Evaluating financial sustainability along the sanitation value chain using a financial flow simulator (eSOSView™)

Claire Furlong **IWA**, Shirish Singh **IWA**, Nitesh Shrestha, Mingma Gyalzen Sherpa, Christoph Lüthi, Fiona Zakaria and Damir Brdjanovic **IWA**

ABSTRACT

A majority of the world's population use onsite sanitation systems, which store or treat excreta close to where it is generated. Sludge from these systems needs to be managed through a series of stages, known as the sanitation value chain. There is a huge diversity of service providers, not only within each part of the chain, but also along the chain bridging the different components. These service providers are linked not only by the flow of materials, but also by the transfer of money. Therefore for this system to be considered financially sustainable all services from the toilet to reuse or disposal need to be considered. A tool has been developed (eSOSView™) to simulate, evaluate, and optimise the financial flows along and within the sanitation value chain. In this paper eSOSView™ was tested, validated (using existing data), and piloted (including data collection). This paper demonstrates how eSOSView ™ can be used to evaluate different financial flow models, to assess financial sustainability in different parts of the sanitation value chain and optimise the financial sustainability along the sanitation value chain.

Key words | business model, faecal sludge, Nepal, onsite sanitation, sustainable, Thailand

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HIGHLIGHTS

- Onsite sanitation is used by a majority of the world's population.
- Sanitation services from the toilet to end use need to be considered to ensure financial sustainability.
- eSOSView™ was designed to simulate, evaluate, and optimize the financial flows along and within this system.
- The tool can be used to evaluate different financial flow models, and assess financial sustainability within and across the system.

INTRODUCTION

A majority of the world's population use onsite sanitation (2.7 billion people) and this number is expected to increase to 4.9 billion by 2030 (Cairns-Smith *et al.* 2014). Onsite sanitation are systems that store or treat excreta close to its generation, e.g. pit latrines and septic tanks. In the Millennium Development Goal period (2000–2015), the focus

was getting people onto the sanitation ladder, by building pit latrines and other onsite sanitation systems. At the start of this period, little consideration was given to the long-term management of these systems, as it was assumed that people would eventually progress to networked (sewered) sanitation. This was an unrealistic goal and the field of faecal sludge management came into being. Faecal sludge (sludge from onsite sanitation systems) needs to be managed through a series of stages, which replicate what happens in a well maintained and operated networked sanitation system

as seen in Figure 1. This is called the sanitation service or value chain depending on the emphasis at the end of the chain (Figure 1).

Sustainable Development Goal 6 (Ensure access to water and sanitation for all) has embraced this systems approach (Figure 1) as it calls for 'safely managed sanitation services'; this goes beyond the provision of toilets and embraces faecal sludge management. There is a huge diversity of service providers, not only within each part of this system (Figure 1), but also along the chain bridging the different parts, e.g. non-governmental organisations, governments, the informal and private sectors. These service providers are linked not only by the flow of materials along the chain, but also by the transfer of money between stakeholders and service providers. Therefore, the sanitation value chain (SVC) needs to be financially viable if it is to be sustainable.

Several financial decision support tools have been developed for faecal sludge management. A majority of them focus on emptying to treatment, due to the capital and operation cost of the user interface and containment being borne by the homeowner. The initial tools incorporated financial aspects as part of overall sustainability such as SANEX ™ (Loetscher & Keller 2002). Later, financial aspects became a major focus for technology selection as in WhichSan (Branfield & Still 2009), which uses capital expenditure (CAPEX) and operational expenditure (OPEX) to assess the financial feasibility of different technology options. This has now expanded to life cycle cost of components or linked components in the SVC (Daudey 2018). WASHCost (2012) can be used to compare the life cycle cost of the user interface and containment, while the Financial Analysis Tool for Urban Sanitation focuses on the life cycle cost of transport and treatment (Cowling *et al.* 2013, WSUP 2013). Both tools were designed to enable the user to compare the overall cost of different technology choices. The Financial Analysis Tool for Urban Sanitation also allows the user to explore the ability of the project to become self-financing by including subsidy options that can used to see the effect of external financing and the adjustment of household tariffs (WSUP 2013). Currently, the only tool that covers the complete SVC is SaniPlan, which is a complete city sanitation (including water and solid waste) planning tool developed for Indian municipalities (PAS 2016). SaniPlan includes performance

assessment, action and financial planning and allows for comparisons of different SVCs and different financing options (PAS N.D. a). It was designed to enable local governments to review the financial impact of different improvements along the SVC through the use of a contextual financial flow model (FFM) (PAS N.D. b). While the complexity of financial decision support tools has grown, only one Indian and local government-focused tool enables the users to explore the whole SVC, while incorporating a financial flow model. Therefore, to our knowledge, none have incorporated a function that allows the impact of different FFMs to be assessed along the SVC.

Financial (capital or cash) flows (or transfer analysis) are a part of the value capture segment of the business model framework (Bocken *et al.* 2014) and are one of the simplest ways to explore financial sustainability (defined in this paper as the ability to ensure the continuity in the delivery of products and services over time). This method has been used to assess financial stability at all levels, ranging from companies to sectors (e.g. the water, sanitation, and hygiene sector (Trémolet & Rama 2012)) up to country level (OECD 2017). It is the analysis of money (cash or capital) movements in and out of an entity; in terms of this paper, the individual components of the SVC (Figure 1) and along the SVC.

Due to the complex nature of faecal sludge management and service delivery, several FFMs have been developed (Steiner *et al.* 2003). These models are divided into two groups based on the use of subsidy or budget support (Steiner *et al.* 2003). The financial transactions included in the FFMs for faecal sludge management are shown in Table 1. The five most common FFMs for faecal sludge management are known as:

Financial Flow Model 1 (FFM 1): Discrete collection and treatment model
Financial Flow Model 2 (FFM 2): Integrated treatment and collection model
Financial Flow Model 3 (FFM 3): Parallel tax and discharge fee model
Financial Flow Model 4 (FFM4): Dual licensing and sanitation tax model
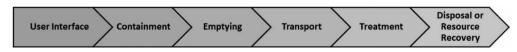Financial Flow Model 5 (FFM5): Incentive discharge model (Tilley & Dodane 2014).

Figure 1 │ The sanitation service or value chain.

Table 1 | Financial transactions included in financial flow models for faecal sludge management adapted from Steiner *et al.* (2003), Tilley & Dodane (2014), and Rao *et al.* (2016)

Financial transaction	Description
Sanitation tax	Fee collected either once or at regular intervals, which is paid in exchange for environmental services such as connection, removal of faecal sludge, or a combination of services.
Collection or emptying fee	Fee that is charged at the household level for removing faecal sludge from the onsite sanitation technology.
License fee	Financial instruments used to control the number and quality of emptying and transport enterprises (that are allowed to discharge faecal sludge at a treatment plant).
Disposal or discharge fee	Fee charged in exchange for permission to discharge or dispose of faecal sludge.
Disposal or discharge incentive	Payment used to reward the emptying and transport enterprises for discharge/disposal of faecal sludge in a designated location and to disincentivise unregulated or illegal discharge.
CAPEX or capital	Costs that are paid once, at the beginning of the project, to cover all materials, labour and associated expenses needed to build the facilities and associated infrastructure.
OPEX or O&M	Costs paid regularly and continually until the service life of the infrastructure/equipment has been reached.
Budget support or subsidy	Cash transfers between stakeholders to partly or fully cover one stakeholder's budget.
Purchase price	Price paid by one stakeholder to another in exchange for becoming the sole owner of a good.

It should be noted that Models 3–5 include budgetary support (defined in Table 1).

FFMs have been used to compare the financial sustainability of faecal sludge management to sewer-based systems in Dakar, Senegal (Dodane *et al.* 2012) and Kampala, Uganda (McConville *et al.* 2019). Both studies concluded that the OPEX and CAPEX of the faecal sludge management system was significantly lower than a sewer-based system (Dodane *et al.* 2012, McConville *et al.* 2019). Although the financial flows of 44 individual faecal sludge management businesses have been mapped out (Rao *et al.* 2016), no tool exists to aid this process or to enable the users to compare different FFMs. It should also be noted that modelling the financial flows along the SVC addresses the call by the Sustainable Development Goals Industry Matrix: '…to apply modelling expertise to help develop financially sustainable models for water projects, using fees and tariff structures which reflect future costs and manage usage while subsidising connections and consumption for the poor', which aims to inspire greater private sector action in meeting the Sustainable Development Goals (UN 2015).

This paper documents the testing, validation (using existing secondary data), and piloting (including data collection) of a financial flow simulator (known as eSOSView™) that covers the complete SVC, and the exploration of financial sustainability in both case study areas using FFMs.

METHODOLOGY

Description of eSOSView™

eSOSView™ is an add-on to the decision support tool documented in Zakaria *et al.* (2015). In eSOSView™, the study area is defined by inputting the number of each toilet type (household, shared, communal or public) combined with each interface type (dry, dry urine diverting, pour-flush, pour-flush with urine diversion or cistern flush), which are pre-set in the tool. Then entering the number of people that use each toilet and interface type daily. The material streams and flows along the SVC are then calculated or estimated (depending on data availability). This is because material flows are linked to financial flows, as many fees are calculated on volume or mass basis. Additionally, the material flows can be used to evaluate the capacity of the subsequent component, e.g. are there enough vacuum tankers to empty all of the faecal sludge generated. Table 2 provides the summary of input and output data of each component of the SVC and the data linkages between subsequent components.

In the eSOSView™, the OPEX and CAPEX are broken down in detail for each component of the SVC, e.g. the CAPEX for the user interface (defined as the superstructure of the toilet) includes sub-components such as construction materials, transport of materials and construction. The OPEX of this component includes the cost of cleaning materials and water. Additional financial information is also included for each component of the SVC, such as the budget support available, sanitation tax, corporate income tax, depreciation, etc.

Table 2 | Summary of input, output and links to the next SVC component in eSOSView™

Component of the SVC	Input	Output	Data flow to the next SVC component
User interface	- Type of user interface - Number of toilets (household, shared, communal or public) - Number of people/toilet/day - Amount of faeces, urine, excreta, water usage, black water generated/day - CAPEX per unit - OPEX per unit - Unit cost of water, electricity, labour	- Amount of faeces, urine, excreta, water and blackwater/toilet/day - Total CAPEX/day, month, year - Total OPEX/day, month, year	Volume of faeces, urine, excreta, water and blackwater/toilet type/day
Containment	- Type of containment - Containment specifications: holding capacity, number of units, faecal sludge, accumulation factor, output streams, sale price of valuable streams (e.g. biogas) - CAPEX per unit - OPEX per unit	- Amount of faecal sludge, black water and urine accumulated/containment unit/day - Emptying frequency - Number of emptying events per year - Total CAPEX/day, month, year - Total OPEX/day, month, year - Revenue/day, month, year	Volume of faecal sludge, blackwater or urine accumulated/containment type/day
Emptying	- Type of emptying - Number of units to be emptied per time unit - Emptying capacity (e.g. volume pumped/hour) - Emptying fee - CAPEX per unit - OPEX per unit (e.g. labour, fuel, energy, technical maintenance, tax, business operation overhead) - Revenue	- Volume of faecal sludge or other products emptied per day - Total CAPEX/day, month, year - Total OPEX/day, month, year - Revenue/day, month, year	Volume of faecal sludge emptied/emptying technology/day
Transport	- Type of transport - Carrying capacity of the transportation unit - CAPEX - OPEX (as with emptying) - Revenue	- Volume of faecal sludge transported per day - Total CAPEX/day, month, year - Total OPEX/day, month, year - Revenue/day, month, year	Volume of faecal sludge transported per day
Treatment and reuse	- Type of treatment - Design capacity - Amount of faecal sludge received at the treatment - CAPEX (e.g. construction costs, land requisition) - OPEX (as with emptying) - Discharge fee (if applicable) - Revenue	- Volume of faecal sludge treated per day - Total CAPEX/day, month, year - Total OPEX/day, month, year - Revenue per/day, month, year - Volume of end products generated per day	

The beta version of eSOSView™ is Excel-based, using interlinked worksheets, outputs are generated in the form of summary worksheets for the five most common FFMs for faecal sludge management (Tilley & Dodane 2014). The CAPEX, OPEX, and revenue (as defined in Table 1) are calculated for each part of the SVC and the whole chain, as are the financial indicators listed in Table 3.

Additionally, graphs are produced showing CAPEX, OPEX, revenue, EBITDA, net profit, or loss (yearly), payback (%), and break-even point for each FFM. The parameters reported in this paper are CAPEX, OPEX, revenue, EBITDA (as neither tax nor depreciation were used in the simulation-based in Thailand), as these were deemed to be the most important parameters for this analysis. eSOSView™ was developed to enable the user to explore different FFMs for one scenario or to compare several scenarios using one FFM. Both approaches aim to explore and optimise the financial sustainability along SVC or at a particular part of the SVC.

Validation process

The validation area was chosen due to the availability of detailed data on the SVC. Nonthaburi City Municipality in Thailand is seen as a model example of faecal sludge management, hence it has been studied extensively, and detailed data were available (AECOM *et al.* 2010; CSE 2011; AIT 2012; Harada *et al.* 2015). Additionally, the financial flows of the SVC in Nonthaburi City Municipality have already been modelled (AIT 2015), so a comparison of results could be made.

Table 3 | Financial indicators generated by ESoSView™

Financial indicator	Description
EBT	Annual earnings before tax
EBIT	Annual earnings before interest and taxes
EBITDA	Annual earnings before interest, taxes, depreciation, and amortization
Payback period	Time required to recoup the CAPEX in months
Net profit/loss statement	Statement of income made
Break-even point	Sales level that pays for all costs and that generates a profit of zero (%)
Return on investment	Amount of return on an investment relative to the investment cost

Nonthaburi City Municipality is located in the central part of Thailand, north of the capital, Bangkok. The city covers an area of 38.9 km^2 and has a population of 256,457 people (129,597 households) (Harada *et al.* 2015). The population density in this city is the second highest in Thailand (Harada *et al.* 2015). The population is reliant on onsite sanitation, predominantly single and double ring cesspools, which generally have open bottoms to allow the effluent to infiltrate into the soil (AECOM *et al.* 2010; Harada *et al.* 2015) or discharge to open drains or sewers (Harada *et al.* 2015). Due to the Public Health Act (1992) the responsibility for faecal sludge management lies with the local government (Harada *et al.* 2015) and the municipality desludges approximately 3,500 onsite systems annually (AECOM *et al.* 2010; AIT 2012; Harada *et al.* 2015). Nonthaburi has a faecal sludge treatment plant, which includes anaerobic digestion tanks, sludge drying beds, and oxidation ponds, which produce and sell compost as an end product (AECOM *et al.* 2010). The SVC at Nonthaburi uses the integrated treatment and collection model (FFM 2), hence this model was used to validate eSOSView™.

The detailed data and assumptions that were used to generate the FFMs for Nonthaburi Municipality can be found in Zakaria (2019). These data were used to generate a baseline scenario and for the basis of exploring four scenarios that could enable full cost recovery (Table 4), FFM5 was not simulated for this case study as it was not contextually appropriate due to the inclusion of a discharge incentive.

Piloting process

Pokhara Metropolitan City in Nepal was the location for the piloting of eSOSView™ due to it being the first open-defecation free district in Nepal (Dahal *et al.* 2014) and the first city in Nepal to construct a faecal sludge treatment plant (Shrestha *et al.* 2001; UN-Habitat 2008). It is located in the Gandaki Province of Nepal, with an area of 464.24 km^2, and is situated 200 km west of Kathmandu (Pokhara Lekhnath Metropolitan City, 2019). It was formed in 2017 by combining two municipalities (Pokhara Sub-metropolitan City and Lekhnath Municipality) and adjacent areas, and had a population of 402,995 (average household size 3.82) in 2011 (CBS 2011). The district growth rate of 2.02% was used to estimate the population in 2017, which was calculated to be 454,372 with 118,946 households (Shrestha 2018).

Detailed data were collected using a mixed-methods approach and were guided by the data requirements for the tool (Table 2). Secondary data were analysed,

Table 4 | Scenarios tested in the validation process

Scenario	FFM (Tilley & Dodane 2014)	Parameters changed
1	2	Emptying fee = US$ 20 (per 1.5 m^3)
2	1	Emptying fee = US$ 15 (per 1.5 m^3) Discharge fee = US$ 5 (per 1.5 m^3)
3	3	Emptying fee = US$ 15 (per 1.5 m^3) Annual sanitation tax = US$ 50 (per household) Discharge fee = US$ 5 (per 1.5 m^3)
4	4	Emptying fee = US$ 15(per 1.5 m^3) Annual sanitation tax = US$ 50 (per household) Annual discharge license = US$ 50 (per vehicle)

e.g. census data 2011 (CBS 2011). Semi-structured interviews were undertaken with stakeholders along the SVC, e.g. an administration officer in the Waste Management Section of the city, supervisors and technical staff at the faecal sludge treatment plant, staff of the emptying and transport (E&T) company, etc. These interviews aimed to gain an understanding of the current situation, challenges and plans for improvements in the SVC.

A household survey was undertaken to assess containment at household level, e.g. size, desludging frequency, and cost of emptying. Fifty surveys were administered using KoboCollect. The wards of the city were stratified according to the type of settlement: (i) tourist area (Ward 6), (ii) residential area (Wards 1, 2, 3, 4, 5, 7 and 12), (iii) local business area (Wards 8, 9 and 10) and (iv) peri-urban/rural area (Wards 11 and 13 to 33) and the number of surveys administered were proportional to the population in these stratified areas.

All data for the current and simulated scenarios were triangulated and validated with the relevant stakeholders in a workshop. In this workshop, the current FFM was validated and the future scenarios were discussed to gather opinions on the appropriateness of other FFM for this city. The data were collected from October 2017 to January 2018. The interview guides and questionnaires were developed in English, but administered in Nepali, the field researcher's native language. The detailed data and assumptions that were used to generate the FFMs for Pokhara Metropolitan City can be found in Shrestha (2018).

RESULTS AND DISCUSSION

Validation process

The CAPEX for the user interface and containment were not used in these simulations, due to most toilets being incorporated into the structure of the home. Hence the CAPEX would be included in the rent or purchase price of the residence. Most other financial tools do not include the user interface and containment, due to the burden of these costs being with the homeowner or occupier. However, this is an important part of the financial flow as it can be used to illustrate the financial cost to the resident compared to other stakeholders, as in McConville *et al.* (2019). It can also be used to calculate a subsidy for CAPEX and enable reasonable estimates for emptying fees and sanitation taxes to be calculated. Including the CAPEX and OPEX for the user interface and containment means that the financial flows can be modelled for the complete system, which is of use when a single organisation is developing a full SVC e.g. in humanitarian camps.

From running the baseline scenario (Baseline, Figure 2), it can be seen that no parts of the SVC were profitable, hence the CAPEX for emptying, transport, and treatment was covered by the Nonthaburi City Municipality (AIT 2015). Even with this budget support, it can be seen that the OPEX was not covered by the revenues generated, hence additional annual budget support is required. The Asian Institute of Technology case study (which covers the SVC from emptying to reuse, and only uses the OPEX and revenue) calculated an annual net loss of US$ -98,000 (AIT 2015). Using the same interpretation of the SVC and financial parameters an annual net loss (EBITDA) of US$98,474 was calculated using eSOSView™. The difference was less than 0.5% and was found to be due to the variation in some input values (Zakaria 2019) compared to those used in the original study (AIT 2015). This validated the eSOSView™ in terms of its ability to calculate the financial flow along the SVC, which led to testing scenarios to optimise the system in Nonthaburi.

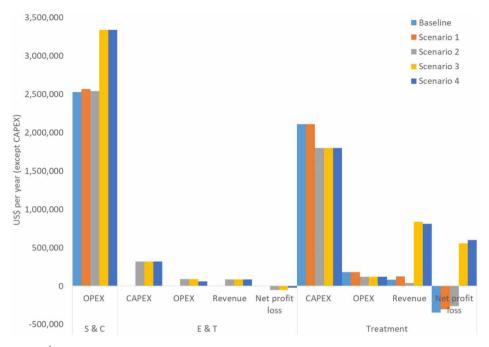In the first simulated scenario, the emptying fee was increased from US$ 13 to US$ 20/system, to see if this

Figure 2 │ Results from the baseline scenario and simulated scenarios (Table 4) for Nonthaburi Key: S & C refers to Superstructure and Containment, E & T refers to Emptying and Transport.

would increase the financial sustainability of the emptying, transport, and treatment (Table 4). It is acknowledged that this would require a change in the law as the Public Health Act (1992) does not allow the public utility to charge above the current rate (AECOM *et al.* 2010). The extra financial burden on residents is relatively small, as OPEX for the user interface and containment rises by 1.6% (Scenario 1, Figure 2). The CAPEX was not covered by the revenue generated (Scenario 1, Figure 2) for the emptying, treatment, and transport, although the increase in emptying fees increases the revenue for this part by 48% (Scenario 1, Figure 2). It can be seen that a significant increase in the emptying fee (>US$ 20/ system) would be required to make this system financially sustainable using FFM 2. This strategy would likely be unpopular with the residents in this area.

In Scenario 2, the emptying fee was increased from the baseline of US$ 13 to US$ 15 /system and a discharge fee of US$ 5/1.5 m^3 was introduced (Table 4). This increased the OPEX for the user interface and containment by 0.5% (Scenario 2, Figure 2). The OPEX for the emptying and transport rose by US$ 28,779 due to the introduction of a discharge fee, while the revenue increased by US$ 11,512. The revenue nearly covers the OPEX for this part of the SVC (Scenario 2, Figure 2). The treatment revenue increased from US$ 9,000 to US$ 37,780, this covers approximately a quarter of the OPEX, hence further

budget support is required for this scenario and FFM to be financially sustainable.

Scenario 3 takes a multipronged approach to obtaining financial sustainability and introduces an annual sanitation tax of US$ 50 (Table 4). This increased the OPEX for the user interface and containment by 32%, which would probably be unpopular, but it should be noted that this was US$ 4.16/month and equates to 1.5% of the minimum wage (of US$ 275) in Thailand. As the financial flows for emptying and transport remain the same as in Scenario 2, it can be seen that this portion of the SVC remains financially unsustainable. The sanitation tax was used as budget support for treatment, which means for the first time this part of the SVC becomes financially sustainable, both the CAPEX and OPEX are recovered (Scenario 3, Figure 2) with a payback time of 29 months. In Scenario 4, the discharge fee was removed and a discharge license was introduced (Scenario 4, Table 4). This led to a significant reduction in the OPEX for emptying and transport, hence this part of the SVC becomes more financially sustainable, with a payback period of approximately 13 years. Although the removal of the discharge fee reduced the revenue for treatment this part of the SVC was financially sustainable, due to the budget subsidy provided by the sanitation tax.

From the scenarios explored (Figure 2), Scenario 4 was the most financially sustainable along the SVC from

emptying to treatment, due to the use of a sanitation tax to provide a budget subsidy for the treatment process. The results gained in Figure 2 can be used to explore further scenarios, i.e. from the results it can be estimated that if the sanitation tax were halved to US$ 25/household/year, that the payback time would be approximately five years, which was still a reasonable period.

The validation process showed that eSOSView™ could be used to model the financial flows between different components of the SVC and that the results gained were <0.5% different compared to an existing case study. The piloting showed that eSOSView™ has the potential for optimising financial flows along and within components of the SVC. This process did not explore changing the components of the system, e.g. the number of collections per truck per day. As more data would be required on the context, logistics, and current practices. It was noted that the faecal sludge treatment plant may be working under capacity, but this could not be confirmed. It is clear is that the financial implications of these changes could be modelled using eSOSView™.

Piloting

As eSOSVeiw™ had been validated, using secondary data, the next step was to pilot it meaning collecting and evaluating data from a city where the financial sustainability of faecal sludge management had not been documented. It was noted that a significant amount of detailed data was required to do this and it took approximately three months to collect this data. Some of the data required could be deemed as sensitive, e.g. income or emptying fee, and when data were not available estimates were made that were verified during the stakeholder workshop (Shrestha 2018).

The existing sanitation value chain in Pokhara Metropolitan City

The household survey (*n = 50*) revealed that 86% of respondents had unlined pits and the remaining (14%) had septic tanks (Shrestha 2018). As the majority of the toilets were in the home, the CAPEX of the superstructure and containment were not included in the simulations. Approximately half of containment systems surveyed had a volume of >10 m^3, particularly in peri-urban and residential areas. The emptying frequency was found to be low, due to the liquid in all systems infiltrating into the ground. Almost

80% of the survey households had never emptied their containment systems (Shrestha 2018).

A private company was contracted by the city to provide the emptying and transport services. This company had five vehicles, tractors connected with locally built metal tanks of 6 m^3 and fitted with suction pumps. Their main customers were restaurants and hotels in the tourist area, with peak demand during the tourist season. The average emptying fee was NPR 5,290 (US$ 51.3) per trip, which equates to US$ 8.55/m^3. This is about average when compared to services in other Asian and African cities, where the emptying fees ranged from US$ 3/m^3 in Bobo Dioulasso to US$ 13/m^3 in Addis Ababa (Chowdry & Kone 2012). From January to September 2017, the company emptied a total of 1,248 systems (Shrestha 2018). The E&T Company operates 7 days a week (except on festivals), which equates to 139 desludgings per month. The emptying of containment systems takes approximately 30–45 minutes with two staff. The emptied faecal sludge was transported to the faecal sludge treatment plant, located at Bachhe-buruwa, which is approximately 10 km from the city centre. The whole emptying and transport process takes between 2 and 2.5 hours, including discharge at the treatment plant where they pay a tipping fee of NPR 1,000 (US$ 9.7) per trip.

The faecal sludge treatment plant was located at the landfill in Pokhara, which treats both faecal sludge and landfill leachate. The co-treatment plant consists of a sludge drying bed (1,645 m^2), followed by horizontal flow constructed wetlands (1,180 m^2) and vertical flow constructed wetlands (1,500 m^2). The treatment plant was designed to treat 70 m^3 faecal sludge and 40 m^3 landfill leachate per day. A private company was contracted to manage the sludge from the drying beds, they remove the dried sludge and dispose of it at the landfill site.

Development and analysis of the existing financial flow model in Pokhara Metropolitan City

The existing FFM for the SVC in the city resembles FFM 1 (Tilley & Dodane 2014), but the treatment was divided into two operations, due to a private company (entity) managing the sludge from the drying beds (Figure 3). This new FFM was created in eSOSView™ and validated at the stakeholders workshop.

Detailed financial data were collected from the E&T Company (Figure 4(a) and 4(b)), the total CAPEX was US$ 128,056 (Figure 4(a)) and the total OPEX was US$ 67,384/year (Figure 4(b)).

The daily average volume of faecal sludge emptied and transported was 28 m^3/day (4.67 trips/day) and the average
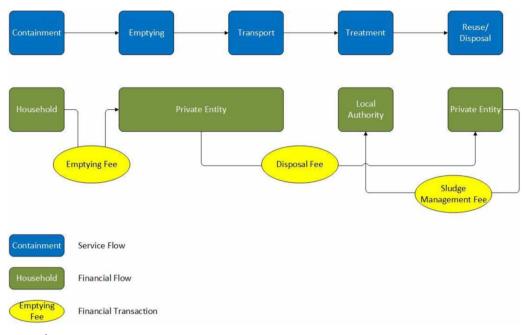
Figure 3 | Existing financial flow model for Pokhara Metropolitan City in Nepal in 2017.
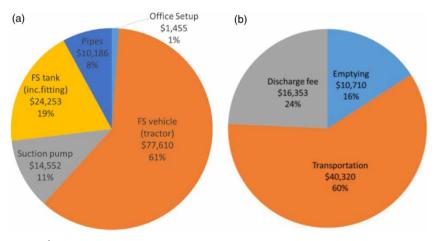

Figure 4 | (a) E&T Company CAPEX in US$ Pokhara Metropolitan City, Nepal. (b) E&T Company OPEX in US$ per year Pokhara Metropolitan City, Nepal.

tariff was US$ 8.55/m^3. The annual revenue calculated was US$ 85,304 (Baseline, Table 5). Considering depreciation of US$ 16,589/year (5 years depreciation period for emptying and 15 years for transportation) and financing cost of US$ 15,367 per year (cost of capital 12% annually), the emptying and transport business had a net loss of US$ 14,036/year (Baseline, Table 5). This was interesting, as emptying and transport are generally thought to be the most profitable part of the SVC (Kome 2011). The primary reason for the loss was that the E&T Company was operating under capacity, each vehicle was only emptying one containment system per day. The company continued to run the service

for the city, as it improved its relationship with the local government.

To establish the CAPEX of the treatment plant for 2017, the base year of the plant was chosen as 1999 and the CAPEX was assumed to be labour (40%) and construction materials (60%). The difference in the cost in labour and construction materials from 1999 to 2017 was ascertained from the Consumer Price Index (Nepal Rastra Bank 2017). The average increase in cost for labour was 25.5% per year and for construction materials was 12.0% per year, the cost of the plant for 2017 was calculated to be US$ 345,293. The cost of land was assumed to be US$ 38.14/m^2 (Neupane

Table 5 │ Results from eSOSView™ for Pokhara Metropolitan City (PMC)

Part of SVC	Financial parameter	Baseline (FFM PMC)	Scenario 1 (FFM 1)	Scenario 2 (FFM 2)	Scenario 3 (FFM 3)	Scenario 4 (FFM4)	Scenario 5 (FFM5)	Scenario 6 (FFM PMC)
Superstructure and containment	OPEX	5,285,352	6,617,789	6,617,789	6,855,681	6,855,681	6,855,681	6,617,789
Emptying and transport	CAPEX	128,056	537,835	Emptying, Transport and Treatment	537,835	537,835	537,835	537,835
	OPEX	67,384	483,234		483,234	225,145	225,145	483,234
	Revenue	85,304	1,417,741		1,417,741	1,417,741	1,471,355	1,417,741
	Net profit loss	−14,036	619,544		619,544	813,111	853,322	619,544
Treatment	CAPEX	535,794	3,476,795	4,014,629	3,476,795	3,476,795	3,476,795	3,476,795
	OPEX	746	190,753	405,397	190,753	190,753	244,367	56,120
	Revenue	9,701	277,542	1,426,694	515,434	257,345	257,345	170,106
	Net profit loss	554	65,092	607,997	243,511	49,944	9,734	85,489
Reuse and disposal	CAPEX	1,000	N/A	N/A	N/A	N/A	N/A	1,000
	OPEX	16,776						295,786
	Revenue	16,353						277,542
	Net profit loss	−576						−18,397

2015) and the cost of land was calculated as US$ 190,500. The total CAPEX was calculated to be US$ 535,793 (Baseline, Table 5). Since the plant was subsidized from government funding from the Asian Development Bank loan under the Pokhara Environmental Improvement Project, 10% of the total CAPEX was considered to be funded by the city.

The OPEX of the treatment plant comprised regular activities, whereas the cost of periodic removal of sludge from the drying beds was placed under Reuse/Disposal (Baseline, Table 5). The OPEX of the plant comprised personnel costs and electricity which were calculated to be US$ 746/year (Baseline, Table 5). The revenue of the plant was the sludge management fee paid by the private company, which amounts to US$ 9,701/year. Considering the depreciation period of 30 years and 12% cost of capital, the data revealed that the plant can generate a net profit of US$ 554/year (Baseline, Table 5).

The private company used the equipment and facilities of the faecal sludge treatment plant and did not have significant CAPEX, but a nominal amount of US$ 1,000 for basic equipment was assumed. The OPEX was calculated as US$ 16,776/year (Baseline, Table 5), which primarily comprises labour cost and the sludge management fee paid to the city, and the revenue was US$ 16,353/year (only disposal fee). Considering 30 years as a depreciation period and 12% cost of capital, the financial analysis showed a net loss of US$ 576/year.

It was found that overall the SVC in Pokhara Metropolitan City was not financially sustainable, with a net loss of US$ 14,057/year (Baseline, Table 5). The only profitable part was treatment, due to subsidy gained for the CAPEX.

Scenario development in Pokhara Metropolitan City

A stakeholder workshop was used to explore different FFM for future implementation of faecal sludge management in Pokhara Metropolitan City. The workshop was used to create a situation that met the needs of all of the stakeholders along the SVC.

To minimise groundwater pollution from the containment systems, it was assumed that all containment systems would be rehabilitated or constructed to work as a septic tank of 7 m^3 capacity and with a desludging frequency of five years. The number of emptying and transport vehicles required to provide emptying services was calculated to be 21, which would generate 454 m^3 of faecal sludge per day. It was assumed that a new faecal sludge treatment plant would be constructed to meet this capacity and that it was fully subsidised by the government as before. For the revenue, a license fee of US$ 500/vehicle/year was adopted for faecal sludge entrepreneurs instead of charging them a discharge fee. The fee was similar to those used in other countries, e.g. Kenya US$ 432–600/truck/year (Bill and Melinda Gates Foundation 2011) and Nigeria US$ 193–1,111 /year (Sridhar *et al.* 2011). For sludge management, the E&T Company pays a discharge fee per trip to the sludge management firm, which pays a fixed service fee to the municipality each year.

This above data was then entered into the eSOSView™ so the financial flows for the standardised models and the adapted FFM for Pokhara Metropolitan City could be analysed. The results gained can be found in Table 5.
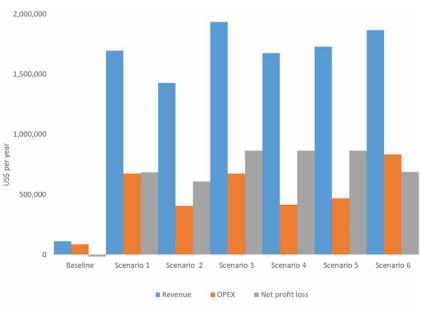
Analysis of future scenarios

The highest increase in OPEX of superstructure and containment was a 3.6% increase in Scenarios 3, 4, and 5 (Table 5), due to the addition of a sanitation tax. This equated to an increase of US$ 2/ year/household or 0.13% of the minimum wage (US$ 130.5 per month) in Nepal (Government of Nepal 2018). Although this seems reasonable, households might dislike these models.

In Scenario 2 the emptying, transport and treatment are combined, hence the CAPEX was significantly higher (Scenario 2, Table 5). Scenario 5 gave the largest profit for the E&T Company (Scenario 5, Table 5), as no discharge fee and only a nominal license fee was paid, but discharge incentive for disposal was given. Scenario 3 was favourable for the treatment component of the SVC, due to the added revenue from the sanitation tax (Scenario 3, Table 5). Scenarios 4 and 5, which also include a sanitation tax, are not as profitable as the discharge fee was replaced by a license fee. If the discharge license were to be fixed closer to the total annual discharge fee, then these two FFMs would be competitive with FFM 3. Even though it was assumed that the sludge management company was given

60% of the service fee for the faecal sludge treatment plant, this component does not become profitable (Scenario 6, Table 5).

When the whole SVC was considered, Scenario 3 (FFM 3) has the highest revenue, while Scenario 6, which uses the current FFM for Pokhara Metropolitan City, has the highest OPEX (Figure 5). Scenarios 3, 4, and 5 have the same net profits (Figure 5) and are therefore appropriate in this area. However, consideration has to be paid to other criteria such as the capacity of the stakeholder to implement more complex models (which include a sanitation tax), compatibility with existing policies and regulations, public acceptance, etc.

The workshop was the first opportunity the stakeholders had to come together to discuss financing faecal sludge management. Presenting the current FFM (Figure 3) and the baseline scenario generated by eSOSView™ (Baseline, Table 5 and Baseline, Figure 5), stimulated a lively discussion on the need for the whole SVC to be financially sustainable, as previously each component of the SVC was considered separately by individual stakeholders. The workshop gave the stakeholders space to discuss current issues in this field, such as the closure of the current faecal sludge treatment plant and the effect of the change in administration structure and processes (as Nepal was becoming a federal structure). Some of these issues were taken into consideration when the future scenarios were modelled, e.g. construction of a new faecal sludge treatment plant. All of

Figure 5 │ Financial sustainability along the sanitation value chain excluding superstructure and containment.

the assumptions required to model the future scenarios (Table 5, Figure 5) were validated by the appropriate stakeholders during this workshop. The validation of data required for eSOSView™ with stakeholders was not easy due to some of the data being sensitive. Within the workshop, novel ideas (for Nepal) were discussed such as scheduled emptying and funding through a sanitation tax. This generated a lively discussion, especially around the sanitation tax as stakeholders had concerns about the resident's willingness to pay a tax for such a service.

Although a substantial amount of data and time was required to model the financial flows using eSOSView™, the data requirements are similar to other financial tools such as SaniPlan (PAS, N.D c). Some tools have guidance on data collection and similar guidance needs to be developed for eSOSView™. The current version of eSOSView™ needs to be made more user friendly, as the Excel version is quite complex. Any future version of eSOSView™ also need to retain the function of allowing the user to build novel financial flows, as this was found to be very useful in the Nepalese case study. It becomes clear when using eSOSView™ that the financial flows along the SVC are context-specific. As financial sustainability is only one aspect of overall sustainability, social and environmental aspects need to be considered if the SVC is to become be truly sustainable.

CONCLUSION

This paper demonstrates that eSOSView™ worked and was used to successfully model the current financial flows in two case study cities. In one case, a novel FFM was developed within the tool. It demonstrates how this tool can be used to support the process of making the SVC financially sustainable in a number of ways, by changing the financial parameters, by exploring the most financially sustainable FFM and by changing the input parameters (modelling future scenarios). It was noted that a substantial amount of data were required, but this was comparable to the data required for other tools. It shows how the process can be used to engage stakeholders and stimulate discussion on the topic of the SVC and financial sustainability. It was noted that stakeholder engagement was critical as it enabled data, new models and assumptions to be validated. The results demonstrate that the eSOSView™ can be used to optimise the financial sustainability, but it also highlights that the model chosen needs to be contextually appropriate, taking into account the other pillars of sustainability

especially the social aspects. eSOSView™ shows great potential for more realistic and fact-based sanitation planning, as it enables the exploration of financial sustainability for sanitation projects and programs both in the development and humanitarian sectors.

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DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories at https://cdm21063.contentdm.oclc.org/digital/collection/masters2/id/81082 and https://repository.tudelft.nl/islandora/object/uuid:91c635b5-a35a-4d25-a874-b4dc8094579e?collection=research.

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