flooding into Africa and a new one can be purchased in Uganda for around \$3000. The mistake made in Dar es Salaam was to fix the tank permanently to the motor tricycle as this effectively limited the use of the motor-tricycle solely to pit emptying. If a removable tank has been installed, the operator could use the motor-tricycle as a general transporter and earn additional money to repay the bank loan by moving other goods. This led to the next iteration of sludge transportation which was to develop a system based on second hand 200 litre drums. These drums, originally used for transporting chemicals such as soap concentrate, are strong, durable, low cost (around \$25 each) and come with a tight fitting lid. For \$125 an operator can own 1m^3 of storage, a lot cheaper than a roto-molded the plastic tank. The main problem is lifting the drums on to the back of the motor-bike tricycle for which the solution being tried by Water for People is a simple winch based tail lift.

<u>Transfer tanks to minimize transport costs</u>
An engineering and logistics based solution to minimizing the transport cost is to use a transfer tank. "Let's put in a series of transfer tanks" is often heard, but easier said than done.

The principle behind wanting transfer tanks is that small transport vehicles (primary transporters), i.e. volumes less than 500 litres, are used to gain access to houses within the communities. When full, the operator takes the sludge to a nearby transfer station to dump the waste. When the transfer tank is full, larger tankers (secondary transporters) are used to take the sludge to the treatment plant. The transfer tank aggregates pit latrine sludge. Good in principle as it maximizes the lower unit carriage cost of larger tankers, but difficult in practice for the following reasons,

1. It entails ‘double handling’ the sludge which is generally regarded as inefficient as it requires two sets of loading and unloading actions and equipment, whereas taking the sludge directly to the treatment plant only requires one set of actions and equipment.
2. They take up space and land can be difficult to find and expensive to buy.
3. Nobody wants a transfer tank near their house and they think, probably correctly, that it will entail dirty, leaking tankers emptying and removing smelly sludge at all hours of the day and night. There will be strong local objection to any proposed location for a transfer tank.
4. The experience of solid waste transfer stations in Dar es Salaam shows that when the secondary collection systems breakdown a huge mountain of rotting waste soon develops. Tankers break, contracts are not paid, poor cash flow means no money for fuel, the driver get sick, other work gets priority etc. are all valid reasons for secondary transport failure.
5. Who is going to pay for the transfer tank? In theory it should be the city or the municipal authority, but in practice they have no money allocated for such infrastructure and even if they did, they would probably spend it rehabilitating or replacing their existing treatment plant which is usually operating beyond its capacity and design life. Some capital cities, like Kigali in Rwanda, do not even possess a central treatment plant and have instead a large hole on a land fill site into which the vacuum tankers discharge their waste. Why should they invest in transfer tanks when there is nowhere suitable to take the waste?
6. Who is going to manage the transfer tank? A poorly managed transfer tank may be worse than having no transfer tank at all. The current trend in African cities would be for the infrastructure to be owned by the city council and managed by a private sector operator who would collect fees from the primary collection operators for dumping their waste. From these fees they are expected to make a profit, and possibly pay the council a license fee to operate the tank. It would be difficult to find an operator with the capacity and interest in managing a network of transfer tanks, particularly with the problems of the economies of managing the tank and managing neighbour complaints. It’s a poisoned challis.
7. The economies of operating a transfer tank. A quick, back of the envelope, calculation over the potential profitably of managing a transfer tank are not encouraging. The table below is based on the current changes and costs for the pit emptying businesses in Dar es Salaam.

The economies of running a transfer tank		
Size of transfer tank	5000	litres
Average volune of sludge dumped by primary transporter	350	litres
Number of trips before transfer tank needed emptying	14.3	times
Dumping fees charged primary operators	$ 3.00	
Transfer tank manager Income from dumping fees	$ 42.86	
Cost of secondary transporter tor empty transfer tank	$ 60.00	
Income minus expenditure	**$ -17.14**	

The figures simply do not add up and it is unrealistic to think that a contractor would agree to run a transfer business based on these figures. This expenditure calculation does not include payment of a caretaker, any form of maintenance or the repayment of bank loans, so the possibility of commercial viability without government subsidies is very low. The dumping fee would have to rise to $6.50 in order for the management of a transfer tank to become attractive, but this rate would represent around 30% of pit emptying operator income from emptying a pit and have the negative impact of making their business unviable. It would also encourage operators to dump the waste illegally.

The only possible way a transfer process could become viable is by reducing the need for secondary transport and trying to change the sludge into something more valuable. The transfer tank should be regarded as the first stage of the treatment process which increases sludge density by removing water from the sludge. If 50% of the water could be safely removed and returned to the environment, a transfer tank could accept twice as many primary collection trips before it needed emptying and the commercial viability would begin to improve, as shown in the table below.

The economies of running a transfer tank			
Size of transfer tank		5000	litres
Average volune of sludge dumped by primary transporter		350	litres
Number of trips before transfer tank needed emptying		29.0	times
Dumping fees charged primary operators	$	3.00	
Transfer tank manager Income from dumping fees	$	87.00	
Cost of secondary transporter tor empty transfer tank	$	60.00	
Income minus expenditure	**$**	**27.00**	

Research needs to be undertaken on improving transfer tank design to enabling the decrease of sludge volumes by the removal of water, with the ultimate goal of entirely removing the need for secondary transport. At this point the plant becomes a micro treatment plant and not a transfer tank which simply holds and aggregates pit waste.

If the primary transport system delivers the pit waste in 200 litre plastic drums, there is no reason why they should be emptied into static tanks and it is more logical to continue using the plastic drums for temporary storage. Fifteen drums would be capable of storing $3m^3$ of pit waste and would cost around $375, a price a lot lower than the equivalent concrete structure. The drums have the advantage in that they can be stored virtually anywhere and the transfer station can become completely mobile and move to any convenient location. The drums can be loaded on to a large flatbed truck for secondary transport and do not need specialized vacuum tanker equipment for removal. This can reduce secondary transport cost by around 60%, a huge saving.

<u>Manufacturing constraints for pit emptying equipment</u>

The designer of urban pit emptying technologies has three basic options as to where and whom is going to manufacture their new product. Each has their own advantages and disadvantages.

1. Designed to be made by an engineering company in a more technical advanced country and shipped to the country where it is needed.

   This is the most favoured option for most northern based design engineers as the process offers few manufacturing constraints and allows the engineer to use a wide range of materials and components. If a design calls for a high degree of accuracy this can be achieve using laser cutters unavailable in most African countries. Northern based designs tend towards the higher end of the technology spectrum.
   Building pit emptying technologies in a more advanced country has a number of unforeseen disadvantages, mainly the cost of shipping escalating the purchase price. The Vacutug when in purchased ex works from the factory in Bangladesh cost $7,000. It cost another $2,000 to ship to Africa and then attracted 20% import duty, 17% VAT and 15% excise duty and in effect doubled its price, putting it beyond the reach of the average entrepreneur. Add to this a lot of incomprehensible paper work and trips to various clearing offices and the transaction costs soon become off putting to all but the most determined.

Spare part supply for the device can be a major problem as anything specialist will usually have to be imported from the manufacturer. In Uganda, some spare parts for the Ravi 4, a four wheel drive off-road vehicle, have to be imported from Dubai and can take 3 to 6 weeks to arrive. There are 1,000s of Ravi 4s on Uganda roads, yet no comprehensive spare part supply chain. The supply of a specialist part for an almost unique pit emptying vehicle would be very difficult to establish. By the time the spare part arrived and had been cleared through customs, the entrepreneur would be probably out of business as they cannot simply afford to have their most expensive piece of capital cost equipment out of action for longer than a few days.

There are also business related problems for northern based manufacturers. The demand for any device is probably going to be low so if ten are manufactured in one production run, they could easily be sitting in the their factory warehouse for the next nine months taking up valuable space and tying up their working capital. A better option would be to do a one-off production when an order was received, but this puts up costs and increased the delivery times. The manufacturer would also be concerned as to how they were going to get paid and would probably not agree to supply the device without a large deposit. “I want the cash in my account before sending anything out“ is how one UK manufacture recently summarized how they prefer to sell their machines to Africa. This lack of trust is reciprocated by African based entrepreneurs who would be reluctant to release large sums of money to an unknown company in a far-away country. They are rightly concerned about the lack of guarantees should the delivery fail and getting their money back.

2. Designed to be built by a more advanced engineering companies in the country (or region) where it is to be used.

   More advanced engineering companies can take some finding, but they do exist in most large cities in Africa. Such workshops contain a variety of welding equipment, lathes, pillar drills, grinders, folding presses, rolling machines, gear cutting equipment and milling machines. The equipment is usually old, very heavy, and well cared for by the owner who knows how difficult it would be to replace should it break. Health and safety standards can be a little lax and unprotected gearwheels and power cables held together with insulation tape are not unusual. The owners tend to have an enquiring nature and be interested in the challenge of developing innovative technologies as a lot of their work can be quite repetitive and boring such are skimming and re-skimming worn out brake drums. Such workshop owners normally agree to make a new device if they know an INGO or donor is going to pay for the work. However, once they realize that the suggestion is to develop a new product line for them to sell to an as yet un-established cohort of pit emptying entrepreneurs; their enthusiasm can rapidly drain away. They know NGOs and donors pay high rates with little risk over none payment. Trying to sell to price sensitive, cash strapped pit entrepreneurs looks uninviting in comparison. When a the owner of a large fabrication company in Kampala was approached to build and sell a motorbike based load carrier with an added tail lift to raise barrels on to the platform, he replied “I like the idea, but there is not enough demand for us to be interested” He knew his business and knew his customers and perhaps reiterated Paul Polak’s sentiments that there is more to technology development than building a better mousetrap. His fabrication business is probably one of the best in Uganda and has a good reputation with full order books. It is not logical for them to enter the time consuming process of developing and then producing a product for an unknown market. His refusal to enter the market means that the designer has to find an alternative supplier, which inevitably means going to the second best fabricator with poorer trained staff and poorer equipped workshops. If they refuse it means going to the third best and so on. The supply and development of new products targeted at the bottom of the pyramid is caught in a Catch 22; the better fabricators won’t enter the market until there is a proven demand and demand cannot be created until there are better products. This is the interesting boundary at which

Water for People has to function as they strive to make the markets work better for the poor and to develop new sustainable sanitation industries.

A solution currently being developed by Water for People's Business Development partners in Africa is to create and build a range of different sanitation technologies and brand them all as "Sanitation Solutions", which they own. They will control the supply chain and manufactures will make branded latrine components and sludge management equipment for them to sell via their website and sanitation entrepreneur business network.

The designers of urban sanitation technologies have to be cautious about using imported components. The best device should only use materials and components locally available and if an imported part is needed, it should be purchased through a recognized local supplier or agent as they will take all the hard work out of getting it into the country. Preferably it should be a standard stock item as they may be reluctant to import a one-off special.

3. Designed to be built by a road side fabricator

   There are many road side fabricators in Africa and what they lack in equipment, they make up for in enthusiasm. Unfortunately this tends not to be enough. A well-equipped road side fabricator would typically have a powered hand drill, a stick welder, an angle grinder, a tape measure, a big hammer, a large piece of RSJ to act as a bench and an over whelming confidence in their ability to construct anything you desire. They seem to survive mainly by making iron gates. If the design can be constructed from mild steel and can work to a tolerance of about 5mm, then this type of fabricator may be the most suitable. The device would be at the lower capital cost end of the market and would have to be simple to understand and reproduce. When such fabricators were asked to copy a Gulper, probably one of the simplest types of pit emptying device available, the results were terrible. The plastic pipes were of the poorest, cheapest quality and would not survive the rigors of pit emptying and the metal plate used in the valves was too thin and patched. Quality is a major issue even with low cost devices.

   The great advantage with this type of fabricator is that they are everywhere, even in the smallest towns and they are cheap.

Pit emptying equipment designers are caught between a rock and a hard place. The more complicated the design, the more difficult it will be to manufacture locally and set up supply chains, the more unlikely it will be to make it to the market and from a project perspective, the more unlikely to go to scale. However, the simpler the design, the harder it is to make it effective at removing dense sludge and more difficult to control quality.
An engineer's task is not just to design a pit emptying device, but to design one which takes out dense sludge <u>and</u> is capable of local a manufacture without the use of imported components or without components made by specialized machinery.

As a general rule, design engineers need to really dumb down their devices so they are simple to understand and construct. This means they have to move away from what appears to be a natural tendency to over complicate and embellish. The real need in engineering innovation may lie within simplifying component construction methods as opposed to actually designing new devices. For example, is it possible to make a three way valve to allow the sucking and blowing of air and sludge from components that can be found in a local plumbers merchant or hardware store? Such three way valves are available through agricultural suppliers of milking machines in the UK or US, but unavailable in most African cities.

Maintenance constraints for pit emptying equipment

The capacity or desire to undertake maintenance is linked to the business model. In Pakistan in the 1990s, a local mechanic told the author "Give a car to a Pakistani organization and it will last for 15 months, give one to a Pakistani and it will last for 15 years". The owner operator models described in the first section should all engender a stronger sense of ownership and responsibility for any equipment, which in turn should ensure basic routine maintenance is undertaken. The higher level franchiser model should be able to build in technicians whose role it is to undertake the routine maintenance as part of the loan arrangement.

The main factors the designers have to ensure are that any repairs can be carried out quickly, cheaply and locally. All the time a device is broken, it cannot be used to earn the operator an income. This means the best devices have a non-reliance on imported or difficult to source components, use none specialist repair equipment and are simple to understand. When a piece of equipment breaks the operator will not take it back to the original supplier, but instead will approach a local mechanic, who he regards as knowledgeable, to try and repair the device. If the repair is simple the local mechanic may be able to cope and perform a reasonable job, if it is complicated and the functioning of the machine hard to understand, he is equally likely to make matters worse and further damage the device. Repair manuals are usually lost and never read.

The designer should be constantly asking "When this breaks, how will it be replaced?"

A well run business would put money to one side to be spent on repairs and maintenance. This requires fiscal discipline and a good accounts system, both of which can be hard to find in the informal sanitation sector. There are likely to be many demands on any income an operator earns as they are likely to have many dependents and large extended families.

As a general rule of thumb, no single component or repair should cost more than 10% of the purchase price of a new complete device, and the repair should take no longer than one day to complete.

Conclusion and design Trade-offs

Just as there is no such thing as the perfect car, there is no such thing as the perfect pit emptying device. Different operators and different business models require different solutions. With urban sanitation chain technologies there is room for very simple low cost human powered devices at one end of the spectrum and more complicated fossil fuel powered devices at the other end. It is the role of the market development organizations to make sure that a wide range of different pit emptying and urban sanitation chain devices are available to any entrepreneurs wanting to enter the sanitation market. It is not their role to dictate to the entrepreneurs what they can or cannot have or what they can or cannot do to make a profit. It is envisaged an entrepreneur setting out in the emptying business may start with simple low cost devices and as they get to know their customers and the demand for their services, upgrade to more expensive technically advance machines.

As the entrepreneur will be buying, maintaining and using any new sanitation technology, it is their decision to decide which best suits their needs and pockets. The main question they will be asking is "What extra value to my business does machine 'x' provide and is it worth the additional 'y' dollars'. They are the ones whose value judgment really counts and they will decide what trade-offs to make. It is up to the product designer and the market development organizations to understand their needs and to design better, cheaper urban sanitation technologies that better meet their anticipated needs and desires.

If the designer better understand the needs of the customers who will be buying their new device and the constraints within the market in which they operate, they should be able to design more appropriate devices. Compromises will have to be made, but it is better to make these compromises based on a sound knowledge of the market, than on uninformed subjective opinions and the latest CNN reports.