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This case study is based on the Life Cycle Cost Analysis (LCCA) project carried out by the Citywide Inclusive Sanitation Technical Assistance (CWIS TA) Hub for South Asia. CWIS TA Hub is an initiative of the Bill and Melinda Gates Foundation that provides rapid technical assistance to international financing institutions, governments, and development partners in the planning, design, and implementation of CWIS projects.

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Introduction

Networks of pipes connected to households that collect and transport generated domestic wastewater to a point where it is treated are usually called sewered sanitation (SS) systems and are the most commonly sought-after solution for wastewater management. While such arrangements generally provide safe sanitation (Sustainable Development Goal [SDG] 6.2), SS systems are not yet feasible in many low- and middle-income countries. While lack of technical capacity plays some role, the most significant impeding factor is the financial cost. The cost of installing and expanding sewer networks is higher than for the non-sewered sanitation (NSS) components. A study conducted in Dakar shows that the combined capital and operating costs for sewered-based sanitation is about five times higher than the costs for non-sewered-based sanitation (Dodane et al. 2012).

As the timeline for the SDGs draws closer, annual progress toward achieving SDG-6 targets is just 1%, while at least 3% progress is required to ensure that as a minimum basic sanitation for all is achieved by the end of 2030 (UN-Water 2020). Given this situation, sanitation provision has become an even more pressing issue in low- and middle-income countries (LMICs). Cities in LMICs typically do not have safe, accessible, and sustainable sanitation. These cities could choose to improve their sanitation situation by implementing sewer-based sanitation systems, but these will only serve a certain percentage of the population that can afford these services. The rest of the population, who live in vulnerable areas and have few economic opportunities, are still left behind from having access to safe and sustainable sanitation.

While decision makers face difficulties in planning sanitation interventions, the sanitation profile of these cities in LMICs also presents challenges. In these cities, non-sewer or sewer-based sanitation is limited to the city center with non-sewered sanitation (NSS) using different on-site sanitation systems (OSSs) such as pits and septic tanks in most of the urban and peri-urban areas. Until the waste generated by these OSSs is safely contained and treated on-site or transported and treated off-site, it is not considered safe sanitation. Given the interconnected service chain for NSS, this can also take on several forms of management profiles, posing challenges for overall planning and implementation effectiveness.

So what is the right sanitation solution for a city? How much do these measures really cost the citizens, the government, or the private sector? Would financial figures alone be enough to provide planning guidance and justify the selection of sanitation interventions for a city? These are some of the questions that decision makers often face and for which they need some evidence-based results to inform their decision-making. To help the city government make an informed decision on sanitation interventions, an economic analysis of different sanitation scenarios was conducted for one of the cities in Nepal.

Financial figures alone may not be sufficient to justify the need for sanitation interventions, as the financial burden of citywide sanitation projects such as the installation of infrastructure required for fecal sludge management and, in particular, the installation or expansion of the sewer network, is usually higher. They also have a running cost and sometimes their only sources of revenue are tariffs. Although there is a potential revenue source from the reuse of treated wastewater and treated end product from fecal sludge management, the market is still underdeveloped and unexplored. However, the financial analysis only looks at the monetary value, but does not capture the benefits of improved wastewater sanitation in place. These benefits can stretch across several sectors, and spillover benefits are difficult to define in monetary value in financial analysis. Therefore, to understand the impact of implementing sanitation projects in the true sense, a cost–benefit analysis (CBA) was conducted for three sanitation scenarios: 100% SS, 100% NSS, and hybrid—a combination of both SS (30%) and NSS (70%).

Objective

The overall objective of this study is to understand the economic viability of sanitation interventions through a CBA of different sanitation scenarios in the Mahalaxmi municipality.[1] This study was conducted from the perspective of three different stakeholders: the residents, the private sector, and the government.

Limitations of this Study

Due to the lack of sufficient and detailed data, other likely benefits from the implementation of sanitation interventions such as impact on economic activity and time savings were not considered in this study. Reductions in the incidence of diarrheal diseases and deaths among the under-5 population and the resulting health benefits for the entire municipal population are the only benefits considered in this study.

Study Area

Mahalaxmi municipality, in the Lalitpur district of Nepal was selected as the study area. This municipality was also a project site for ISO 24521[2] and generated a variety of up-to-date city and demographic data to provide a more realistic analysis of sanitation scenarios. The availability of credible data was the reason Mahalaxmi was selected for this study. This municipality has a total population of 144,820 (2019) living in an area of 26.5 square kilometers (km^2) and has a sewerage network that serves about 32% of the population, while the rest of the population depends on the NSS system. Currently, the municipality does not have a wastewater treatment plant and is in the process of installing a fecal sludge treatment plant for the management of fecal sludge generated in the municipality.

Methodology

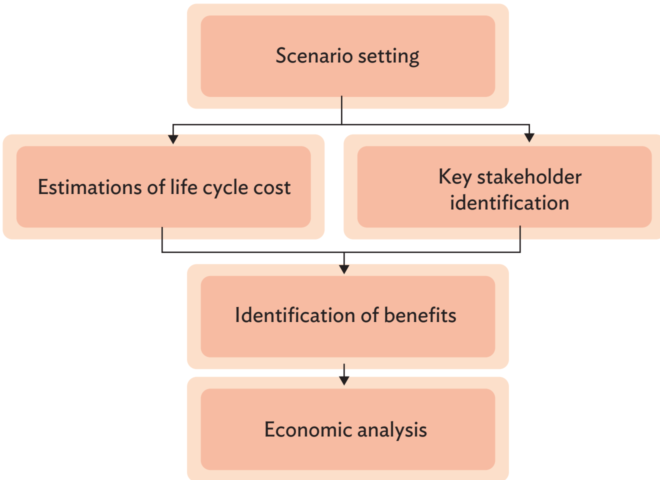
The economic analysis using CBA for Mahalaxmi was performed based on available secondary data. The overall process began with setting assumptions for key CBA parameters, setting sanitation scenarios, identifying key stakeholders, estimating life cycle costs and benefits, and finally conducting the economic analysis, as shown in Figure 1.

CBA is an analytical framework for converting the costs and benefits of a project into comparable monetary units so that they can be systematically compared and incorporated into a measure of project worth (ADB 2013). CBA compares the costs and benefits using a basic net present

1 "City" and "municipality" are used interchangeably in this case study.

2 ISO 24521 refers to the guidelines for on-site management of basic domestic wastewater services.

Figure 1: Overall Process Adopted for Cost–Benefit Analysis



Source: Citywide Inclusive Sanitation Technical Assistance Hub (2020).

value (NPV) formula (net present benefit – net present cost), and values with a positive NPV are considered favorable project values.

The assumptions for the key CBA parameters in this study are as follows:

(i) **Baseline mortality** (BL_mort) and **baseline morbidity** (BL_morb) cases are only considered for the population under 5 years of age in Mahalaxmi municipality.

(ii) **Individual beneficiary population** (ind_ben) considers all household members with a 5-year-old child. Although the baseline morbidity for the under-5 population is only 5,125, it is assumed that the risk of contagion is still prevalent for all under 5-year-olds in Mahalaxmi, i.e., 14,643 individuals. Considering a family size of five persons in Mahalaxmi, the total number of beneficiaries is assumed to be at most 73,215.

(iii) **Change in disease incidence rate** (DI) after the implementation of these sanitation interventions is assumed to be 25% for Mahalaxmi. In the absence of actual data on improved water quality and reduction in the incidence of diarrheal diseases for Mahalaxmi, this value is based on a literature review (Wolf et al. 2018).

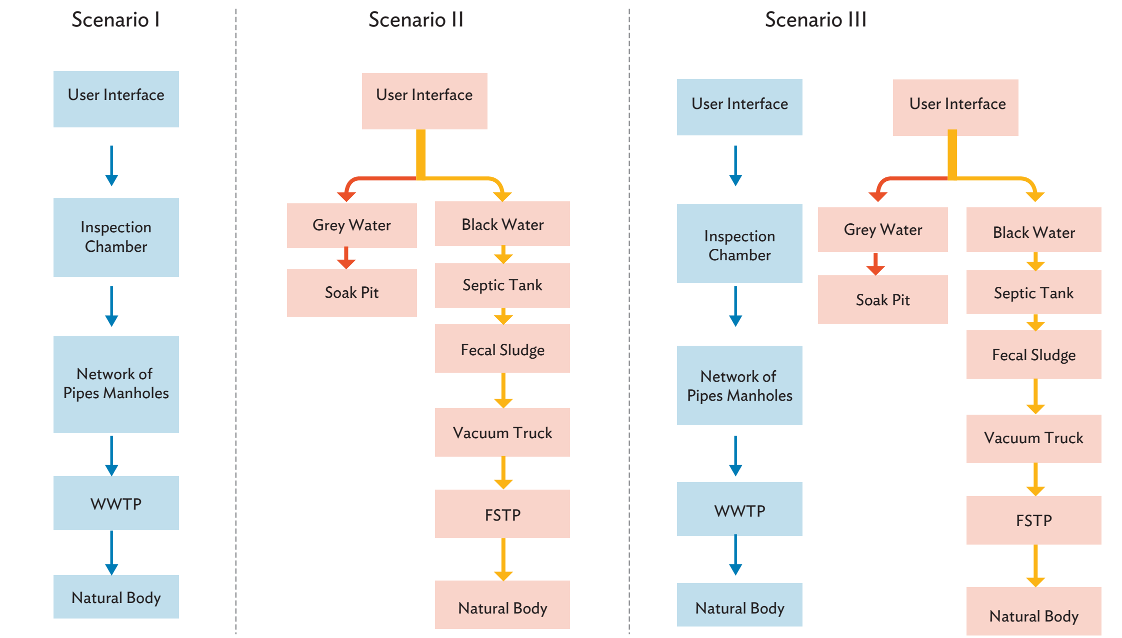
(iv) In the absence of local data, **value of statistical life** (VSL) for Nepal was estimated using the benefits transfer formula, which takes into account the VSL value for the United States provided by the Environmental Protection Agency, the ratio of GDP_{Nep} and GDP_{US}, and the income of elasticity for VSL (Tan-Soo 2021).

(v) In the absence of local data, standard value for parameters such as **income elasticity for VSL** I and **cost of incidence** (COI) for diarrheal diseases were selected.

Scenario Setting

Considering the existing scenario of Mahalaxmi, where 32% of the population is already served by sewered sanitation systems and the rest by NSS, three different sanitation scenarios were designed. The first two sanitation scenarios assume an expansion of sanitation interventions that is either 100% SS or NSS, while the third is a hybrid scenario that reflects the expansion of sanitation interventions according to the existing sanitation situation of the municipality, shown in Figure 2.

Figure 2: Sanitation Scenarios for Cost–Benefit Analysis



FSTP = fecal sludge treatment plant, WWTP = wastewater treatment plant.
Source: Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Estimation of Life Cycle Costs

For each of these sanitation interventions and their components along the value chain, reference was made to an earlier study in Mahalaxmi (Citywide Inclusive Sanitation Technical Assistance Hub 2020). Life cycle costs were estimated using a 20-year design period. A description of the scenarios and assumptions required for system design is presented in Table 1. Life cycle cost is an approach that assesses the total cost of an asset over its life cycle, including initial capital costs, maintenance costs, operating costs, and the asset's residual value at the end of its life (Sesana and Salvalai 2013).

Table 1: Details of Sanitation Scenarios

	Scenario 1: 100% Sewered Sanitation (SS)	Scenario 2: 100% Non-Sewered Sanitation (NSS)	Scenario 3: Hybrid Situation
Description	This scenario considers that Mahalaxmi is served only by SS, i.e., all existing and upcoming households are connected to the sewer network by 2040. The sewer network will safely collect and transfer wastewater to the designated wastewater treatment plants (WWTPs). Wastewater is treated and disposed of safely.	This scenario considers that Mahalaxmi is served only by NSS, i.e., all existing and upcoming households will have their toilets connected to a standard septic tank by 2040. The fecal sludge accumulated in the septic tanks will be mechanically emptied with a desludger and transported to the fecal sludge treatment plant (FSTP). The treated product is disposed of safely.	This scenario considers the existing situation, i.e., 32% connected to SS and 68% to NSS, also for future projections. WWTPs and FSTPs both exist in this scenario.
Design population	**2020** (base year): 144,820; **2040** (design year): 312,811		
Building types	Residential/Mix (94%), commercial (3%), industrial (1%), others (2%)		
Building growth rate		5.8%	
Inflation rate		6.7%	
Discount rate		6.7%	
Tariffs	Residential/Mix: $2.17 Commercial: $5.67 Industrial: $1.01 Other: $8.13	$1.43 (irrespective of building types)	Combination of scenarios 1 and 2

SS = sewered sanitation, NSS = non-sewered sanitation.

Source: Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Identification of Key Stakeholders

For the economic analysis, this project considered three specific stakeholders: the residents, who receive sanitation services but also pay for them; the private sector which usually bears some risk as a service provider and fills the gaps of the public service provider; and finally, the government which is the main responsible stakeholder for the provision of sanitation services and is more concerned with social welfare than with financial benefits and returns. The estimated life cycle costs for the sanitation value chain were also determined according to the responsible stakeholders. Each of their roles in the sanitation scenarios was set and is shown in Table 2.

Table 2: Roles of Stakeholders according to Sanitation Scenarios

Scenario	Residents	Private Sector	Public Sector
Sewered sanitation (SS)	Responsible only for the construction and maintenance of an inspection chamber for connection to the sewer network. Pays the wastewater tariffs along with the water bill.	Plays a minimal role: assists in the construction of the inspection chamber.	Responsible for CAPEX and OPEX of the sewer networks and treatment plants. Pays 10% of CAPEX of inspection chambers and containment systems for LICs.
Non-sewered sanitation (NSS)	Solely responsible for construction and maintenance of the on-site sanitation system (OSS). Responsible for desludging the OSS and paying monthly sanitation fees to the government.	Service provider for desludging and transportation services. Responsible for required CAPEX and OPEX.	Responsible for CAPEX and OPEX of fecal sludge treatment plants. Pays 10% of CAPEX of containment systems for LICs. Government engages the private sector to provide desludging services.
Hybrid	Population served by SS is responsible for the construction and maintenance of an inspection chamber. Population served by NSS is responsible for the construction and maintenance of the OSS. Responsible for desludging the containment systems. Responsible for payment of fees to the government along with the water bill and monthly sanitation fees.	For areas served by an SS system, responsible for construction support of the inspection chamber. For areas served by an NSS system, service provider for desludging and transportation services. Responsible for required CAPEX and OPEX.	Responsible for CAPEX and OPEX of wastewater treatment plants and fecal sludge treatment plants. Pays 10% of CAPEX of inspection chambers and containment systems for LICs. Government engages the private sector to provide desludging services.

CAPEX = capital expenditure, OPEX = operating expenditure, LICs = low-income community.
Source: Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Identification of Benefits

Improvements on health through reduced mortality and morbidity cases due to a decrease in diarrheal disease were considered benefits of these sanitation interventions. Based on these assumptions for CBA, the actual benefits from reduced mortality and morbidity in Mahalaxmi were estimated for the entire design period. A list of parameters and estimated values for the baseline year can be found in Table 3, while the detailed calculation for the entire design period can be found in the Appendix. The present value benefits from reduced mortality and morbidity for Mahalaxmi were estimated to be $16,432,366 for the entire design period.

Table 3: Cost-Benefit Analysis Parameters and Estimated Values for the Base Year, 2020

Baseline information for Mahalaxmi (2020)		
Parameters	Standards	Estimated Values
Total population		144,820
Total under-5 population		14,643
Baseline morbidity (BL_morb)[a]	350 per 1,000 i.e., 35%	
Baseline mortality (BL_mort)[a]	74 per 100,000	
Individual beneficiary population		73,214
Change in disease incidence rate (DI)	0.25	
Income elasticity for VSL (e)[b]	0.55	
VSL_{US}	7,400,000	
GDP_{US}	63,544	
GDP_{Nep}	1,555	
VSL_{Nep}	961,599	
COI[c]	37	
Att-morb	ind_beneficiary/ population *BL_morb	2,591
Att-mort	ind_beneficiary/ population *BL_mort	5.48
Reduced mortality	USD (DI*Att-mort* VSL_{Nep})	1,316,896
Reduced morbidity	USD (DI*Att-morb*COI)	23,966
Total benefit ($)		16,432,366

COI = cost of incidence, GDP = gross domestic product, VSL = value of statistical life.

[a] Department of Health Services (2019).
[b] Viscusi and Aldy (2003).
[c] Baral et al. (2020).

Source: Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Results and Discussion

Life Cycle Cost

Total project costs were divided into four specific categories: revenue, direct expenses, capital expenditure (CAPEX), and operating expenditure (OPEX), which would be borne by the various stakeholders under different sanitation scenarios. The rates presented in this study are discounted to net present value at 6.7%.

Revenue

Households are responsible to pay for both sewered and non-sewered services tariffs. A total of $17,431,997 was collected for the SS scenario, $11,111,853 for the NSS scenario, and $14,313,222 for the hybrid scenario, throughout the project period. The tariffs for the sewered scenario are higher compared to the other two scenarios, mainly because a differential tariff system based on household types was implemented, with part of the monthly water bill allocated to sanitation. However, in the NSS scenario, a uniform tariff of $1.43 per month (Rs4,000/desludging/2 years) was collected from all households as sanitation fees.

Direct Expense

This expense is incurred for project development and is included in CAPEX. These costs were incurred by the public sector in all three scenarios. A total of $11,848,720 was observed for the SS scenario; $551,584 for NSS; and $8,731,143 for the hybrid scenario. This shows that the project development costs for sewered sanitation are more than 20 times the costs for the NSS scenario, mainly due to the intensive design and planning required to lay the sewer network. For the hybrid scenario, these costs are about 1.3 times lower than for the SS scenario, since majority of the municipal area (70%) will be served by the NSS.

Capital Expenditure and Operating Expenditure

As mentioned earlier, different stakeholders are responsible for covering the CAPEX and OPEX of the sanitation components depending on the scenario, as shown in Table 4 and Table 5, respectively. Most of the costs in the sewered situation, i.e., the construction of the sewage treatment plant and the laying of the sewer network, are borne by the public sector, while in the NSS the construction of containment systems is the responsibility of residents. The role of the private sector is observed only in the NSS scenario and the NSS component in the hybrid scenario, but is completely absent in the SS scenario. One of the main reasons for this is the separate components of the sanitation value chain in the NSS, which entail the possibility of private sector engagement and the distribution of total project costs. In this study, following the current in practice in Nepal, treatment plants are constructed by the public sector as part of its mandate to provide sanitation services to the public. This is another reason why the public sector takes the majority of the investment in all scenarios.

As shown in Table 4, CAPEX for the SS scenario is 1.8 times higher than for NSS and 1.01 times higher than for hybrid sanitation scenario.

Table 4: Capital Expenditure of Sanitation Components in Each Scenario

	SS	NSS	Hybrid
Project development cost	$11,848,720	$551,584	$8,731,143
Inspection chamber	$19,124,394		$32,755,262
Containment[a]		$95,965,984	$41,988,258
Conveyance	$44,048,650		$22,777,724
Emptying/Transport		$680,378	$333,911
Sewage treatment plant	$112,384,850		$71,742,908
Fecal sludge treatment plant		$7,158,548	$2,966,622

Public sector
Residents
Private sector

NSS = non-sewered sanitation, SS = sewered sanitation.

[a] 10% of the households covered by the public sector to address the low-income communities in the area.

Sources: Authors; Citywide Inclusive Sanitation Technical Assistance Hub (2020).

In terms of OPEX, as shown in Table 5, it can be observed that households in the NSS scenario and households served by NSS in the hybrid scenario are solely responsible for managing their containment systems. This cost is about two times the cost of all other components of the value chain in all three scenarios combined. There is no OPEX for households in the SS scenario and households served by SS in the hybrid scenario because the toilets are directly connected to the sewer network through an inspection chamber, whose OPEX was minimal or close to zero and was not considered in the study. The other components of the value chain, such as conveyance and sewage treatment plants in sewered areas in the SS and hybrid scenarios, fall under the public sector. In both scenarios, the cost is covered by the tariffs paid by households as monthly bills. In the NSS scenario and the hybrid scenario with non-sewered areas, the emptying fees are part of the household costs paid as monthly bills. The public sector procures the private sector to provide emptying and transport services, with truck operation and maintenance being the sole responsibility of the private sector. The tariffs are paid directly to the public sector, which then passes on the associated costs to the private sector. This is the reason why these cost items are still marked as public sector investments in Table 5. Fecal sludge treatment plants are considered a public sector cost in both the NSS and in hybrid scenarios, as are sewage treatment plants in the SS scenario, since they are also a public sector service.

Table 5: Operating Expenditure of Sanitation Components in Each Scenario

	SS	NSS	Hybrid
Containment		$77,156,020	$36,654,034
Conveyance	$5,711,519		$2,918,052
Emptying/Transport*		$12,491,871	$5,523,562
Sewage treatment plant	$11,671,854		$9,037,079
Fecal sludge treatment plant		$719,658	$274,936

Public sector
Residents
Private sector

NSS = non-sewered sanitation, SS = sewered sanitation.
* Partly covered by the private sector and partly by the public sector.
Sources: Authors; Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Cost–Benefit Analysis

As mentioned earlier, the improvement in health through the reduction in mortality and morbidity cases due to the decrease in diarrheal diseases was considered the only benefit of these sanitation interventions. The total health benefit from the reduction in mortality and morbidity was estimated to be nearly $16.5 million if a sanitation intervention is in place. However, the individual CBA analysis for the three scenarios differs depending on the individual costs incurred for putting these interventions in place. Benefits are also discounted to net present value at 6.7%. The CBA values for each scenario are shown in Figure 3, and detailed estimates can be found in Table 6. Values with positive NPV are considered a favorable project.

Figure 3: Net Present Values for All Scenarios for Cost–Benefit Analysis

Sources: Authors; Citywide Inclusive Sanitation Technical Assistance Hub (2020).

The CBA analysis presented in Figure 3 shows that only the NSS scenario seems feasible with a positive NPV of $5,127,803, while both the sewered and the hybrid scenarios are negative with $151,801,230 and $98,904,772, respectively. This study identified three reasons for this result:

(i) **Cost of implementing sewered sanitation.** In both scenarios, the cost of implementing sewered sanitation is higher than the estimated health benefits, especially for scenario I which is 100% sewered and scenario III which has only 32% sewered.

(ii) **Selection of benefits.** Due to the lack of sufficient data, this study considered only the reduction of diarrheal disease as one of the major benefits and estimated a value for it. However, if other benefits were considered (such as the impact on economic activity due to the presence of having these sanitation facilities situations in place), there could have been some positive or less negative NPVs, contributed to a higher benefit value. This in turn could have potentially affected the CBA results.

(iii) **Number of beneficiary population.** Considerations were made for the total and individual beneficiary population, which is under 5 years old in the municipality and represents only 10% of the total population. Thus, the factored benefit is small.

Table 6: Net Present Value Estimates for Cost-Benefit Analysis of Each Sanitation Scenario

Sewered Sanitation (SS)	Cost ($)	Benefit ($)
Residents		
Cost of inspection chamber ($)	19,124,394	
Reduced diarrhea-related illness		16,432,366
Tariffs paid for sewage charge	17,431,997	
Private sector		
Cost of inspection chamber ($)		19,124,394
Public sector		
Revenue collected for sewage charge		17,431,997
CAPEX for conveyance	44,048,650	
CAPEX for treatment	112,384,850	
OPEX for conveyance	5,711,519	
OPEX for treatment	11,671,854	
Cost for project development	11,848,720	
NPV (net present benefit – net present cost)	–	**151,801,230**

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Table 6 *continued*

Non-Sewered Sanitation (NSS)	Cost ($)	Benefit ($)
Residents		
Tariffs paid for desludging services along with the water bill	11,111,853	
CAPEX containment	86,951,802	
OPEX containment	77,156,020	
Reduced diarrhea-related illness		16,432,366
Private sector		
Revenue collected for desludging		10,297,475
Revenue collected from residents for the construction of containments		86,951,802
Revenue collected from the public sector for the construction of containments		9,014,182
Revenue collected from the OPEX of containments		77,156,020
CAPEX truck	680,378	
OPEX truck	2,194,396	
Public sector		
Revenue collected from households for desludging services along with the water bill		11,111,853
CAPEX for containment	9,014,182	
OPEX for desludging	10,297,475	
CAPEX for treatment plant	7,158,548	
OPEX for treatment plant	719,658	
Cost for project development	551,584	
NPV (net present benefit – net present cost)	**5,127,803**	

Hybrid (32% SS, 68% NSS)	Cost ($)	Benefit ($)
Residents		
Tariffs paid for wastewater along with the water bill	9,302,057	
Tariffs paid for desludging services together with the water bill	5,011,165	
CAPEX for inspection chamber	9,977,538	
CAPEX containment	38,008,949	
OPEX for containment	36,654,034	
Reduced diarrhea-related illness		16,432,366

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Table 6 *continued*

Hybrid (32% SS, 68% NSS)	Cost ($)	Benefit ($)
Private sector		
Revenue collected for desludging		4,484,400
Revenue collected from residents for the construction of inspection chambers		9,977,538
Revenue collected from residents for the construction of containments		38,008,949
Revenue collected from the public sector for the construction of containments		3,979,309
Revenue collected from the OPEX of containments		36,654,034
Revenue collected for desludging		4,484,400
CAPEX truck	333,911	
OPEX truck	1,039,162	
Public sector		
Revenue collected from households for wastewater along with the water bill		9,302,057
Revenue collected from households desludging services along with the water bill		5,011,165
CAPEX for containment	3,979,309	
CAPEX for conveyance	22,777,724	
OPEX for conveyance	2,918,052	
OPEX for desludging	4,484,400	
CAPEX for treatment plant – SS	71,742,908	
CAPEX for treatment plant – NSS	2,966,622	
OPEX for treatment plant – SS	9,037,079	
OPEX for treatment plant –NSS	274,936	
Cost for project development – NSS	1,186,818	
Cost for project development – SS	7,544,325	
NPV (net present benefit – net present cost)	–	**98,904,772**

CAPEX = capital expenditure, NPV = net present value, OPEX = operating expense.

Sources: Authors; Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Conclusions and Recommendation

A key conclusion from this CBA is that the NSS intervention is more favorable than the other two interventions, even when considering only the health benefits for a limited group of the population. However, a single solution will not be sufficient to meet the sanitation demand of the town. In this case, the municipality can aim for a hybrid scenario, but with the benefits considered in this study, the hybrid scenario still has a negative CBA. Therefore, it would be advisable to conduct further research on other benefits of sanitation services and interventions.

Other conclusions that can be drawn from this study include the following:

(i) The direct cost of the SS scenario is about 20 times higher than the NSS scenario, and the hybrid scenario is about 1.3 times lower than the SS scenario.

(ii) The CAPEX of the SS scenario is 1.8 times the cost of the NSS scenario and 1.01 times the cost of the hybrid scenario.

(iii) Although the public sector was the key stakeholder responsible for covering OPEX, in all three sanitation scenarios, with the private sector covering part of the OPEX, it was the households that were solely responsible for the OPEX of containment, which is about two times higher than all other components of the sanitation value chain combined. This shows that despite the higher CAPEX for the SS scenario, the NSS scenario turns out to be more expensive for the households.

(iv) Households are responsible for paying for services, and currently there are different tariffs imposed in the SS scenario. However, in the NSS, a flat tariff is imposed to all. However, to ensure equitable and accessible sanitation services for all socioeconomic groups, differentiated tariffs should be introduced.

(v) Private sector participation, as shown in the results above, is zero in the SS scenario and much of the cost is borne by the public sector, while in the NSS scenario, households bear most of the CAPEX and OPEX and the private sector has limited cost sharing with the public sector. In both SS and NSS scenarios, opportunities for increased private sector involvement should be explored so that costs can be shared.

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Appendix: Estimation of Reduced Morbidity and Mortality Rates as Health Benefits from the Implementation of Sanitation Services

	Remarks	2020	2021	2022	2023	2024	2025	2026
Population - projected for 2020		144,820	153,220	161,619	170,019	178,418	186,818	195,217
% of population below 5 years	Data from 2020	10.11%	9.99%	9.84%	9.67%	9.48%	9.27%	9.04%
Population of 5 years		14,643	15,492	16,145	16,735	17,258	17,709	18,091
Morbidity rate - National	With the morbidity rate of 350 per 1,000 i.e., 35%	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Total morbidity (cases) - baseline	< 5 years old (Source: Annual report on Department ofHealth Services 2076/2077)	5,125	5,422	5,651	5,857	6,040	6,198	6,332
Mortality rate - National	74 per 100,000 (Source: Annual report on Department of Health Services 2076/2077)	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074
Baseline mortality		10,836	11,464	11,947	12,384	12,771	13,105	13,388
Individual beneficary	Considering average hh size of 5	73,214	77,460	80,725	83,677	86,289	88,546	90,457
Change in Disease Incidence Rate	25%	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Att-mort	ind_beneficiary/ population *BL mortality	5.48	5.80	5.97	6.10	6.18	6.21	6.20
Att-morb	ind_beneficiary/ population *BL morbidity	2,590.92	2,741.19	2,822.40	2,882.82	2,921.27	2,937.78	2,934.00
e	standard	0.55	0.55	0.55	0.55	0.55	0.55	0.55
VSLus	EPA	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000
GDPus	USD per capita	63,544	63,544	63,544	63,544	63,544	63,544	63,544
GDPnep	USD	1,555	1,555	1,555	1,555	1,555	1,555	1,555
VSLnep	USD	961,599	961,599	961,599	961,599	961,599	961,599	961,599
COI	USD	37	37	37	37	37	37	37
reduced mortality	USD (DI*Att-mort*VSLnep)	1,316,896	1,393,276	1,434,550	1,465,263	1,484,807	1,493,198	1,491,275
reduced morbidity	USO (DI*Att-morb*COI)	23,966	25,356	26,107	26,666	27,022	27,174	27,139
Benefit	USD	1,340,862	1,418,632	1,460,657	1,491,929	1,511,828	1,520,372	1,518,414

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Appendix continued

	Remarks	2027	2028	2029	2030	2031	2032	2033
Population - projected for 2020		203,617	212,016	220,416	228,816	237,215	245,615	254,014
% of population below 5 years	Data from 2020	8.80%	8.56%	8.32%	8.07%	7.84%	7.84%	7.84%
Population of 5 years		18,407	18,662	18,867	19,029	19,154	19,248	19,906
Morbidity rate - National	With the morbidity rate of 350 per 1,000 i.e., 35%	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Total morbidity (cases) - baseline	< 5 years old (Source: Annual report on Department ofHealth Services 2076/2077)	6,442	6,532	6,604	6,660	6,704	6,737	6,967
Mortality rate - National	74 per 100,000 (Source: Annual report on Department of Health Services 2076/2077)	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074
Baseline mortality		13,621	13,810	13,962	14,081	14,174	14,244	14,731
Individual beneficary	Considering average hh size of 5	92,033	93,312	94,336	95,144	95,768	96,240	99,531
Change in Disease Incidence Rate	25%	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Att-mort	ind_beneficiary/ population *BL mortality	6.16	6.08	5.98	5.86	5.72	5.58	5.77
Att-morb	ind_beneficiary/ population *BL morbidity	2,911.84	2.874.75	2,826.24	2,769.35	2,706.44	2,639.70	2,729.97
e	standard	0.55	0.55	0.55	0.55	0.55	0.55	0.55
VSLus	EPA	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000
GDPus	USD per capita	63,544	63,544	63,544	63,544	63,544	63,544	63,544
GDPnep	USD	1,555	1,555	1,555	1,555	1,555	1,555	1,555
VSLnep	USD	961,599	961,599	961,599	961,599	961,599	961,599	961,599
COI	USD	37	37	37	37	37	37	37
reduced mortality	USD (DI*Att-mort*VSLnep)	1,480,013	1,461,159	1,436,505	1,407,589	1,375,614	1,341,689	1,387,573
reduced morbidity	USO (DI*Att-morb*COI)	26,935	26,591	26,143	25,617	25,035	24,417	25,252
Benefit	USD	1,506,947	1,487,751	1,462,648	1,433,206	1,400,648	1,366,107	1,412,825

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Appendix *continued*

	Remarks	2034	2035	2036	2037	2038	2039	2040
Population - projected for 2020		262,414	270,813	279,213	287,613	296,012	304,412	312,811
% of population below 5 years	Data from 2020	7.84%	7.84%	7.84%	7.84%	7.84%	7.84%	7.84%
Population of 5 years		20,564	21,223	21,881	22,539	23,197	23,856	24,514
Morbidity rate - National	With the morbidity rate of 350 per 1,000 i.e., 35%	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Total morbidity (cases) - baseline	< 5 years old (Source: Annual report on Department ofHealth Services 2076/2077)	7,198	7,428	7,658	7,889	8,119	8,349	8,580
Mortality rate - National	74 per 100,000 (Source: Annual report on Department of Health Services 2076/2077)	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074	0.00074
Baseline mortality		15,218	15,705	16,192	16,679	17,166	17,653	18,140
Individual beneficary	Considering average hh size of 5	102,822	106,114	109,405	112,696	115,987	119,279	122,570
Change in Disease Incidence Rate	25%	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Att-mort	ind_beneficiary/ population *BL mortality	5.96	6.15	6.34	6.54	6.73	6.92	7.11
Att-morb	ind_beneficiary/ population *BL morbidity	2,820.24	2,910.52	3,000.79	3,091.06	3,181.34	3,271.61	3,361.88
e	standard	0.55	0.55	0.55	0.55	0.55	0.55	0.55
VSLus	EPA	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000	7,400,000
GDPus	USD per capita	63,544	63,544	63,544	63,544	63,544	63,544	63,544
GDPnep	USD	1,555	1,555	1,555	1,555	1,555	1,555	1,555
VSLnep	USD	961,599	961,599	961,599	961,599	961,599	961,599	961,599
COI	USD	37	37	37	37	37	37	37
reduced mortality	USD (DI*Att-mort*VSLnep)	1,433,456	1,479,339	1,525,222	1,571,106	1,616,989	1,662,872	1,708,755
reduced morbidity	USO (DI*Att-morb*COI)	26,087	26,922	27,757	28,592	29,427	30,262	31,097
Benefit	USD	1,459,543	1,506,262	1,552,980	1,599,698	1,646,416	1,693,135	1,739,853
NPV	16,432,366							

COI = cost of incidence, EPA = Environmental Protection Agency, GDP = gross domestic product, hh = household, NPV = net present value, VSL = value of statistical life.

Sources: Authors; Citywide Inclusive Sanitation Technical Assistance Hub (2020).

Study Questions

1. This study considered only the health benefits of the sanitation scenarios. If there are sufficient data to estimate other likely benefits from implementing the interventions, how would incorporating additional benefits influence the results? What value would change?
2. This study examines the perspectives of three different key stakeholders. What would cost–benefit analysis look like for specific stakeholders, such as the private sector, under each scenario?

Note: In this publication, "$" refers to United States dollars.

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