Eawag
Überlandstrasse 133
P.O. Box 611
8600 Dübendorf
Switzerland
Phone +41 (0)44 823 55 11
Fax +41 (0)44 823 50 28
www.eawag.ch

Assessing the Costs of on-Site Sanitation Facilities

Study Report

Lukas Ulrich, Prit Salian, Caroline Saul, Stefan Jüstrich & Christoph Lüthi

March 2016

Contents

Assessing the Costs of on-Site Sanitation Facilities

Study Report by

Lukas Ulrich, Prit Salian, Caroline Saul, Stefan Jüstrich & Christoph Lüthi

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

eawag
aquatic research

Sandec
Sanitation, Water and
Solid Waste for Development

This report was published under the Eawag research program **'Wings'** (Water and sanitation innovations for non-grid solutions). Wings is an inter- and transdisciplinary strategic research program that strives to develop novel non-grid-connected water and sanitation systems that can function as comparable alternatives to network based systems.

This research was funded by the Swiss Agency for Development and Cooperation (SDC) and Eawag, the Swiss Federal Institute of Aquatic Science and Technology.

Please cite as:

Ulrich *et al,* 2016. Assessing the Costs of on-Site Sanitation Facilities, Study Report by Eawag-Sandec, Sanitation, Water and Solid Waste for Development, Dübendorf, Switzerland.

1. Summary

Why are sanitation facilities like ventilated improved pit (VIP) latrines and other dry toilets so much more expensive in sub-Saharan Africa than in Asia? This report compiles the findings of a multi-country study comparing costs of on-site sanitation infrastructure in Asia and sub-Saharan Africa. It attempts to provide answers to the question why hardware costs for on-site sanitation are so much higher in Sub-Saharan Africa than in Asia and examines the main factors that lead to these high costs. The report specifically looks at the capital costs of household-level, on-site sanitation technologies which are prevalent in most cities and rural areas of Africa and Asia. The report does not attempt to quantify software costs (e.g. public support to promote sanitation coverage and create demand).

Engineers and project managers struggle to provide site-specific cost estimates that allow for sound technology decision-making and budget planning in sanitation programming. Estimating capital and operational infrastructure costs is not easy, especially considering all the context-specific and variable factors that determine the total costs. It is notoriously difficult to compare costs of different sanitation facilities as these facilities can be built in different sizes and using different technologies, depending on the number of people they are designed to serve and the level of service they are designed to provide. The authors have decided to focus on the two most widespread on-site technologies found in low-income urban contexts: the VIP latrine and the single pit latrine. This multi-country comparative assessment analyses data obtained from Sandec's field research between 2012 and 2015 as well as data on the costs of on-site sanitation infrastructure found in related literature. As an output of this study, a simple and adaptable bill of quantities (BoQ) based costing tool was developed (see chapter 3.3.1).

This report provides a detailed analysis of the reasons for cost differences between the countries studied. It also gives specific and field-tested recommendations on how the problem of high costs can be addressed (including prefabrication to increase productivity and decrease construction time, the development and use of material alternatives, as well as financing mechanisms like microcredits and subsidies).

The following points highlight the main findings of the study:

- For the on-site toilet technologies analysed, African sanitation facilities are on average three times more expensive than Asian examples, due to the high material costs (esp. cement and bricks), lack of prefabricated or mass produced toilet components (which are common in Asia), and the informality of the construction sector dominated by micro-entrepreneurs.
- Costs of the analysed on-site options (VIP latrines and lined single pit latrines) are greater than households' willingness to pay in urban sub-Saharan Africa and financing mechanisms like public subsidies will be required if substantial progress is to be made in sanitation uptake.
- Labour costs are very low: less than a third of the overall toilet costs both in Africa and Asia are labour costs, reflecting the low remuneration in the informal building sector.
- Conversely, high material costs (ranging from 55% to 86% of total hardware costs) are the common feature of all on-site sanitation technologies analysed in this study. Therefore, efforts to lower on-site facility costs must focus on material costs, not labour inputs.
- As most sanitation facilities in Africa's low-income areas are built as outhouse structures, the cost of a durable superstructure constitutes about a third of the overall toilet cost.
- Due to difficult accessibility of informal settlements, transport costs can also significantly increase costs by 5% to 7% of overall capital expenditure.
- A further reason for the high toilet costs is the information asymmetry in sanitation services: because there are no standard toilet designs and the construction sector is informally organised, clients (mainly landlords) find it difficult to make informed market-based decisions.

2. Introduction

Low ability and willingness to pay are among the main reasons why access to adequate sanitation infrastructure remains low in both rural and urban areas of low and middle-income countries. In Uganda's capital Kampala, for instance, a ventilated improved pit (VIP) toilet costs over USD 500[1], which is equal to the average annual income of a slum dweller (Günther *et al.* 2011). Are people willing to acquire improved sanitation facilities even if they are so expensive? A detailed analysis of the willingness to pay (WTP) for improved sanitation in Kampala (Horst 2015, survey conducted in 2010) revealed that the stated demand or willingness to pay was much lower than the actual market price of improved sanitation facilities (The mean WTP is about 25% of the market price for an improved VIP toilet as built by the U-ACT project). This finding excludes owners with existing improved access to a sanitation facility (16% of the sample) (Fig. 2-1). The Kampala case is characteristic for the challenges in sub-Saharan Africa, where a clear mismatch between the willingness to pay and the market price for improved sanitation hardware results in the widespread use of sub-standard simple pit latrines (Figure 2-2).

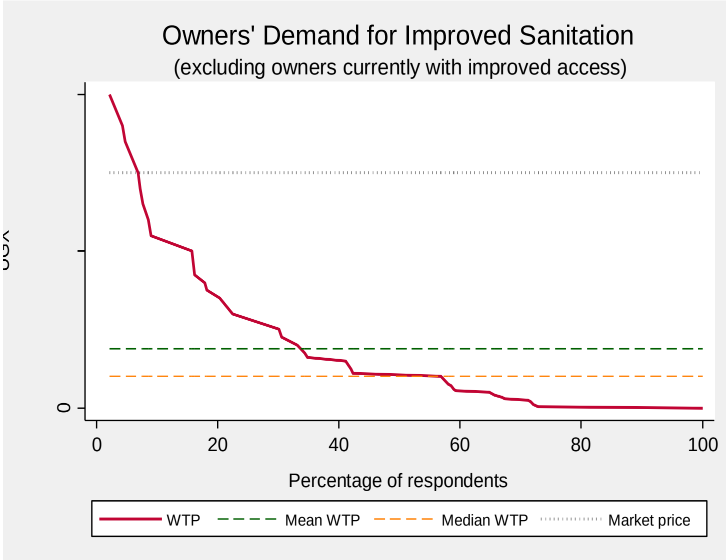


Figure 2-1: Willingness to pay for a new sanitation facility for landlords in Kampala. Source: Horst, A. (2015)

Figure 2: Sub-standard pit latrine in Kampala, Uganda.

The urban poor in Kampala currently need to spend their annual per capita income to own an improved VIP toilet (Günther *et al*., 2011). A simple VIP latrine with a 3 m deep pit costs between US$ 400 (unlined pit) to US$ 800 (lined pit) in informal settlement areas. To obtain a depth of 3 m in high water table areas, the pit has to be elevated, adding further construction costs.

Asia, however, reveals a different situation with sanitation infrastructure components often available at relatively low prices and thus within the means of poorer households. A frequently cited example of low-cost toilets comes from rural Bangladesh: after a social mobilisation campaign in the mid-1990s, the demand for toilets rose considerably. Since then, thousands of small private workshops sell latrines (pan, slab and rings) for less than US$ 100 (BRAC & IRC, 2015, Heierli et al. 2011, Sijbesma 2008).

This report aims to take a closer look at the striking cost differences for sanitation hardware between Sub-Saharan Africa and Asia as revealed by the Uganda and Bangladesh comparison. In order to analyse the reasons behind the regional variations of costs, the study aims to identify the factors determining the capital costs of specific on-site sanitation options in different African and Asian

[1] 2011 exchange rate

countries. The comparative assessment includes field data and literature from Bangladesh, Nepal, India, Kenya, Tanzania and Uganda. Finally, practical solutions how the prohibitive costs of household-level sanitation infrastructure (particularly in sub-Saharan Africa) could be reduced are proposed based on the findings. This includes an evaluation of the potential of non-conventional construction materials, but also the exploration whether some of the experiences from Asia can be transferred.

3. Methods

This multi-country comparative assessment analyses data obtained from Sandec's field research between 2012 and 2015 as well as data on the costs of on-site sanitation infrastructure found in related literature.

For the comparative costing study of on-site technologies three focus countries were selected based on the availability of data and the experience from previous Sandec projects: Nepal, Uganda and some cost data available from a case study in Mauritania was also used. A large amount of cost figures and existing bills of quantities were compared from the focus countries to analyse and compare the different cost factors.

3.1. Comparing the cost of on-site sanitation facilities across countries

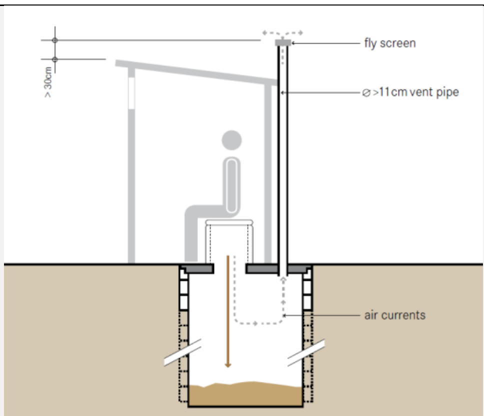
3.1.1. Ensuring comparability

This study does not include a cost comparison across technologies (e.g. VIP vs. septic tank), because different technologies may provide different levels of service. The focus of the comparative assessment is on different contexts in which a given technology is used (e.g. VIP in a sub-Saharan vs. Asian country). This report does not aim to compare the costs of different sanitation system alternatives. The costs in different contexts can only be compared if the same system boundaries are used. Differences in the underlying conditions and cost calculations are analysed and taken into consideration. The fact that different materials have different lifetimes also has to be taken into consideration. For costs to be comparable, they have to be related to a specific facility performing during a defined time span for a given number of users.

3.1.2. Selection of technologies

In order to be able to compare technologies across continents and different countries, two common on-site sanitation technologies were chosen: the ventilated improved pit toilet (**VIP latrine**) and urine-diverting dehydration toilets (UDDTs**).** Both are well known and popular sanitation technologies in all of the study countries. The single VIP toilet (U.1 and S.3 in the Compendium, see Tilley *et al.* 2014) is appropriate for arid and water scarce contexts and works in rural and medium dense peri-urban contexts. dehydration vaults (U.2 and S.7 in the Compendium) is also a dry toilet technology well adapted to water scarce environments and has the advantage that the dehydrated faeces can be self-emptied and the risk of groundwater pollution is low.

Figure 3-1 below explains the main features of the two of the technologies compared in this study.



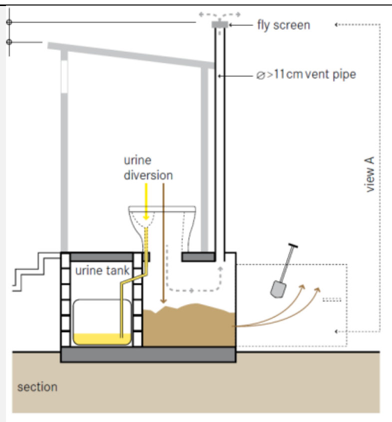
VIP toilet (S.3)

Main advantages

+ flies & odours are significantly reduced
+ can be built and repaired with locally available materials
+ small land area required

Main disadvantages

- low reduction in BOD and pathogens with possible contamination of groundwater
- costs to empty may be significant compared to capital costs
- sludge requires secondary treatment and/or appropriate discharge



Dehydration Vaults (S.7)

Main advantages

+ simple and robust technology
+ can be built with locally available materials
+ no or low operating costs if self-emptied
+ requires training and acceptance to be used correctly

Main disadvantages

- requires constant source of cover material like ash
- manual removal of dried faeces is required

Figure 3-1**:** main features of VIP latrines (left) and dehydration vaults (right)

3.2. Cost items included in the country comparison

An integrated economic analysis needs to take into account the costs occurring during the entire life cycle of a facility (see Figure 3-2). Since the present study looks at the differences in hardware costs across countries, the focus is on capital expenditures only (one-time upfront investment costs). However, related life cycle cost are also discussed where applicable (e.g. implications of material choice on operation and maintenance (O&M) requirements or expected lifetime). Especially when analysing the cost reduction potential, not only material costs and expected lifetimes should be taken into consideration but the entire life cycle costs, including O&M expenditures.

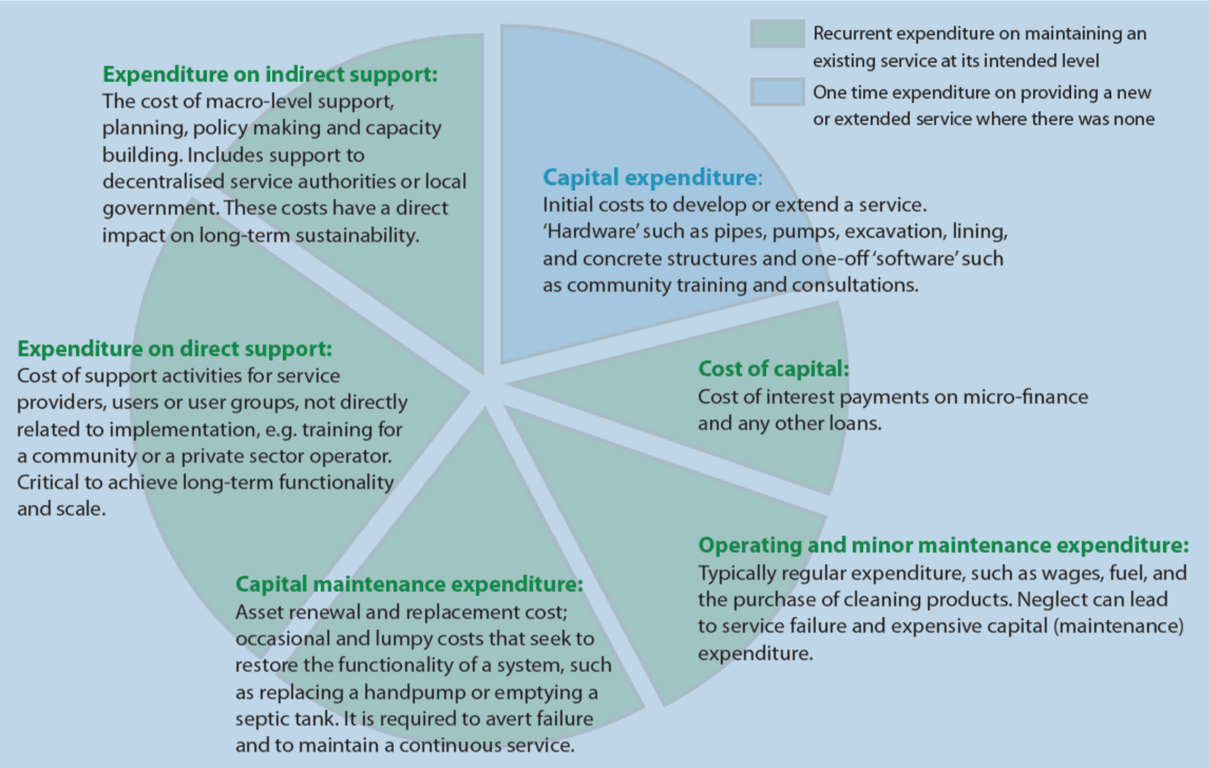


Figure 3-2: Life cycle cost of providing a sustainable level of service (Source: Fonseca et al. 2011)

Capital expenditure includes all costs that accrue during the construction phase of a sanitation facility, namely:

i. Material cost = material rates x material quantities + transport cost
ii. Labour cost = labour rates x labour quantities
iii. Land cost
iv. Cost of planning and construction supervision, etc.

iii. and iv. are in grey because they are usually less of interest for on-site sanitation infrastructure and are excluded from this study for the following reasons:

- Costs for land acquisition are site-specific and in most cases the person commissioning an on-site sanitation facility already owns the land.
- Planning and supervision costs are not commonly documented for on-site facilities because
  - either not much planning is involved for simple designs and supervision is managed by the builder or client (e.g. VIP toilet),
  - or it is part of a building contract and difficult to allocate separately (e.g. septic tank).

3.3. Data collection and analysis

After analysing existing costing tools developed by different organisations (e.g. WASHCost by IRC, the CLARA simplified planning tool or the Economics of Sanitation Initiative (ESI) Toolkit) the authors decided to focus on a detailed sanitation technology cost analysis based on disaggregated cost data collected from implemented sanitations projects. However, getting access to reliable and comparable data across different countries proved to be one of the most difficult endeavours of this study. Data is often very specific to one project or context, and material and labour costs are not documented in detail (lump sum aggregate rather than unit rates and quantities for individual components), making it difficult to analyse the various costs.

3.3.1. Development of a bill of quantities (BoQ) based model for cost estimation

Data availability is still a key constraint for practitioners aiming to develop reliable cost estimates and budgets for decision-making regarding the construction and operation of sanitation and wastewater infrastructure. This is of particular relevance for non-conventional sanitation technologies that are not widely known and used. With the goal to contribute to closing this gap, Sandec proposed the development of a BoQ-based sanitation costing Excel tool, which will be featured as part of the CLUES toolbox as a tool for obtaining realistic technology-specific cost estimates. Eawag-Sandec initiated the collection of cost data for sanitation technologies from its own projects as well as through implementing partners willing to share their BoQs. Key challenges encountered in this endeavour were: i) collected designs are often project-specific (e.g. from small-scale pilots with special designs) and highly variable and therefore difficult to standardize or use in other contexts, ii) the BoQs provided by third-party sector organisations often lack the corresponding metadata (design information, drawings and pictures). The BoQ approach has its limitations, particularly for the more complex technologies where the BoQ depends on the design approach and more complex dimensioning. For a relatively accurate estimate of the cost of on-site sanitation technologies, however, it proves to be the best approach. Due to these difficulties the further development of this tool and further data collection will remain an ongoing task in the coming years. An automated, easy-to-use and transparent Excel template has been developed, where data can be filled in easily and new technologies and designs added in a continuous process. The use of this template will help to make further data collection more easy and systematic.

The Excel tool runs without macros in order to reduce the security risk and make it more robust. It was designed to compare the cost of two models (design alternatives) and comes with default categories, components and units. These can be easily modified by the user for any context. Furthermore, if one wants to analyse the cost in a different currency or if the exchange rate has changed, this can be done with little effort, even retrospectively.

By assigning items to (i) categories (such as material, labour, transport, etc.) and (ii) components (e.g. superstructure, substructure or user interface), it allows the user to get a detailed overview on the different cost items. An automatic graphical representation of the cost shares according to the categories and components in the form of pie charts (Fig. 3-3) simplifies the identification of cost drivers. The comparison of two different models (designs) in the form of column charts (Fig. 3-4) facilitates the selection of the economically more suitable system.

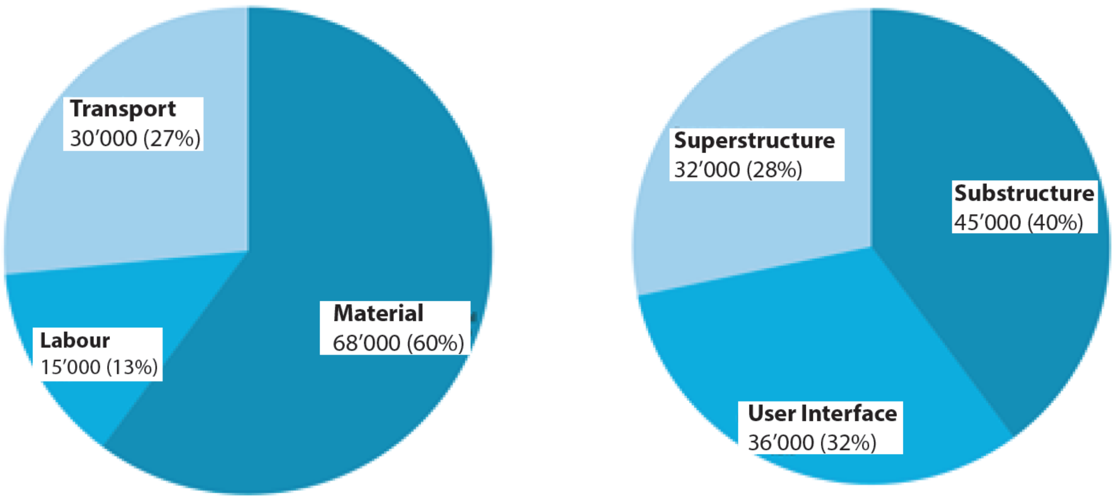
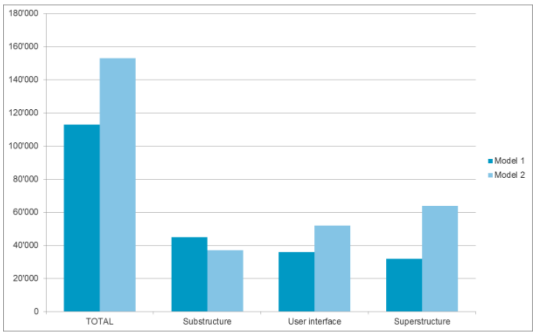


Figure 3-3: Visualisation of cost shares in the Excel template according to expenditure categories (left) and building components (right). Categories and components can be defined by the user.



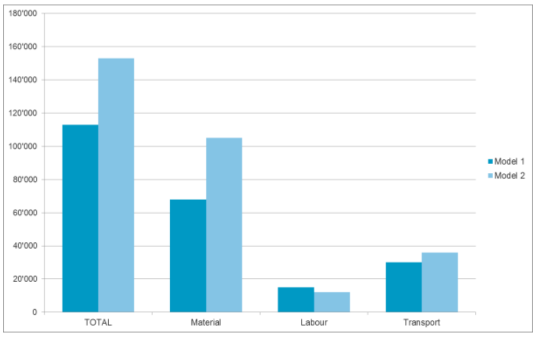


Figure 3-4**:** The Excel template offers easy comparison of two different design alternatives (models) according to expenditure categories (left) and building components (right).

Possible future developments of the tool include the compilation of widespread design data for key sanitation technologies into typical (or even standardized) BoQs. Such a tool could then be used by decision-makers and planners to obtain substantiated and informed cost estimates by simply making context-specific adaptations (e.g. of the types and quantities of materials to be used) and entering local unit rates.

4. Results

Detailed cost data from ten different dry toilet case studies was analysed from Bangladesh, Nepal, India, Kenya, Tanzania and Uganda. Technologies included: Single VIPs, UDDT, lined single pits and Fossa Alterna. For reasons of space, detailed costs for only four of these toilets are presented on page 15. The results of the analysis of costs of those different dry toilet case studies in Africa and Asia reveals the following findings:

i. On average the cost of the five toilets analysed in Africa was **US$ 423** (ranging from US$ 172 to 783) (these included two VIPs from Uganda and Tanzania, a Fossa Alterna and UUDT from Tanzania and a lined single pit latrine from Kenya). The average cost of the five on-site toilets in Asia was **US$ 141** (ranging from US$ 40 to 280) (the Asian toilets compared included two single pit pour flush toilets from Nepal, two UDDTs from India and Nepal and a single pit lined pour flush toilet from Bangladesh) This means that on average African on-site toilets were **three times** more expensive than the cost of Asian on-site toilets.

ii. The average labour costs amounted to 31%, these costs were slightly higher in Asia (34,7%) than in Africa (28,5%).

iii. All of the 10 toilets were outhouse toilets with purpose-built superstructures (except one example from Nepal without a superstructure). The superstructure is a significant cost factor, albeit one with big variations. It was not possible to evaluate the superstructure cost for all technologies, but for the four technologies where it was possible, it represented 34% of the overall toilet cost.

4.1. Key factors that determine local costs

Figure 4-1 below provides an overview of the different cost factors that were found to be influential on the capital expenditure for an on-site sanitation facility, i.e. material and labour cost. Those influences are either direct or indirect, as shown by the different arrows. The key cost factors are described in the following paragraphs.

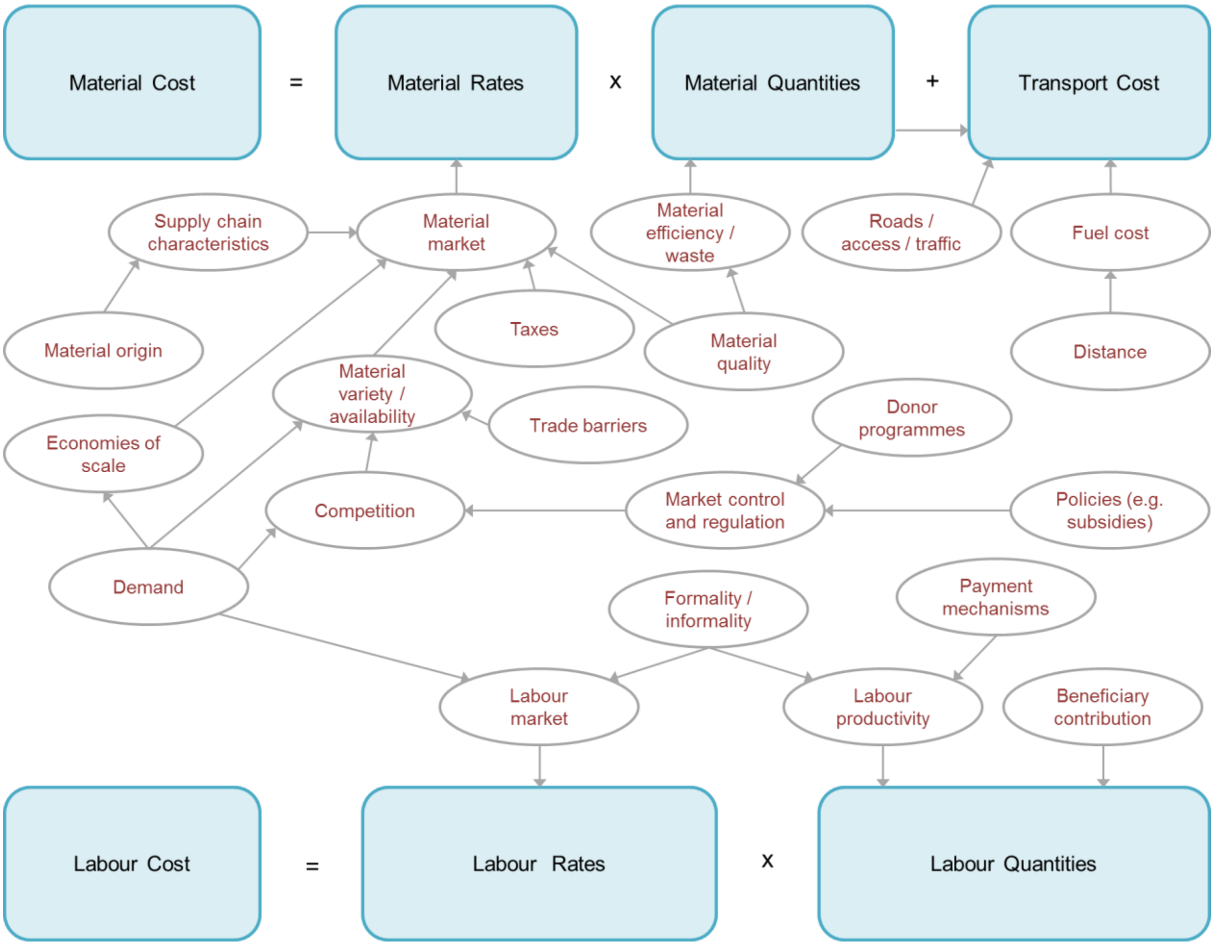


Figure 4-1: Cost factors (oval shapes) influencing material and labour costs of on-site sanitation facilities. The arrows represent key influences.

4.1.1.Material market

Markets are complex systems that are influenced by numerous factors. Material prices are determined by market structures and regulations (e.g. taxes), programmes and policies of governments and donors (e.g. subsidies), as well as properties of supply chains and distribution channels (e.g. production sites and processes, transport). Sanitation markets in Africa and Asia are very fragmented and there is no real competition at local (neighbourhood) scale.

4.1.1.Quality of material and resulting material efficiency

The quality of material has a large influence on the required construction time and the quantity of material required. For example, across most parts of Sub-Saharan Africa the basic quality of bricks is extremely poor because they are poorly manufactured either on-site or in nearby make-shift kilns. This results in bricks crumbling before being touched by the mason. In addition, the mason applies a larger layer of mortar, sometimes as thick as 2-3 cm in order to cover up the inconstancies and to get the level, shape and size of the wall right. This process leads to a 15-20% (if not more) increase in sand and cement (both relatively expensive materials) as well as labour time required to construct a wall. In Asia, the quality of materials available is typically considerably better, which also contributes to lower cost.

4.1.2. Roads / accessibility / traffic

In large metropolitan areas, transport costs can be a considerable cost factor, mainly due to heavy traffic congestion and poor accessibility. Building sanitation facilities in dense slums without proper road access means that bulky materials need to transported manually or by hand cart to the construction site (and transporting away the earth from pit excavations). Materials are prone to theft and therefore require supervision by watchmen, or only small quantities can be stored on-site, basically what can be built during one working day. For this reason, transportation costs in informal settlements can vary between 4% to 7% of overall construction costs (Lüthi et al, 2013)

4.1.3. Labour market

Most small-scale entrepreneurs active in latrine construction can be considered as micro-entrepreneurs belonging to the urban informal sector. Masons will try to maximize the building time to cover all non-core activities and to increase their income and, therefore, there is no real incentive to improve efficiency and productivity – building a toilet in less time would mean less remuneration. Small-scale entrepreneurs are risk averse and latrine construction is usually a secondary business line next to house construction or improvements.

4.1.4. Labour productivity

The most commonly used measure of labour productivity is hours worked in relation to output. However, there are limitations to comparing labour productivity across countries[2]. The factors affecting labour productivity are of broadly the same type as those that affect the performance of manufacturing firms as a whole. They include: (1) physical location, and technological factors; (2) motivational and behavioural factors; (3) managerial-organizational and wider economic and political-legal environments; (4) individual rewards and payment systems, and (5) lack of professional training of masons, plumbers, etc. Due to the low skills base and poor remuneration, labour productivity in the cases studied in Sub-Saharan Africa was lower than in Asia featuring longer construction times. The lack of professional training for masons, plumbers, etc. largely inhabits productivity. In most low-income countries, the primary reason for the lack of a skilled labour force can also be attributed to the non-existence of technical vocational training institutes.

4.2. Cost analysis across countries

4.2.1. Local design differences

Local design requirements and preferences are key factors that explain the high diversity of on-site latrine designs and varying costs. In order for a system to function properly, its technical parameters have to meet the requirements of the specific socio-cultural and physical context (e.g. preference of sitting or squatting user interface, watertight construction for wet and flood-prone areas). Such special local design requirements also need to be taken into account as they can have a significant impact on the costs. Toilet technology also differs greatly across countries. Recent innovations in Bangladesh involving the national NGO BRAC and private sector suppliers show that affordable on-site technology that encompasses the entire supply chain is possible. The standard BRAC toilet design includes a

[2] The validity of international comparisons of labour productivity can be limited by a number of measurement issues. The comparability of output measures can be negatively affected by the use of different valuations, which define the inclusion of taxes, margins, and costs, or different deflation indexes, which turn current output into constant output. Labour input can be biased by different methods used to estimate average hours or different methodologies used to estimate employed persons. In addition, for level comparisons of labour productivity, output needs to be converted into a common currency. The preferred conversion factors are Purchasing Power Parities, but their accuracy can be negatively influenced by the limited representativeness of the goods and services compared and different aggregation methods (Wikipedia 2014).

pour-flush toilet squat pan with two alternating off-set pits which use prefabricated concrete rings for lining the pits (see Fig. 4-2). This on-site solution provides for a higher level of hygiene and comfort, thanks to the water seal. The toilet can also be built and repaired using locally available materials. Concrete rings are the preferred material for lining the toilet pit. On average, five concrete rings were used per pit. The majority of the superstructures are made of durable materials. However, the ultra-poor and poor also use traditional non-durable materials such as thatch and bamboo. Toilet prices vary greatly between US$ 15 (single pit with simple superstructure) to US$ 130 (double pit) and the average amount households spend on their sanitation facility is Taka 6,850, which amounts to US$ 90 (BRAC and IRC, 2015). The cost differences can be explained by the amount of cement rings installed and the varying quality of the superstructure.

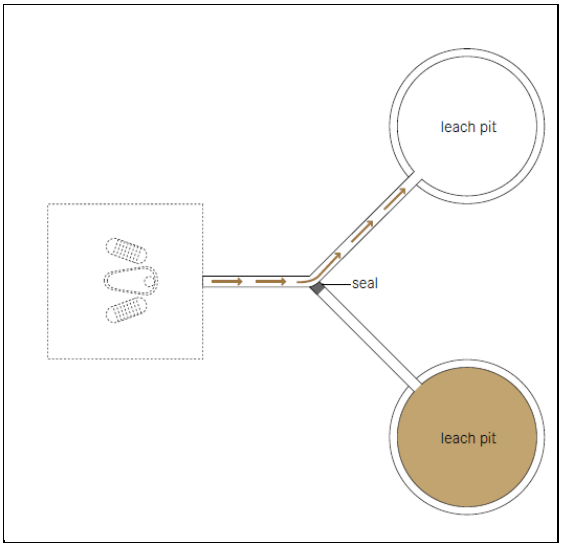


Figure 4-2: Twin pit for pour flush technology used in Bangladesh.

Most ultra-poor and poor households will find it difficult to construct the types of hygienic toilets promoted by BRAC without financial support. BRAC provides ultra-poor households with an in-kind grant, which covers the costs of a complete set of toilet parts for a double off-set pit (Fig. 4-3). It does not, however, cover all the costs associated with installing a toilet (e.g. labour or transport). Poor households receive an interest free loan from BRAC, which covers part of the costs. The ultra-poor spent an average Taka 1,500 (US$ 20) on top of the grant received (BRAC and IRC, 2015).

This case study from Bangladesh exemplifies the large cost implications that different design alternatives can have, even within one contextual setup and technology option. The design alternative with prefabricated concrete rings for pit lining which is widespread in Bangladesh is rarely found in sub-Saharan Africa. This is not because the local environment would not permit for such a design; rather, this design alternative is not widely known and corresponding material, prefabrication and retail supply and service chains are lacking.

Figure 4-3: Owner of a hardware store in Bangladesh presenting various latrine components (© Ingeborg Krukkert/IRC)

4.2.2. Cost breakdown: material vs. labour costs

High material costs (ranging from 53% to 86% of total costs) are the common feature of all on-site sanitation technologies analysed in this study. This is in accordance with other large-scale sanitation programmes recently finalised, e.g. a sanitation project in rural India started in 2009 (7,000 twin soak pits including superstructure with a cost of USD 184 per unit), where materials accounted for 76% of the total cost. The main cost factors were key material inputs (sand, cement, aggregate, bricks) (accounting for 53% of the total cost), followed by the door (11%), the roof (6%), the toilet seat (3%), and pipes, plumbing and vent pipes (3%) (Graf *et al*. 2014).

In another project, 61,000 flush toilets, composed of a squat pan and a slab without pit lining, were installed in rural Cambodia (Table 4-1).

	US$	**%**
Input material	27.50	56
Labour	5.00	10
Transport & delivery	4.00	8
Manufacturer’s margin	10.00	20
Sale agent’s margin	1.63	3
Micro finance institute	1.00	2
Total	**49.13**	**100**

Table 4-1**:** Cost breakdown of rural toilets in Cambodia (Source: Graf *et al.* 2014)

Material costs are highest in landlocked countries like Uganda and Nepal, where the price of cement is usually a key cost factor. In Uganda for example one cement bag (40 kg) costs UGX 28,000 (wholesale sellers) to 30,000 (USD 12) (retail sellers).

Surprisingly, labour costs are extremely low: less than a fifth of the overall toilet costs both in Africa and Asia are labour costs, reflecting the low remuneration in the informal building sector. In the above mentioned example in rural India, labour accounted for only 22% of the total cost.

Figure 4-4: Comparison of material and labour costs of four dry toilets in Africa and Asia

Sanergy Toilet (Nairobi) (2014)

Nr	Item	Cost KSHs	US$	%
1	Material Costs	23440	246.74	55%
2	Labour costs installation (9 man-days)	6027	63.44	14%
3	Sanergy management	6214	65.41	15%
4	Transport costs	6728	70.82	16%
		42409	**446.41**	**100%**

UDDT Dry Toilet with bucket system with pre-fab cement superstructure

1US$ = KSH 95

U-ACT VIP Toilets (Kampala) (2013)

Nr	Item	Cost UGXs	US$	%
1	Material Costs	1695000	676.38	86%
2	Labour costs construction (15 man-days)	290000	94.31	12%
3	Transport costs	40000	13.01	2%
		2'025'000	**783.69**	**100%**

Single VIP toilet with lined 3m^3 pit volume & handwashing unit

1US$ = UGX 2506

Pour flush toilet with leach pit (Nala, Nepal) (2015)

Nr	Item	Cost NPR	US$	%
1	Material Costs	20'000	200.00	71%
2	Labour costs construction (10 man-days)	6'000	60.00	21%
3	Transport costs	2'000	20.00	8%
		28'000	**280.00**	**100%**

Single pour flush toilet with offsetunlined leach pit, 1 m pipe and brick superstructure

1US$ = 100 NPRs

Pour flush toilet with leach pit* (Surkhet District, Nepal)

Nr	Item	Cost NPR	US$	%
1	Material Costs	7'931	79.30	52,5%
2	Labour costs construction (4,5 man-days)	7'175	71.70	47,5%
		15'106	**151.00**	**100%**

Single pit with off-set pan
* does not include costs for superstructure

1US$ = 100 NPRs

The comparison between the two on-site technologies in East Africa (the single urine diverting dry toilet from Sanergy, Nairobi and the single VIP toilet with a lined pit built by U-ACT in Kampala) exemplifies the high costs involved in building new sanitation facilities. The U-ACT toilet is 43% more expensive than the Sanergy toilet due to the lined pit and on-site high-end finish of the superstructure. Sanergy has been investing a lot in producing pre-fabricated elements that ensure a quick installation time (two days) as well as material savings (see Fig. 4-5 below). Important to note is that the operational costs of the Sanergy toilet are significantly higher, due to the daily emptying by a service team.

The two examples from Nepal show that labour costs are slightly higher than in the African examples, even though Nepal is a landlocked country with relatively high cement prices. The single pit toilet built in Nala, Nepal is more than 2.5 times cheaper than the toilet example from Kampala priced at USD 783, although it has to be noted that the design in Nala did not have a pit lining.

Fig 4-5: Sanergy prefabrication workshop in Mukuru, Nairobi (left)

Pre-fab urine-diverting squatting pan ready for installation (right)

4.2.3. Substructure vs. superstructure costs

Depending on the physical environment and architectural concept, the cost of a sanitary installation may differ significantly. If the latter is built inside a new or existing house (which is possible e.g. with a pour-flush or urine-diverting user interface technology), the superstructure cost can be reduced (less materials required compared to a separate outhouse building, possibly economies of scale). However, if a shelter (superstructure) has to be constructed (especially with brick or block design), this can add a substantial amount to the total cost. In urban and peri-urban Haiti, for instance, 251 home toilets and 31 shared toilets were installed (urine diverting dry toilets). The production cost of the in-house solution was US$ 50, whereas for the shared toilets it was situated in the range of USD 175 to 400 (Graf *et al.* 2014).

5. Conclusions and Recommendations

The results from this study reconfirm that the costs for on-site sanitation hardware are too high for the urban poor, without even considering if these technologies are appropriate for the context from an environmental health perspective. Adequate and durable on-site sanitation hardware and services can only be rendered economically accessible for the urban poor through innovative building methods (e.g. prefabrication) and/or financing mechanisms (e.g. microfinance and subsidies), especially in sub-Saharan Africa, where the cost of quality materials and labour remain unaffordable for the urban poor.

The following sections explain why this challenge is more significant in sub-Saharan African countries (5.1) and discuss possible ways to reduce infrastructure costs (5.2). In addition to interventions on the technology side, some promising approaches for managing the high cost and developing an enabling market environment are also described (5.3).

5.1. Reasons for high construction costs

Four main factors contribute to the high cost of sanitation facilities which presents a tremendous burden in particular for residents in Africa´s informal settlements.

The **first** are high *material input* costs, especially cement and burnt or concrete bricks. In most countries bricks, wood and cement are becoming more and more expensive but often they are the only materials readily available. The use of these materials accounts for more than 50-60% of the overall capital expenditure for typical dry toilet installations (see section 4.2.2 for details). Data from a project in Mauritania revealed that six material components (cement, sand, aggregate, steel bars, bricks and the toilet door) accounted for 76-87% of the total capital cost of an on-site toilet facility (different designs of UDDT or double VIP), and only three of those materials (cement, bricks and steel bars) were responsible for 62-76% of the total cost (Ulrich *et al.*, 2015). Both material and labour costs are higher in sub-Saharan Africa than in South Asia, even when compared to the relative high construction costs in land-locked Nepal. In all study cases, labour costs were comparatively low. Therefore, efforts to lower on-site facility costs must first and foremost focus on material costs, not labour inputs. Low labour costs favour in situ manufacturing. Combining the latter with pre-fabrication (see 5.2.1) seems to be a possible approach to reduce the costs as it reduces transportation costs and (more importantly) imported material expenses for which import taxes are exorbitantly high.

The **second factor** is *site-related*. Lack of access in unplanned neighbourhoods makes the delivery of materials cumbersome – often materials have to be carried to the construction site by hand, thus increasing the cost and loss of materials as many bricks break or are stolen. Difficult access in these neighbourhoods can thus inflate the transport costs, in some cases up to 7% of overall capital expenditure costs (Lüthi et al, 2013).

The **third factor** are the *lacking economies of scale* found in most African informal settlement areas. As in rural and peri-urban areas, on-site sanitation is built and provided by local masons which often lack the training to provide value and quality. Prefabricated and mass-produced toilet components are widely unavailable. This results in low productivity labour inputs and material-intensive constructions that often take more than a week to build.

The **fourth factor** affecting urban and peri-urban areas of sub-Saharan Africa is *information asymmetry* with regards to cost of toilet construction and contact to service providers. In many cases, clients are unaware of the cost of constructing a toilet and whom he/she can approach to build one at a known price – this emphasizes the informality of the sanitation sector in developing countries. The information asymmetry results in masons/contractors charging a premium price (up to two or three fold) to build toilets, in spite of delivering sub-standard quality of construction. Data from a field survey conducted in Kampala in 2010 also confirms this: almost 70% of the interviewees did not know the market price of about Ugandan Shillings (UGX) 1,500,000, or US$ 681, which prevailed in 2010 for a VIP latrine in Kampala (depending on water table depth and soil conditions). Specifically, 28% of the interviewed households (mostly tenants) stated right away that they did not know about the price for a ventilated improve pit (VIP) latrine and only 32% estimated the price to be between UGX 1,000,000 and UGX 2,000,000 (Horst, 2015).

5.2. Possibilities to reduce the sanitation hardware costs

The growing challenge in urban on-site sanitation is to offer a technology that responds to a variety of sustainability, functionality and quality criteria, and this for an affordable price. Based on the above analysis, there are three main pathways for trying to reduce capital expenditure costs of on-site sanitation facilities: (i) design optimization, (ii) prefabrication and mass production, and (iii) alternative building materials.

5.2.1. Design optimization

Morgan (1990) lists several possibilities on how to reduce the cost of on-site sanitation infrastructure using the example of the Blair Latrine[3]:

- Reducing the pit size reduces the amount of materials needed but has the disadvantage of reducing the life time of the pit.
- Reduce the toilet dimensions to save on materials.
- Building an outhouse latrine adjacent to the residential house means that only three walls need to be built.

The promotion of toilet solutions that can be fully integrated in residential buildings (which is possible for pour-flush as well as urine-diverting systems) and do not require a separate building (outhouse) would not only reduce the cost further, but also increase the comfort for the users.

Two interesting but not very widespread design approaches that contribute to the cost reduction of pit-based systems have been presented by Franceys et al. already in 1992: the corbelled brickwork pit lining and the unreinforced concrete slab (see Fig. 5-1 and 5-2 for more information).

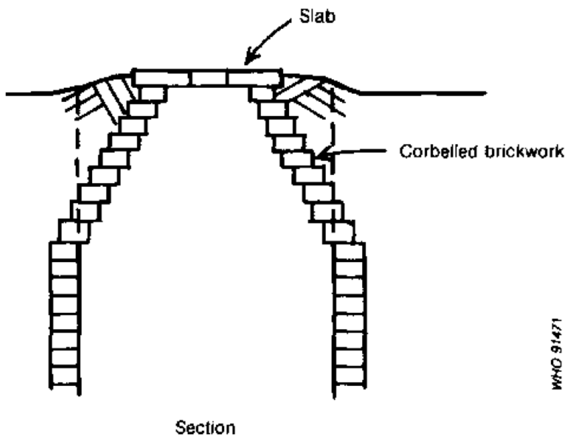


Fig. 5-1: Corbelling the top of the pit lining reduces the span of the slab and, thus, decreases the amount of material required (Franceys *et al.*, 1992)

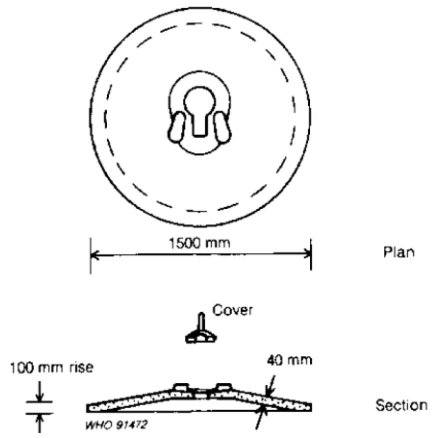


Fig. 5-2: Small dry toilet slabs do not require reinforced concrete if they are cast in the form of a flat arch or shallow circular dome. This can save the cost of expensive steel reinforcement.

5.2.2.Prefabrication and mass production

Prefabrication of components can also be a promising option for cost reduction as it can offer economies of scale. Moreover, prefabrication can be a way to control the material quality and reduce wastage. Examples can include cement rings for lining the pits as described above in the Bangladesh case study (see 4.2.1), cement slabs for the outer walls of the superstructure or prefab squat pans or toilet seats out of cement or plastic. Many user interface solutions are now mass produced by plastic or ceramic companies which offer a large variety of solutions for conventional dry toilets as well as pour-flush and source separating toilets.

In sub-Saharan Africa, prefabricated toilet components have not yet reached the market as it is the case for the South-Asian context. The replication of successful approaches like the promotion of prefabricated concrete rings or innovative mass-produced user interface products like the SaTo pan from Bangladesh (see Figure 5-3) could be a highly promising pathway for African countries.

[3] The Blair Latrine is a ventilated pit latrine that was introduced in 1975 in Zimbabwe.

Figure 5-3**:** Various mass produced plastic squat pans. The blue squat slab in the middle is produced in Kampala and costs USD 12. The model on the right is the SaTo pan designed by iDE and American Standard for Bangladesh. It is a very low flush design and costs USD 1.5.

5.2.3. Using alternative construction materials

As seen in chapter 4.2.2, material inputs represent the predominant cost factor of on-site sanitation facilities. Alternative low-cost construction materials are a great option for reducing the cost of outhouse superstructures. In arid areas the use of compressed soil blocks may be considered as a viable and ecological alternative to cement blocks or burnt bricks at less than half the cost (see Fig. 5-1). Best results are achieved when using a hydraulic or mechanical compression machine for brick production. Attention must be paid on the influence of alternative materials on robustness and operational and maintenance expenditures.

Figure 5-4: Soil cement blocks used in Dar es Salaam, Tanzania. © Centre for Community Initiatives.

Morgan (1990) lists further possibilities on how alternative materials can be used:

- Reduce the amount of cement or replace it by traditional mortar. However, as this is at the expense of structural safety, special attention needs to be paid to avoid failure.
- Using sun dried bricks instead of cement or fired bricks. Care needs to be taken that the sun dried bricks do not erode too quickly. Soil from ant mounds has proven to guarantee a long lifetime.
- Use cheap and locally available materials for the superstructure (thatched reeds, bamboo, etc.).

In general, the use of locally available materials should be encouraged whenever possible to replace materials that need to be purchased, transported or even imported; the materials necessary should be minimized to obtain the most economical solution; and opportunities for replacing “high-tech” materials by traditional materials should be sought, especially in low-income peri-urban areas (SSWARS, 2007).

5.3. Possibilities to facilitate access to sanitation infrastructure and services

5.3.1. Promoting market innovations for on-site solutions

Recently, a number of market-based innovations have been introduced by development organizations and social enterprises. Two solutions are worth mentioning:

i. In-house mobile toilets - they are compact, waterless and portable toilet units that can be used in homes. They offer the privacy, convenience and safety of ‘modern toilets’, without the investment into fixed infrastructures (i.e. septic tanks or sewers). See Annex A1 for details.
ii. Fixed branded sanitation solutions such as “Sanergy” in Nairobi. These solutions offer container-based collection systems that separate urine and faeces. See Annex A2 for details.

5.3.2. Providing adequate financing mechanisms

Both public (e.g. subsidies) and private funding sources and mechanisms can help making sanitation accessible for the poor. Whilst it will always be in part the responsibility of municipal governments to provide basic urban and public health services, there are promising innovative financing mechanisms that can enable households to gain access to a toilet. This section showcases different sanitation microfinancing approaches.

Microfinance is the provision of financial services to the poor, generally dealing with relatively small sums of money. An aspect of microfinance is microcredit, through which people who would not ordinarily be able to gain access to loans at relatively reasonable interest rates. In many cases a latrine costs well over the monthly or even annual income of a household. By splitting the expenditure into smaller payments over time, people can access new products and infrastructure.

Several organizations have begun expanding microfinance to the sanitation realm. Household on-site sanitation differs from typical microfinance products in that it is not (directly) income generating. Steps are being taken to make microfinance accessible to both producers and potential consumers of sanitation products and services.

Water.org has expanded their WaterCredit model to include sanitation products — their partners now offer loans for financing pit latrines, toilets with septic tanks, and household toilet connections, in addition to rainwater harvesting, water purifiers and boreholes with tanks. This approach involves working with microfinance providers to develop loan packages for water and sanitation products and helping them partner with WASH NGOs, who are able to better educate potential clients about the benefits of safe water and improved sanitation.

Using a different approach, *iDE / Hydrologic* has worked to build up a network of sales agents in Cambodia, which promote water and sanitation products at sales meetings in villages. Interested buyers are able to fill out their loan applications directly at these meetings. If approved, the loan amount is disbursed to the latrine business, once the components have been delivered. The customers need to pay separately for the installation and any superstructure. Employees of the local microfinance institution (MFI) then come by to collect the loan repayments. In Cambodia all loans must be approved by a governmental agency, which can slow down the process, but may have contributed to their high repayment rates.

Microcredit for sanitation can take various forms including individual or group loans. The Water and Sanitation program of the World Bank has worked with various implementers to assess how loan design can affect demand for credit and the population segments that are willing to go into debt for sanitation access. People are unwilling to go to much effort (i.e. travel far) in order to make payments.

BRAC takes a multifaceted approach to their sanitation products and financing based on the income level of the customer. While the ultra-poor are offered subsidized latrines with bamboo superstructures, the poor are offered a microcredit option for a latrine with a metal superstructure, which spreads the payments across a year (see section 4.2.1 for details).

Some microfinance organizations find that while sanitation and water loans are not the most profitable parts of their portfolio, they can serve as a way to recruit new customers or generate return business from current ones. One approach to increasing the attractiveness of sanitation loans to the MFI is to bundle them with other water, hygiene, or popular loan products. Depending on the context, accepting mobile payments can be a way to reduce the transaction costs of collecting payments, albeit at a price of having less contact with the customer.

Multiple organizations work with *Kiva.org*, an online microlending platform, to raise capital for the loans for both private sanitation and sanitation business. Entrepreneurs who invested in products such as the Fresh Life Toilets had the option of paying their franchise fee outright or taking a loan (see more in Appendix A2). Table 5-1 examines some of the different applications for microcredit for sanitation.

Table 5-1: Adaptation of microfinance to the sanitation sector

	Traditional microcredit	**Sanitation Microfinance**		
	Entrepreneurs	Households	Landlords	Entrepreneurs
Duration	Up to two years	Generally a year	Less than a year	Less than a year
Type	Group or Individual	Group loans	Individual	Individual
Amount	Up to $1000	$30-100	Up to $500	Up to $1000
Motivation	Start or expand business	Social status, health	Increase rents, conform to regulations	Start business, enhance customer experience
Benefit for MFI	Business as usual	Recruit new customers for other products	Creditworthy customers	

5.3.3 Reducing information asymmetry in sanitation services

Local governments should be encouraged to actively engage in framework agreements with sanitation masons and contractors to build toilets for urban dwellers at a set price over a period of time, and following standard designs and procedures. By entering into such framework agreements, the masons and contractors could benefit from

- a higher volume of business as the local government would market their services as authorised or certified agencies to provide standardised toilets,
- local tax exemptions, and lastly
- legitimisation (or formalisation) of the services rendered by them.

Additionally, such framework agreements can also be used to promote up-coming market innovations and financing mechanisms for on-site sanitation technologies within urban settlements.

6. Outlook

This study has investigated why on-site sanitation facilities are so much more expensive in Sub-Saharan Africa than in Asia. The main findings show that in order to bring down costs to affordable levels, future efforts need to target the high material costs (ranging from 55% to 86% of capital expenditures in the examples documented) – usually in the form of cement-based products.

To reduce costs for urban sanitation coverage in Sub-Saharan Africa the following actions show the most promise:

(i) **Mass production** of latrines or latrine components by companies with a track record in reaching base-of-the-pyramid customers. Most countries have plastic or cement industries that are already producing competitive products, but their market penetration is currently too small (e.g. plastic squatting pans). Programme support by national governments and the donor community would be needed to promote these market-based solutions for pre-fabricated products and create strong demand. The successful case of rural and peri-urban Bangladesh could hereby serve as an example.

(ii) Further research into **low-cost building materials –** especially for the expensive superstructures. Finding alternatives for high-cost cement products is not really new, but there have been interesting innovations in using waste products in recent years, e.g. densified waste materials, i.e. products based on the principle of compressed refuse such as cardboard or reconfigured waste or other materials using agricultural or packaging waste (e.g. Rematerial). Using compressed soil-cement blocks can also lead to substantial cost savings by reducing the amount of cement needed.

(iii) **Formalisation** of the services rendered by small-scale builders by encouraging local governments to actively engage in framework agreements with sanitation masons and contractors to build toilets for urban dwellers at a set price over a period of time and following standard toilet designs and procedures.

7. Acknowledgements

We would like to acknowledge financial support received from SDC’s Global Water Initiatives Division. We would like to thank the following individuals for their contributions and comments: Roman Grüter, Isabel Günther, Alexandra Horst, Ingeborg Krukkert, Henry Ssuna, Charles Niwagaba, Rajendra Shrestha, Mingma Sherpa and Elizabeth Tilley.

8. References

BRAC and IRC (2015). Rapid Assessment of Sanitation Demand and Supply in Rural Bangladesh Recommendations for strengthening the supply chain for rural sanitation, Briefing Note IRC: The Hague and BRAC, Dhaka.

Fonseca, C., Franceys, R., Batchelor, C., McIntyre, P., Klutse, A., Komives, K., Moriarty, P., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, R. and Snehalatha, M. (2011). Life-cycle costs approach: Costing sustainable services. WASHCost Briefing Note 1a. IRC International Water and Sanitation Centre.

Franceys, R., Pickford, J., & Reed, B. (1992). A Guide to the Development of on-Site Sanitation. Geneva, CH: World Health Organisation.

Graf, J., Kayser, O. and Brossard, S. (2014). Designing the next generation of sanitation businesses. A report by Hystra for the Toilet Board Coalition, Hystra Consulting, Paris.

Günther, I., Horst, A., Lüthi, C., Mosler, H.-J., Niwagaba, C.B. and, Tumwebaze K.I. (2011). Where do Kampala's poor "go"? An overview of urban sanitation conditions in Kampala's informal settlement areas. Research Evidence for Policy. Bern, Switzerland: NCCR North-South.

Heierli, U., Münger, F. and Walther, P. (Eds.) (2004). Sanitation is a business: Approaches for demand-oriented policies. SDC, WSP and WSSCC.

Horst, A. (2015). Economics of Slum Sanitation. Dissertation No. 22773. PhD Thesis ETH Zürich, Switzerland,

Lüthi, C. et al (2013) Ventilated Improved Latrine construction in the slum areas of Kampala, Uganda. Technical Factsheet, SPLASH – U-ACT.

Morgan, P. (1990). Low cost Blair Latrines – A study of recent developments in Zimbabwe.

O'Keefe, M., Lüthi, C., Kamara, I. and Tobias, R. (2015). Opportunities and limits to market-driven sanitation services: evidence from urban informal settlements in East Africa. Environment & Urbanization, 27(2).

Sijbesma, C. (2008). Sanitation and hygiene in South Asia: Progress and challenges. In: Beyond Construction – Use By All. London, UK and Delft, The Netherlands: WaterAid and IRC International Water and Sanitation Centre.

SSWARS (2007). Sustainable Toilet Options Catalogue. pp. 40. Published under the 'Product development for social marketing of sanitation and waste' in Kampala, Uganda.

Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph. and Zurbrügg, C. (2014). Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.

Ulrich, L., Diagana, I. and Lüthi, C. (2015). Systèmes d'assainissement pour les quartiers précaires de Nouakchott. Une composante du Projet Communautaire pour l'Accès à l'Eau (PCAE), 2012-2014. Synthèse et recommandations. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland.

Annex: Market Innovations for On-Site Sanitation

A 1: Rent-a-toilet mobile toilets

Home mobile toilets are compact, waterless and portable toilet units that can be used inside homes. They offer the privacy, convenience and safety (no need to go outside at night) of 'modern toilets', without the investment into fixed infrastructures (i.e. septic tanks or sewers) – an ideal solution for tenant populations. These toilets are 'rented' for a service fee, whereby the toilet provider operates a regular collection service for the waste, which accumulates and is stored in a container under the toilet. This approach brings a constant source of revenue for the mobile toilet operators, as opposed to one-time sales, and ensures that customers do not try to dispose of the waste themselves or call on the services of informal waste collectors that might dump the waste illegally. Despite their novelty, mobile toilets seem to be well adopted in informal urban settlements.

Households are willing to pay a relatively high service fee when the mobile toilet is modern-looking, odourless, hygienic and comfortable to use. It has been found that families, including children, use them more systematically than public or community toilets.

Some well-known examples are x-runner, based in Lima, Peru; Clean Team in Kumasi, Ghana; SOIL in Haiti; and Loowatt in Madagascar.

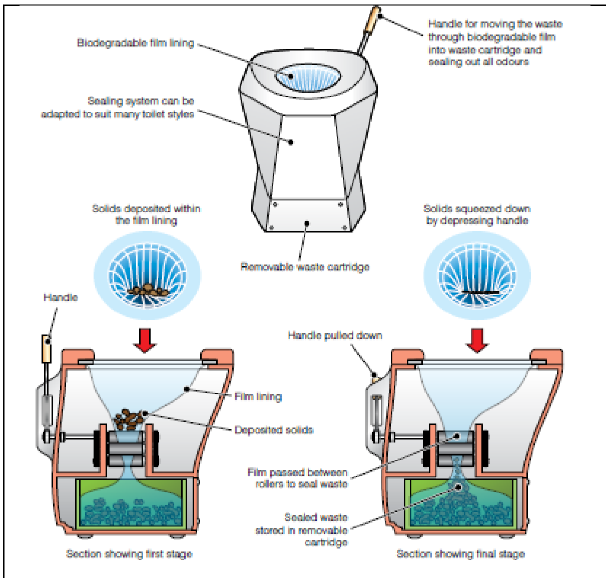


Figure A1: The Loowatt ® toilet (Madagascar)

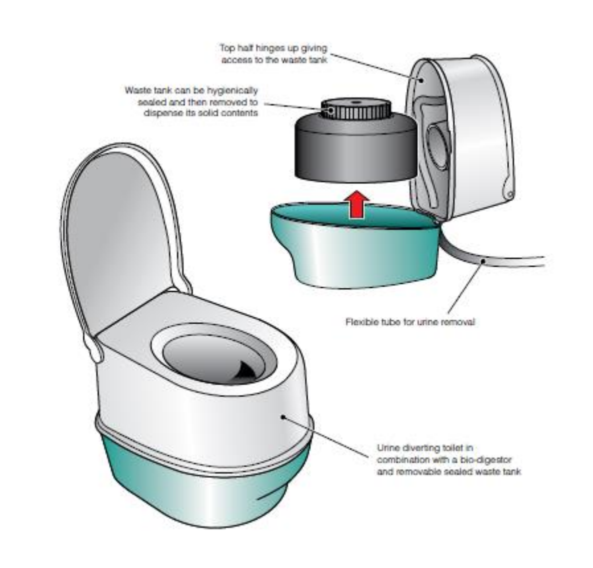


Figure A2: The Clean Team Toilet (Ghana)

Common problems of mobile toilet solutions

First of all, although some innovation has already taken place in terms of the toilet design, more hygienic and odourless solutions need developing to improve customer experience, reduce the cost of waste storage (bags, cartridges or liquid chemical, see Fig. A3) and allow for easier and safer handling and cleaning. The toilet servicing operations also present many challenges when scaled up. Waste collection at scale would require deploying very large teams of low-skilled workers circulating in informal urban settlements. In parallel, transport and logistics are challenging to organize in areas with poor infrastructure and congestion, especially under time, storage and accessibility constraints. As a consequence, toilet servicing requires having a certain density of customers in a given area to be profitable. Existing initiatives have to deploy innovative sales and marketing strategies. Afterwards, these strategies should be extended towards positive word-of-mouth (e.g., customer referrals) to grow their customer base. Besides, renting home mobile toilets versus selling them implies operating frequent payment collection, which needs to be performed regularly by a dedicated team. Finally, home mobile toilet providers often have to develop their own treatment systems, since existing treatment facilities are usually inadequate. These systems typically utilize composting or solar heating to inactivate pathogens and produce marketable products; however, these treatment systems need to be responsive to the amount of waste that is collected.

Figure A3: Existing containers used by various mobile toilet solutions

Our own research and collaborations with sanitation providers revealed that these solutions, although promising, do not yet generate sufficient revenue to pay for the waste processing costs, let alone cross-subsidize collection operations, as was the hope of many initial business model designs. In addition, many of these by-products face important challenges to commercialization, ranging from lack of local markets, to regulatory hurdles (e.g. the use of human-based fertilizer for agricultural purpose is forbidden in many countries) and logistics issues (e.g. transport for urine or biogas). Finally, most of these technologies are still in the early stages of development. Clean Team Ghana has installed 510 toilets, serving 3000 inhabitants, x-runner's service is reaching around 2000 people, and SOIL has around 700 toilets and operations in two cities.

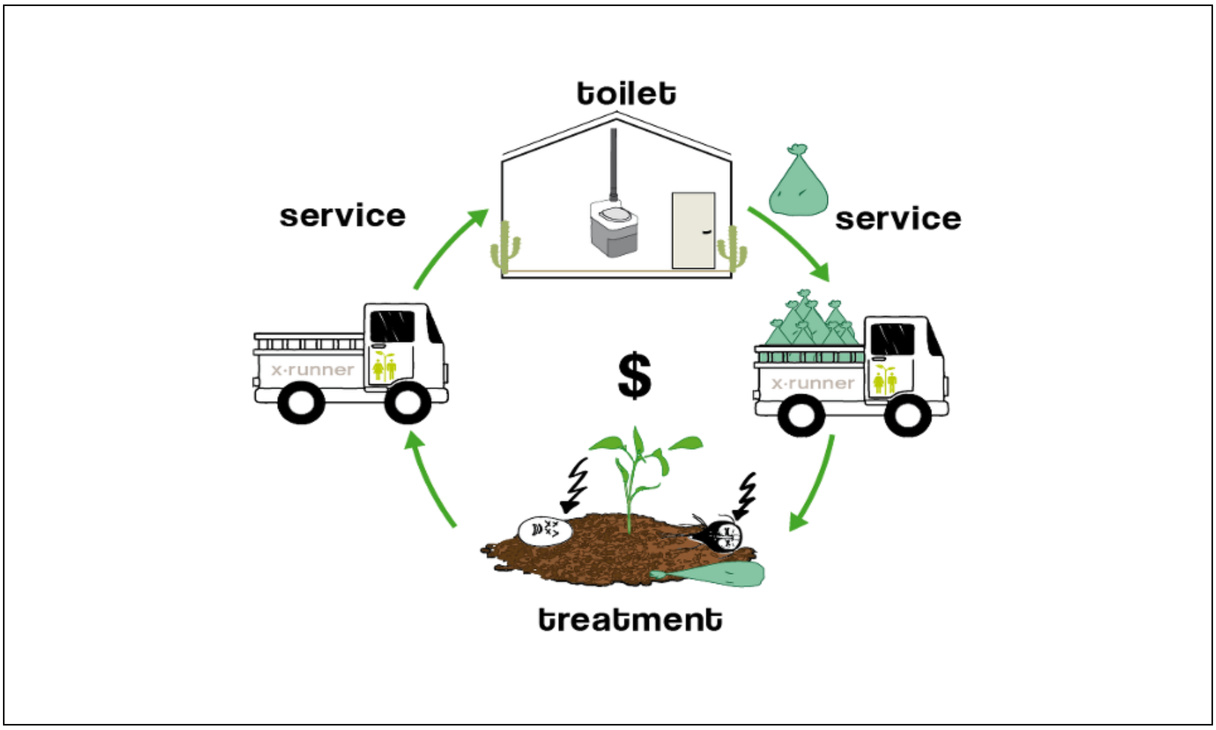


Figure A4: Mobile toilet value chain (example x-runner, Peru)

Affordability for end users: Each organization operates in a different socio-economic context and users pay between five and twelve US dollars a month for weekly collection, which can represent three to ten percent of a household's income.

A 2: Fresh Life Toilets (Sanergy, Nairobi)

Sanergy is a social enterprise company and non-profit organisation based in Kenya that offers a branded integrated sanitation solution for informal settlements called Fresh Life. The franchise package includes the toilet, training, cleaning material and one year of waste collection for 600 USD to entrepreneurs that want to start a Fresh Life Business. The entrepreneur pays for the toilet through a cash payment or a microfinance loan. The entrepreneur is then linked to the Sanergy waste collection and operational support teams. Sanergy provides marketing support and the quality of the toilets is monitored by a field support officer. The business owner can decide her/himself how much the usage fee is, but Sanergy suggests 5 KShs per use. Assuming 50 users per day, this calculates to 2.50 USD per day. The maintenance costs of the Fresh Life toilets is about to 0.3 USD per day. A total income of 800 USD/year for such a toilet is guaranteed. It is assumed that the business is run by a single person/family. After the initial year of collection service, the franchisee pays a renewal fee of 100 USD/year to continue having collection and marketing support.

Figure A5: Fresh Life toilets in Mukuru, Nairobi. Prices advertised: kids: 2 KShs, adults: 3 KShs

Emptying and Transportation

Emptying and transportation is independent from the Fresh Life Operator's business and remains in Sanergy's responsibility. Their collection team passes by daily to exchange used cartridges for empty ones.

Technical Aspects of Fresh Life

- **User Interface**

Urine diversion dry toilets without an extra urinal. The urine and faeces are collected separately and converted into organic fertilizer.

○ **Storage**

30 L cartridge. Urine and faeces are separated, stored in the same cartridge but in different compartments. No information available on how big the individual compartments are. Expected that 80 to 100 users can use the toilet daily before the container needs to get exchanged. The faeces in the cartridge have a total solids content of 65%.

○ **Collection and Transport**

On average the 600 Fresh Life toilets serve six informal settlements in Nairobi each serving 50 to 55 users (O'Keefe et al, 2015).

○ **Treatment**

Sanergy is currently validating different treatment mechanisms for the faeces:

- **Composting:** Most of currently collected faeces is manually composted in a location outside of Nairobi where it is transformed into branded organic product that is sold to farmers and the Kenyan flower industry. An attempt to introduce an innovative composting technology named BioMax (www.biomaxtech.com) that speeds up the process of fertilizer production is not being pursued because of the high energy consumption involved.
- **Other treatment options being investigated include:** anaerobic digestion technology in a tubular digester using wet fermentation under thermophilic conditions and waste conversion using black soldier flies.