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Developing and Testing a Citywide Inclusive Sanitation Financial Tool

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ABSTRACT

Citywide Inclusive Sanitation (CWIS) represents a paradigm shift in the provision of safely managed sanitation services with a framework of three outcomes—equity, safety and sustainability. There are several sanitation financial tools, but none of these fully address all CWIS outcomes. *C*itywide *I*nclusive *S*anitation *Fi*nancial *T*ool (CWIS-FiT) is an innovative decision-support tool designed to strengthen financial planning and integrate all CWIS outcomes. The tool captures both sewered and non-sewered systems, as well as low-income and non-low-income households, while accounting for non-infrastructure costs such as workforce safety and gender equity for sustainable sanitation. Applications in Kenya and Nepal demonstrate the tool's ability to estimate financial analysis and planning, tariffs and fee analyses for cross-subsidy simulations. By assessing CWIS indicators, CWIS-FiT enables inclusive scenario planning aligned with SDG 6 (clean water and sanitation), SDG 10 (reduced inequalities), SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production) and provides a scalable approach to planning equitable, safe and sustainable sanitation investments.

1 | Introduction

Citywide Inclusive Sanitation (CWIS) is a paradigm shift in providing safely managed sanitation services. Its outcomes—equity, safety and sustainability—address urban sanitation challenges by considering access and quality of sanitation services in low-income (LI) and non-low-income (NLI) communities/households, safety in service provision, along with financial viability and resource management (Schrecongost et al. 2020). CWIS covers all sanitation value/service chain (SVC) and delivery methods in the city, including sewer-based conveyance to treatment (Sewered Systems—SS); at-source containment with road-based conveyance to treatment; and land-based treatment (Non-sewered Systems—NSS) (Strande et al. 2023).

Finance is crucial for CWIS implementation; therefore, multiple Sanitation Financial Tools (SFTs) are used for a diverse set of goals, tailored to different levels, targets and stages of planning or projects. These tools capture capital costs for investments (CAPEX), operational/maintenance costs (OPEX), sales/revenue and/or financial projections over time. For example, CWIS assessments in cities such as Kampala and Lusaka highlighted that insufficient cost recovery and unclear subsidy mechanisms constrained service expansion to low-income areas (World Bank 2019; UN-Habitat 2020). In Dakar, despite

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technical feasibility, limited household affordability and dependence on external grants delayed scaling of safely managed services (Dodane et al. 2012). Similarly, CWIS planning exercises in South Asian cities have shown that weak tariff structures and fragmented financing responsibilities undermine long-term sustainability (ADB 2021). Financing safely managed sanitation under CWIS framework is a strategic pathway to advance Sustainable Development Goal (SDG) 6 on universal access to safe water and sanitation complemented by several other SDGs like SDG 11 on inclusive, safe, resilient and sustainable cities. Promoting equity in sanitation access between LI and NLI households, SS and NSS users and sanitation workers (including women and minorities) supports on reducing inequalities (SDG 10), while protecting both users and sanitation workers from health risks contributes to SDG 3 on good health and well-being. Ultimately, financial sustainability coupled with resource recovery promotes long-term efficiency of water, energy, carbon and nutrient through responsible consumption of sanitation reuse products, aligning with SDG 12 (United Nations 2015; Schrecongost et al. 2020; Franco et al. 2025).

SFTs address either one or the other CWIS outcomes (FSM Toolbox, n.d.) such as for equity—technological diversity on sewer and non-sewered systems (Finney et al. 1998; UN Millennium Project 2005; Hutton and Varughese 2017; Langergraber and Weissenbacher 2014) and emphasizing LI communities (Athena Infonomics 2020). For safety, protective gear for workers, laboratory costs (Sainati et al. 2020), service quality and key performance indicators (SaniPlan 2016) and for sustainability, business model (Furlong et al. 2020), resource recovery (Oertlé et al. 2019); long-term planning (Basyal et al. 2023), GIS-based models for service optimization and costs savings (Zoungrana et al. 2024); systems designs under uncertainty (Li et al. 2022). However, none of the existing SFTs fully address all CWIS outcomes (Franco et al. 2025). In most SFTs, costs to promote inclusivity are not computed, resulting in unfair prices for maintaining toilets and containment between LI and NLI users, as well as between SS and NSS. They overlook investments needs on reducing gender gap, training, legal support and healthcare to reduce sanitation workers health risks as well as monitoring treatment plants performance and quality of any reuse products (Franco et al. 2025). Therefore, city's sanitation financial model must address costs not only for infrastructure but also for such non-infrastructure costs along the SVC (Strande et al. 2014).

To incorporate the non-infrastructure costs and financial gaps, a comprehensive SFT, CWIS Financial Tool (CWIS-FiT) was developed and tested in Nakuru city in Kenya, and Mahalaxmi municipality in Nepal, both medium-sized cities in low- to middle-income contexts, selected for their coexistence of sewered and non-sewered systems. Nakuru has a utility to manage wastewater and faecal sludge co-treatment plant, a mature reuse business, and established tariffs. Mahalaxmi has limited faecal sludge treatment capacity and currently lacks wastewater treatment, a transparent tax/tariff mechanism and a utility for the regulation and management of SS and NSS. The two cities also exhibit distinct spatial distributions of low- and non-low-income households, thereby providing contrasting contexts for testing the tool's adaptability. Both cities are planning and implementing sanitation interventions aligned with CWIS principles to achieve safely managed sanitation. Interventions focus on eliminating unsafe services and ensuring financial sustainability for both LI and NLI households, SS and NSS managed by NGOs, public and private companies. The study has a dual objective. First, it presents and applies CWIS-FiT as a decision-support tool for assessing inclusivity and sustainability in urban sanitation systems. Second, it analyses the cost components required to achieve inclusive and safely managed sanitation in selected cities by examining monetary transfers, tariffs and fees, and by enabling cross-subsidy simulations. A set of equity, safety and sustainability indicators is used to classify the level of sanitation inclusivity and sustainability at the city scale.

2 | Material and Methods

2.1 | Tool Structure Description and Overview

The CWIS-FiT development is based on the eSOSView tool as background (Furlong et al. 2020) and unlike eSOSView, which primarily focused on NSS flows, CWIS-FiT integrates SS flows (Waziri 2020), distinguishes LI and NLI household technologies and associated costs and incorporates non-infrastructure inputs for CWIS. The tool is developed in Excel with nine interconnected worksheets and in two phases. In the first phase, the tool was updated by introducing new functionalities, including simplified wastewater and faecal sludge inputs for domestic and non-domestic sources and an automated improvement plan for phasing out unsafe sanitation services within a defined timeframe. Furthermore, CWIS-FiT included non-infrastructure costs and CWIS indicators for equity, safety and sustainability (Franco et al. 2025), providing a more holistic and actionable framework. This version was applied and tested in Nakuru City, Kenya. Although most modifications functioned as intended and produced the desired outputs, a critical question remained: *Is the city's sanitation service truly inclusive?* The first tool's application demonstrated that the mere calculation of indicators, even when methodologically sound, was insufficient to provide a meaningful answer to this question (Ocharo 2024) (Figure 1).

The second phase updated the tool and enabled users to standardize and weigh the CWIS indicators, allowing for a traffic-light assessment of each indicator and their combinations across three outcomes: equity, safety and sustainability. Moreover, the updated tool (Figure 2) was tested in a different context: Mahalaxmi Municipality in Nepal, where the CWIS assessment was implemented and discussed with stakeholders.

All non-infrastructure elements embedded in CWIS-FiT—including unit costs, cost escalation rates, technology lifespans, service frequencies, user behaviour, workforce composition and gender-related indicators—are not hard-coded in the model. Instead, they must be explicitly provided by users for each application. These inputs are populated using empirical data whenever such data are available (e.g., municipal records, feasibility studies, tariffs and operational reports), or, where data gaps exist, through context-specific assumptions derived from consultations with local stakeholders and key informants. This approach ensures that the tool's financial logic remains flexible and grounded in local realities, while making all assumptions transparent and open to revision as new empirical evidence becomes available.

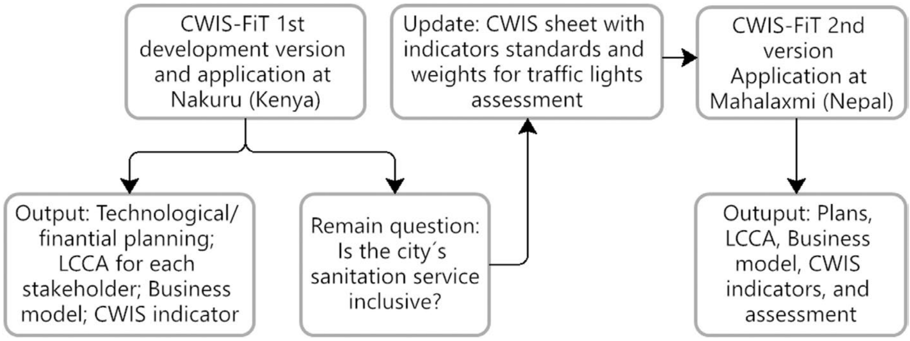


FIGURE 1 | CWIS-FiT development and application.

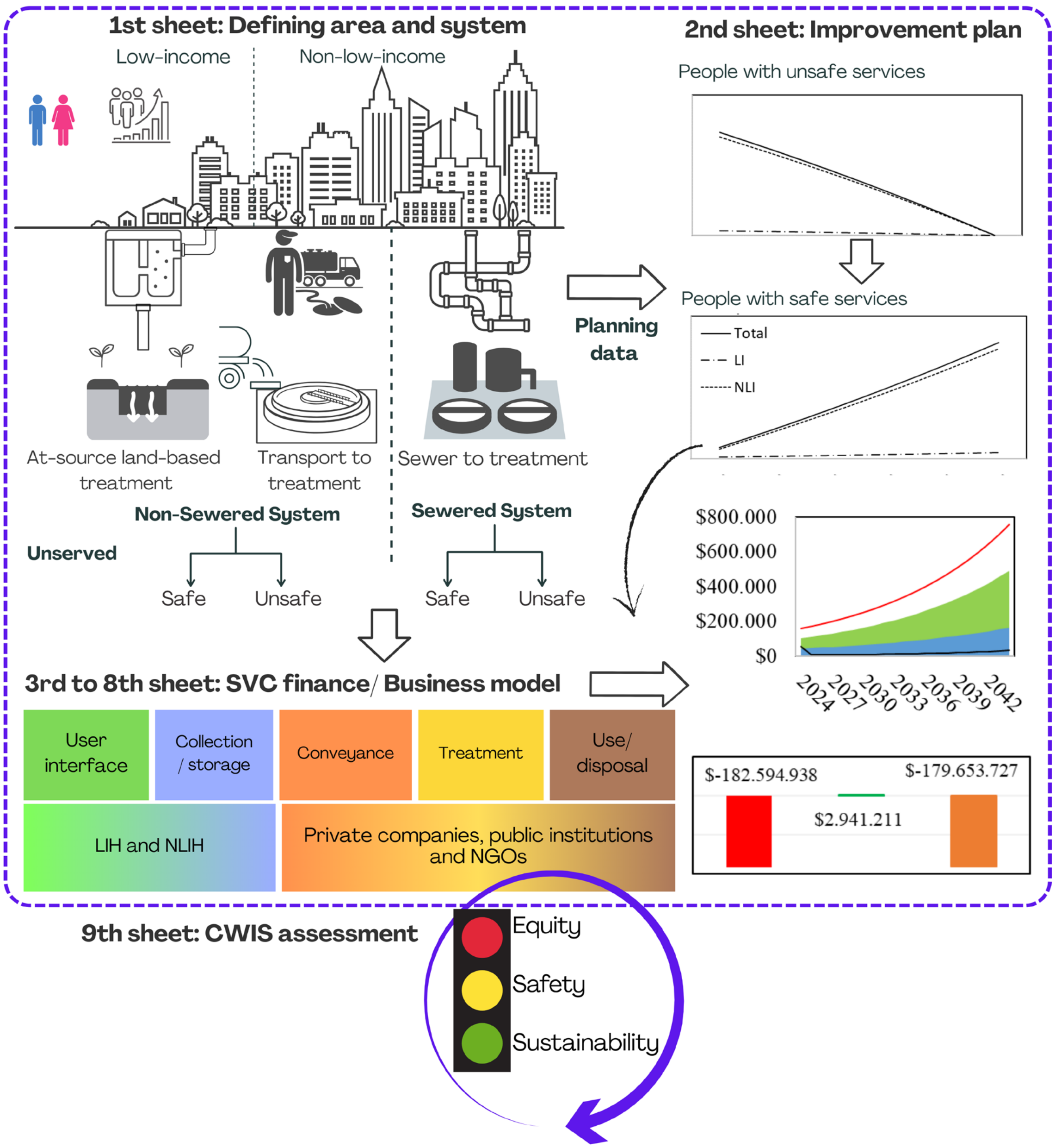


FIGURE 2 | Tool overview.

Similarly, the thresholds and weights applied in the traffic-light system used to assess CWIS indicators are fully user-defined. Although default values appear in the tool to facilitate initial use and demonstration, minimum and maximum values for red, yellow and green performance, as well as the relative importance (weights) assigned to individual indicators and outcome

TABLE 1 | Inputs and outputs for the city's improvement plan.

Inputs	Outputs
• Number of people (P) or number of households (HH) in LI and NLI areas	• People with SSS for each year to y_f
• Average number of people per household (P/HH)	• People with SNSS for each year to y_f
• HH using shared toilets at LI and NLI areas	• People with UNSS for each year to zero at y_f
• Percentage of women in the city	• People with USS for each year to zero at y_f
• Start-year (y_0)	• People with U for each year to zero at y_f
• End-year (y_f)	• Number of women using shared toilets
• People with Safely managed SS (SSS) at y_0	
• People with Safely managed NSS (SNSS) at y_0	
• People with Unsafe SS (USS) at y_0	
• People with Unsafe NSS (UNSS) at y_0	
• People Unserved (U) at y_0	
• Population growth rate (G) for SS, NSS areas and for non-domestic sources (city's population growth rate if it is the only available data)	
• Percentage of U to be covered by SNSS at y_f	
• Percentage of people with SSS system at $y_f (w_f)$	
• Discount rate	

categories, are established through stakeholder consultation to reflect local policy priorities, regulatory standards and socio-economic conditions.

2.2 | Worksheet 1—Defining the Area, Systems and the Improvement Plan

The starting point, that is, 'city data and improvement plan' sheet, requires inputs (Table 1) on people and household size in LI and NLI areas and their sanitation systems coverage, which was developed to enable integration with the existing Shit Flow Diagram (SuSanA 2026), a highly used framework that shows percentage of population's excreta that is safely or unsafely managed by SS and NSS (Furlong et al. 2023).

Once existing/current sanitation system has been defined, a user could develop improvement plan to eliminate unserved and unsafe services, potentially to achieve national targets or SDG 6. Like the WASHCost tool (Hutton and Varughese 2017), CWIS-FiT aims to achieve safely managed sanitation but focuses on individual cities rather than the entire country, which allows for calculations to be differentiated between SS and NSS and LI and NLI areas. This separation provides users with a flexibility to plan transfers between NSS and SS areas, if feasible and desired within the city. To achieve this, calculation of people in each sanitation system was developed to allow for flow between systems (Figure 3) as desired by the user and achieve planned outputs (Table 1). The main advantage is that it show a gradual improvement plan that reports both the percentage of the population with safe sanitation and the corresponding annual cost, thereby linking incremental service improvements to their financial implications.

It is assumed that the number of unserved (U) and those with unsafe sanitation services (UNSS and USS) would gradually decrease by a constant rate (β) once they transitioned to safe sanitation services (SNSS and SSS), considering population growth rate on both. In addition, a rate (α) is applied to estimate population reaching SSS at the desired percentage in the end-year. Finally, difference between total population and people with

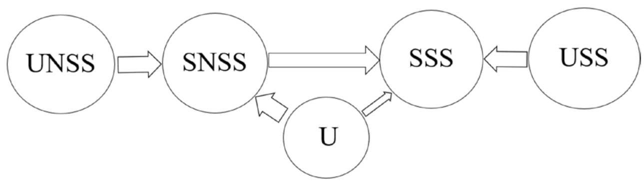


FIGURE 3 | Improvement plan: Moving people to safe sanitation services in the city.

each sanitation service estimates people with SNSS, calculated annually.

To clarify, decrease in number of people unserved and unsafe sanitation can be mathematically written as: $U_i = \left(U_{i-1} - \beta_u\right)(1+G)$, where U_i is unserved people in the city in year i, β_u is the decreasing rate of people with no sanitation service and g is the population growth rate. As the number of people in the end year (U_f) must be zero: $U_f = 0; U_{f-1} = \beta_u$ (Equation 1).

$$U_{f-x} = \beta_U \frac{\sum_{i=0}^{x-1} (1+G)^i}{(1+G)^{x-1}}; U_0 = \beta_U \frac{\sum_{i=0}^{f-1} (1+G)^i}{(1+G)^{f-1}} \therefore \beta_U = \frac{(1+G)^{f-1} U_0}{\sum_{i=0}^{f-1} (1+G)^i} \tag{1}$$

For SSS growth, summing alpha people means: $SSS_i = SSS_{i-1} + \alpha \cdot P_i$, where SSS_i is people using safe sewered sanitation systems in the city at the year i, α is the constant rate of people with SSS applied to P_i, which is the total population in the city at year i, so: $\triangle SSS = \alpha \sum_{i=1} P_i = \alpha P_0$, or $\triangle SSS = SSS_f - SSS_0 \rightarrow \sum_{i=1}^{f} \triangle SSS_i = P_0 \times (1+G)^{\triangle y} \times w_f - w_0 \times P_0$, where w_0 and w_f are the percentages of people with SSS at the start year and plan for the final year, respectively: $\triangle y = y_f - y_0$ α is defined in Equation (2).

$$\therefore \alpha = \frac{w_f \times (1+G)^{\triangle y} - w_0}{\sum_{i=1} \left[(1+G)^i\right]} \tag{2}$$

The main output of this sheet is a gradual decrease in individuals unserved or using unsafe sanitation systems, ultimately reaching zero. Simultaneously, the number of people with *SSS* will increase, aiming to achieve the desired percentage by the end of the specified year. Finally, $SNSS_i = P_i - U_i - UNSS_i - USS_i - SSS_i$. Demonstrations and examples are provided in Section S2.1.

2.3 | Worksheet 2—Wastewater and Faecal Sludge Estimations

Second sheet estimates WW and FS generation. Domestic WW generation is estimated by inputting—daily WW generation per capita and peak factor, which is multiplied by the number of people with *SSS* (calculated in the previous sheet) (Equation 3). There are two options for calculating domestic FS generation: (i) FS production method based on annual FS generation per capita or (ii) FS collection method based on containment average volume and desludging frequency. Both are converted to daily volumes and multiplied by the number of people with *SNSS* and *UNSS* (Equation 4).

Two options are also available for non-domestic WW and FS generation: to input daily value or to convert from domestic sources as its percentage. For future estimations/projections, growth rate inputted in the previous sheet is used and calculated as per Equation (5). Finally, total WW and FS generated are the sum of domestic and non-domestic sources—NDS (Equation 6).

$$Domestic\ WW = WW\ per\ capita\ day.\ peak\ factor \cdot SSS \tag{3}$$

$$Domestic\ FS = \frac{FS\ per\ capita\ year}{365} \cdot SNSS;\quad or\ \frac{Containmente\ volume}{Disludge\ frequency \cdot 365} \cdot SNSS \tag{4}$$

$$NDS = Daily\ generation \cdot (1+G)^{\triangle y};\quad or\ Domestic\ converting\ percentage \cdot (1+G)^{\triangle y} \tag{5}$$

$$Total\ generated = (Domestic\ source + NDS\ source) \tag{6}$$

2.4 | Worksheet 3–7—Technological, Financial Plans and Life-Cycle Cost Assessment for SVC Components

The following five sheets consist of detailed data on each SVC component. Users have to select appropriate technologies in each SVC component (Figures S2–S5), as listed and defined in the 'Compendium of Sanitation Systems and Technologies' (Tilley et al. 2014). There is also an option to include additional technologies not listed. Alongside selecting the technologies, users must input existing quantities and capacities for each technology (Figure S7).

For financial planning, CAPEX, OPEX, revenue and any money transfers such as tariffs, fees and budgetary support (external and national grants, loans, equity) are required. The disaggregated costs (Table S1) and lifespan are necessary for each SVC component technology chosen separately by LI and NLI households, as well as SS and NSS.

A technological and financial plan is developed using data input for each SVC component. This plan outlines required quantities and gaps over the years based on the defined start and end years and annual number of people using each sanitation service (SS and NSS). It calculates costs associated with ending unsafe sanitation services and unserved within the end year. Each SVC component's life cycle costs are calculated using annual CAPEX, OPEX, revenue and profit or loss, applying the discount rate (r) for a defined life span (d) (Equation 7). A life-cycle approach to cost estimation for various technical developments promotes service provision long-term sustainability, especially when considering major repair needs and operational maintenance.

$$Profit\ or\ loss = \sum \left[(Revenue + Budgets - CAPEX - OPEX)\right] \times \frac{r}{1-(1+r)^{-d}} \tag{7}$$

Financial data in many contexts is often unavailable, unreliable, or difficult to compile in detail. To address this in practice, the tool was intentionally designed to be flexible regarding the level of financial disaggregation required. In each SVC component sheet, users can enter aggregated cost information—such as total CAPEX without further breakdown and generalized OPEX for routine maintenance—without specifying costs. More detailed cost disaggregation remains optional and can be provided when reliable data is available. The responsibility for defining cost and its assumptions remains with the user, though, who may rely on local records, expert judgement, or stakeholder consultation. While incorporating uncertainty ranges could enhance precision, it would require substantial updates to the tool, which is a priority for future versions.

2.5 | Worksheet 8—Business Model

The existing business model is structured around five SVC components, reflecting cost and revenue data from previous sheets. One component's costs can be a revenue for the next, allowing for profit and loss calculations (Figure S9). User interface is analysed separating LI and NLI households, as well as SS and NSS; conveyance can have multiple combinations—gravitational and simplified sewer, semi-mechanical and motorized emptying; and for treatment and use/disposal, WW and FS are analysed separately. All the financial analysis, that is, costs, revenue, profit/loss, and so forth are summarized for each SVC component over its life cycle and reflecting perspectives of households, private, public, or NGO. The tool offers a unique opportunity to feed in different financial modalities (grant, equity and loans) to explore financial viability of business along or entire SVC.

2.6 | Worksheet 9—CWIS Assessment

The final sheet explores assessing alignment of sanitation interventions with CWIS indicators for equity, safety and sustainability as outlined by Athena Infonomics (2021) (Figures S6, S8, and S10). To achieve equity, indicators focus on three key areas: (1) fair access and costs for LI/NLI areas and sanitation systems (NSS/SS), (2) gender and minority (GM) equity among workers and decision-making positions and (3) women's access to toilets. The first and second areas are addressed by differentiating data

TABLE 2 | CWIS indicators calculated by the tool for each outcome.

	Input	Indicator[a]
Equity	NSS vs. SS costs at SVC component sheets	Amount paid for NSS/amount paid for SS
	LI vs. NLI at SVC component sheets	Amount paid by LIH/amount paid by NLIH
	# Women workers and their salaries	% of women workers and their gender pay gap
	# Women engineers or managers and their salaries	% of women workers in decision-making positions and the gender pay gap
	# Transgender workers and their salaries	% of transgender workers and the gender pay gap
	# Transgender engineers and their salaries	% of transgender workers in decision-making positions and the gender pay gap
	# of caste and/or religious minority workers and their salaries	% of caste and/or religious minority workers and their pay gap
	# caste and/or religion minorities engineers or managers and their salaries	% of caste and/or religious minorities workers in decision-making position and their pay gap
	% of women and the number of toilets in the city	% of women using shared toilets
	Number of toilets in LI regions	% of LIH with access to individual toilets
Safety	% of workers' salary used for health insurance	Health insurance support
	Costs/worker to provide PPE	PPE regularly provided
	% of OPEX used for training	Capacity building or training
	Workers' coverage by social/legal insurance (yes or no)	Legal/social support
	WW and FS treatment capacity	WW and FS treatment capacity/ total volume generated
	WW and FS total volume generated	
Sustainability	The volume of WW and FS reused at the reuse/disposal component	% of treated FS and WW treated that is reused
	Costs, revenue and budget funds in all SVC components	% of OPEX recovered by revenue
	Costs, revenue and budget funds in all SVC components	% of CAPEX covered by funds

[a]Adapted from Athena Infonomics (2021).

on cost for sanitation systems, household income and number of workers, genders and minorities, along with their salaries (Equations 8 and 9) and the third area is captured in the city information (Table 2).

$$\%\,GM\ in\ the\ worforce = \frac{\sum_{SVC} \#\,GM}{\sum_{SVC} total\,\#\,of\ workers} \tag{8}$$

$$\%\,GM\ pay\ gap = 1 - \frac{\overline{GM\ salaries}}{\overline{workers\ salaries}} \tag{9}$$

Safety outcome is evaluated using indicators related to workers' safety and sanitation management (Table 2). For workers' safety, expenses for training, social and legal support, health insurance and PPE are considered at each SVC component (Equation 10). In assessing safe sanitation management, existing capacity of technologies in the city is compared with total amount of WW and FS generated as well as comparing the number of households with unsafe management WW/FS to those with safe management.

$$Workers\ safety = (1 + Health\ insurance\%) \cdot \sum salaries + PPE\ costs \cdot \#workers + (1 + training\%) \cdot OPEX \tag{10}$$

For sustainability assessment, percentages of WW and FS reused (Equation 11) costs covered by revenue and budget funds (Equation 12), and number of sanitation workers compared to ideal required number (based on population size) are evaluated.

$$\%\,WW\ or\ FS\ used = \frac{Volume\ of\ WWor\ FS\ treated}{Volume\ of\ WW\ or\ FS\ used} \tag{11}$$

$$\%costs\ covered\ by\ revenue\ and\ budget = \frac{\sum costs_{conveyance,\ treatment,\ use}}{\sum Revenue\ and\ budgets_{conveyance,\ treatment,\ use}} \tag{12}$$

To assess performance against each indicator, a traffic light system is used and minimum and maximum values should be established for each indicator to define the colour of the traffic light. For example, regarding the gender pay gap, the default threshold for a green light is a gap of 0%. A yellow light is assigned for a gap between 0% and 20%, while gaps above 20% receive a red light. Stakeholders must determine what standards are acceptable in the city for each colour. Finally, stakeholders set criteria for outcome-level colours, combining all indicators related to the outcome. This is calculated by multiplying the sum of weights by colour value (0 for red, 50 for yellow and 100 for green), as shown in Equation (13). It is envisaged that the user should consult stakeholders to decide on the weight of each indicator as it is very contextual and subjective (by default, all indicators are assigned equal weight).

$$\textit{Outcome traffic light} = \frac{\textit{Color number} \times \textit{Indicators}'\textit{weight}}{\sum \textit{indicators}'\textit{weights}} \tag{13}$$

2.7 | Illustrative Application of the Tool

The tool's application was part of its development. To illustrate and improve the tool, it was tested in two cities with distinct contexts: Nakuru City in Kenya (08/2024), improved it based on the first experience and applied in Mahalaxmi Municipality in Nepal (01/2025) (Figure 1).

Nakuru city is located approximately 160 km west of the capital, Nairobi, Kenya, with 570,674 inhabitants (KNBS 2019). People own land on freehold and leasehold, except for sprawling of about eight informal settlements (Figure S9), with poor delivery of sanitation services (UN-HABITAT 2020). SS accounts for about 31% of the population, predominant in the old, planned areas (over 200 km of sewer lines with 18,000 connections). NSS is mainly found in newly developing areas and LI households, using septic tanks for formal areas and pit latrines with slabs for informal settlements (Figure S10). The city has two wastewater treatment plants (WWTPs) with a combined capacity of 16,200 m^3/day, and FS is used to produce charcoal briquets and seed balls (Figure S13). There is also a plan to install a membrane bioreactor for FS treatment. Details are available in the Section S2.1.1.

Mahalaxmi municipality is in the northeast of Lalitpur District of Bagmati Province (Figure S15), with a total population of 122,966 and a density of 5493 people/km^2, spread across an area of 26.5 km^2. Ninety-eight percent of the buildings are residential, while 2.86% and 0.69% are commercial and industrial, respectively. The municipality is a historic town with cultural and archaeological significance (Badal 2020). Its sewerage network serves about 47% of the population, while the rest rely on the NSS system (Figure S16), mostly septic tanks and 7.5% pit toilets (CBS 2021). Currently, the municipality has a small FSTP of 6 m^3/week capacity (Figure S16). However, it does not have a wastewater treatment plant, but there is a plan to install one at Balkumari (Section S2.2.1).

Nakuru and Mahalaxmi were selected for testing because of ongoing interventions towards city-wide inclusive sanitation, representing low- and middle-income country contexts and data availability. These cities, located on different continents, also differ significantly in their institutional setup, infrastructure and services, which enables testing the tool's adaptability across varying governance and service conditions. Nakuru has a relatively mature sanitation utility, partial sewer network coverage and existing wastewater and faecal sludge treatment facilities, supported by established tariff structures and operational data systems. In contrast, Mahalaxmi has a mature FSM information system but currently lacks tariff structures and faecal sludge and wastewater treatment, which remain at an early stage. The LI and NLI household spatial distributions also differ significantly across the two cities: Nakuru has informal settlements (slums) distinct from planned neighbourhoods, whereas Mahalaxmi has mixed-income neighbourhoods.

For both cities, comprehensive data were gathered (Table S4) using a mixed-methods approach guided by the tool's data requirements. First, quantitative and qualitative data were collected from secondary sources to obtain baseline information from published sources and unpublished reports, such as strategic plans and feasibility reports. The second step involved field visits to collect primary data through anonymized and volunteer surveys. Key Informant Interviews (KIIs) were conducted with stakeholders along the SVC (Sections S2.1.2 and S2.2.2, Tables S2 and S3, Figures S11 and S16). Participants were selected based on their role as sanitation stakeholders along the SVC, including municipal officers, managers, technical staff at treatment plants and staff of E&T companies. A purposive and snowballing technique was employed for the KIIs, where selected participants referred other knowledgeable individuals in the sanitation sector. These interviews aimed to understand the current situation, challenges and plans for improvements in the SVC. After filling out the tool, the results were discussed at a Joint Stakeholder Meeting. This triangulation approach helped reduce individual reporting bias and ensured that inputs used in the tool reflected locally agreed and contextually grounded assessments. The final output is the existing CWIS scenario. The inputs were then modified to run in an inclusive scenario (all green lights) to achieve costs and revenue for an inclusive and safely managed sanitation service provision in the city.

3 | Results and Discussion

3.1 | Improvement Plan

Input data is presented in Table 3 which also shows calculated β value and α values. The improvement plan (Figure 4) shows a gradual decline in unsafe sanitation services for both cities. While Nakuru city opted for a 20-year improvement plan, Mahalaxmi municipality chose 5 years to align with the SDGs deadline.

The CWIS-FiT improvement plan enabled estimation of ending unsafe sanitation services in both contexts, leading to a faster increase in the number of people with SSS as the cities strive to progress from 41% to 55%, and 47% to 60% of SS in Nakuru and Mahalaxmi, even having 0% of SSS in Mahalaxmi. It is also possible to plan for distinct coverages for unserved areas, as Nakuru anticipated that most people without a toilet will first pass through SNSS, whereas Mahalaxmi aimed to serve them with SSS directly.

Sanitation improvements in cities typically increase gradually; however, they do not increase at a constant rate. For calculation purposes, the tool uses an incremental increase; however, it reports both the percentage of the population with safe sanitation

TABLE 3 | Inputs and rates for Nakuru, Kenya and Mahalaxmi, Nepal improvement plan and WW/FS streams calculations.

Inputs and rates	Nakuru						Mahalaxmi					
LIH	89,043						1716					
NLIH	100,410						30,390					
#people/LIH	4						3.8					
#people/NLIH	4						3.8					
Women in the city	51%						49%					
Start and end years	2024–2044						2025–2030					
Population growth	3.1%						5.8%					
U % to be covered by NSS	90%						40%					
% of people to be covered by SS	55%						60%					
Inflation rate	7%						6.1%					
Service coverage (%)		SSS	SNSS	UNSS	USS	U		SSS	SNSS	UNSS	USS	U
	LIH	1.5	18	24	1.5	2	LIH	0	0.3	2	2	0.2
	NLIH	26.5	18	7	1.5	0	NLIH	0	4.8	46	45	0
Daily WW/person	100 L/person day						75 L/person day					
Peak factor	2.5						1.8					
Non-domestic WW sources	4810 m^3/day						351.7 m^3/day					
Yearly FS/person	0.28 m^3/person year						0.22 m^3/person year					
Average containment volume	5 m^3						2.5 m^3					
Emptying frequency	3 years						3 years					
Non-domestic FS	30% of domestic						1.6 m^3/day					
α (Equation 3)	0.03						0.13					
β (Equation 2)	System			UNSS	USS	U	System			UNSS	USS	U
	LIH			15,457	748	468	LIH			602.54	643.60	54.90
	NLIH			11,967	748	—	NLIH			12,542.19	12,226.64	—

and the corresponding annual cost, thereby linking incremental service improvements and the financial implications. The tool enables users to identify target levels of sanitation improvement including inclusive sanitation coverage and estimate costs required to achieve them. To achieve more realistic and local level financial planning, it is to be foreseen to enable users for a stepwise implementation planning (e.g., by neighbourhoods or by treatment facility).

3.2 | Business Models

Figure 5 illustrates existing business models in Nakuru and Mahalaxmi, and Table 4 highlights key differences between the two cities. In general, households are responsible for installation and O&M of toilets, for example, individual private toilets in Mahalaxmi; however, in Nakuru, LI households receive financial support from national grants, and in many cases, it is shared toilets within LI communities. In both locations, private E&T companies operate and households pay an emptying fee to desludge their containments (septic tanks or pits). These companies, in turn, pay a discharge fee at treatment plants. In Nakuru, semi-mechanical emptiers are private, but the municipality transports FS emptied by them to the treatment plant. In Mahalaxmi, households connected to sewer system still have septic tanks, which are emptied less frequently than those not connected. Nakuru employs monthly tariffs from households connected to sewer, along with 5% support from water bills from all households to support sewer conveyance and treatment, while Mahalaxmi relies on annual household taxes to manage its services (where there is currently no sewer treatment). Reuse of FS in Nakuru is supported by revenue from charcoal sales, whereas revenue in Mahalaxmi comes from using treated liquid from FS, sale of agricultural products and using biogas. Both cities rely on external

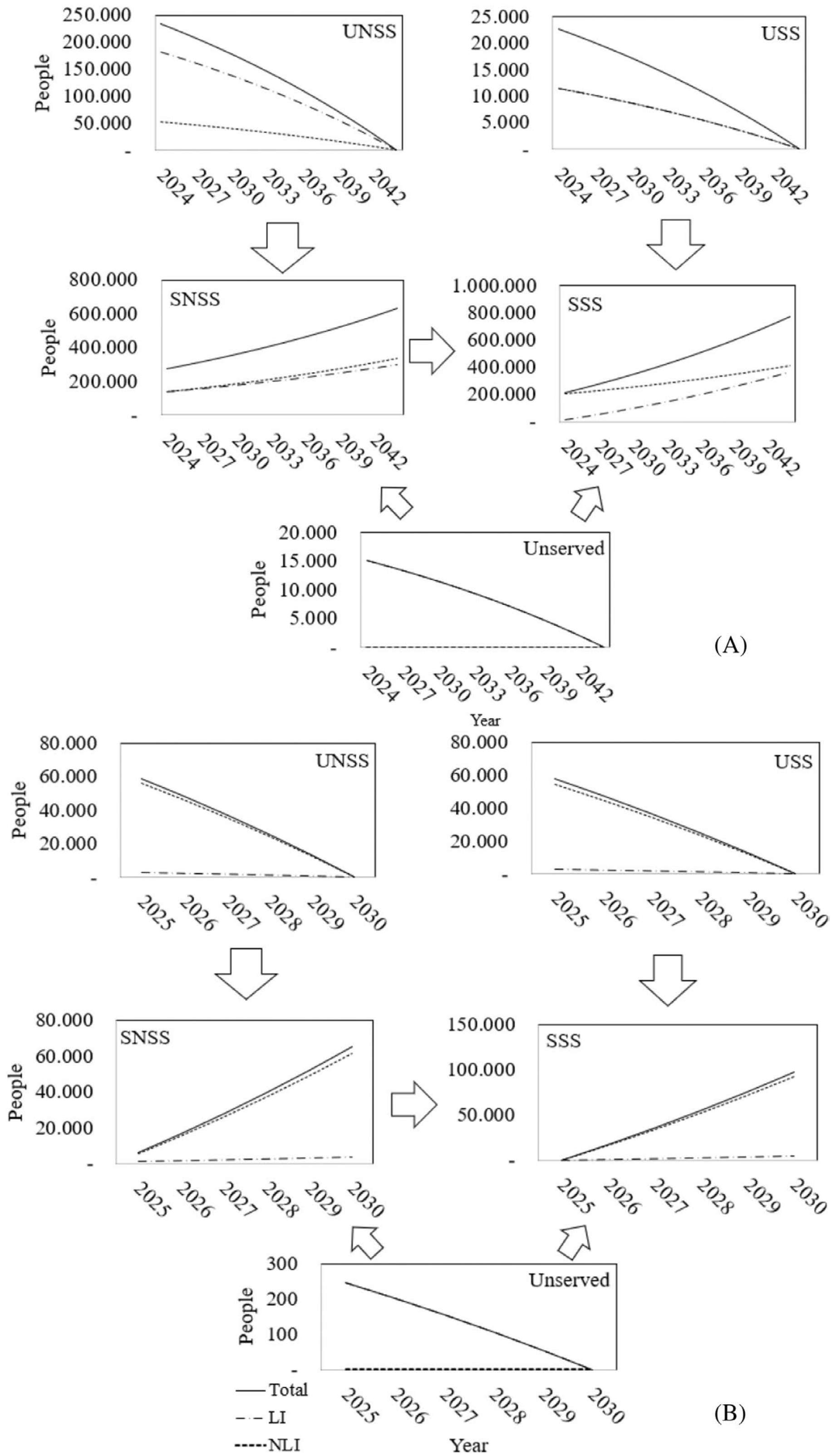
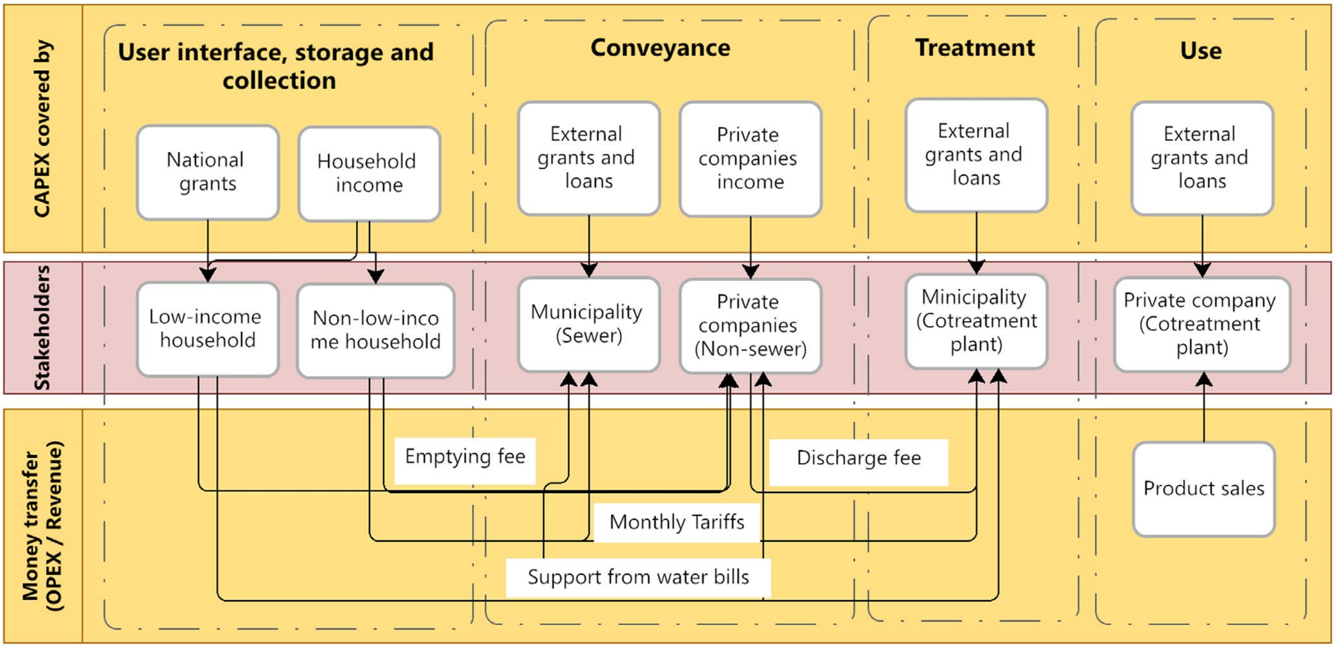


FIGURE 4 | Nakuru's (A) and Mahalaxmi's (B) improvement plan. SNSS, safe non-sewered system; SSS, safe sewered system; UNSS, unsafe non-sewered system; USS, unsafe sewered system.

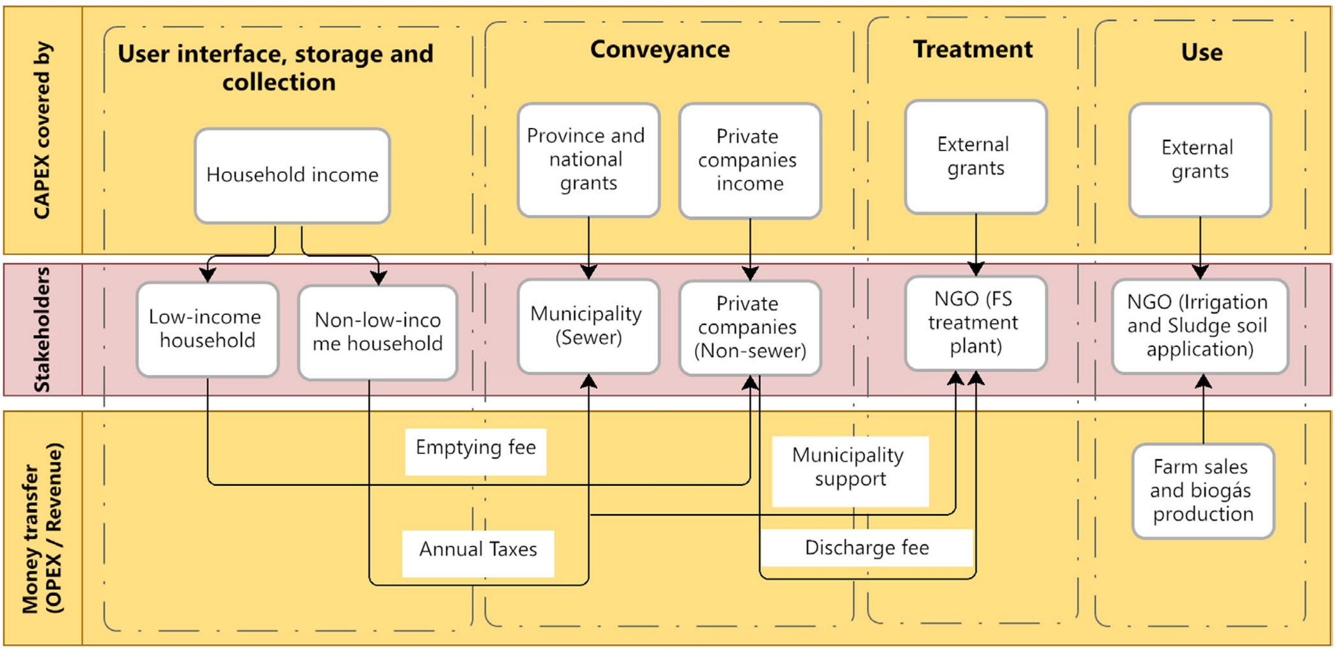
grants for sewer conveyance, treatment and reuse, but in Nakuru, the municipality and reuse companies also employ loans. These business models align with model 5—Incentive discharge model from Tilley et al. (2014) applied with financial flow simulator eS-OSview TM (Furlong et al. 2020), but without discharge license.

3.3 | Financial Plan

Based on the improvement plan, financial plans were developed for each component of the SVC, which present CAPEX, OPEX and revenue over the planned period (Figure 6). In Nakuru,



(A)



(B)

FIGURE 5 | Existing sanitation business models in (A) Nakuru, Kenya and (B) Mahalaxmi, Nepal.

LI households spend nearly \$340 to install user interface, containment, or collection; this price is expected to reach \$1300 in 20 years (Figure 6A). For NLI households, prices start at \$413 in 2024 and increase to \$1600 in 20 years. LI households spend around \$50/year to maintain the facilities; this price is expected to increase to \$190 in 20 years. NLI households start with \$80/year and are expected to grow to \$300/year in 20 years (Figure 6A). For sewer conveyance, there is a gradual increase in CAPEX for expanding sewer lines (Figure 6B) and for FS conveyance (Figure 6C), CAPEX peaks are related to fulfilling gaps to eliminate unsafe sanitation services by buying new trucks and tractors. However, once people transition from NSS to SS services, OPEX and revenue associated with FS conveyance are restricted to the population using this service, which is also growing. The situation is similar to treatment, where existing treatment plant (TP) capacities are currently insufficient for 100% safe treatment, especially for SS, which requires expansion, along with its associated costs (Figure 6D,E).

Difference between CAPEX, OPEX and revenue results in profit or loss; however, CAPEX is generally subsidized for treatment component and covered by grants from external, national, or

TABLE 4 | Comparative aspects of existing sanitation business models in Nakuru (Kenya) and Mahalaxmi (Nepal).

Aspects	Nakuru (Kenya)	Mahalaxmi (Nepal)
Governance & institutional setup	Dedicated water and sanitation utility (NAWASSCO) with defined roles across sewered and non-sewered sanitation systems	Municipal management with limited regulations for sanitation services
Ownership—user interface & containment	Existence of shared toilets, CAPEX subsidies for LI households	Private individual toilets inside houses, no subsidies
Ownership—emptying & transport (E&T)	Private and semi-mechanical operators; municipality supports transport to FSTP	Private operators
Ownership—treatment	Public (municipality/utility), supported by grants and loans	Public (municipality/NGO), largely grant-funded, run by an NGO, with some support from the municipality, but not regulated
Treatment infrastructure	Existing wastewater treatment plant with co-treatment of faecal sludge Limited capacity; expansion planned	No wastewater treatment plant; small FSTP Wastewater treatment plant is planned
Household payments	Sewer tariff (monthly); emptying fees for NSS; regulated cross-subsidy via water bills	Emptying fees for NSS; annual household tax supporting sewer conveyance, but not regulated
Tariff structure	Differentiated tariffs for SS and NSS	Flat household tax; limited linkage between tariffs and service costs
Discharge fees at treatment	Applied, primarily regulatory, not adequate to recover costs	Applied at FSTP; minimal contribution to cost recovery
OPEX cost recovery	Partial for conveyance and treatment	Low; minimal OPEX recovered through tariffs or fees
CAPEX financing	Predominantly external and national grants, with some loans	Almost entirely grants and municipal funds
Reuse revenue	Yes—contributes to OPEX recovery at reuse component	Limited but present (treated liquid, biogas, agricultural products)

other sources of funding. Private companies in E&T component are making profit, while public treatment services, especially FSTP, will be in loss, as also observed by Ćetković et al. (2022) and Estu et al. (2021), indicating need for increase in taxes for NSS. Reuse technology/plant was installed with a grant of $389,105 and a loan of $132,296; however, revenue generated from briquette sales is more than OPEX and repaying loan, thus making a profit (Figure 6F), as also found by Mohideen et al. (2022). Reuse of FS/sewage sludge and business models is getting recognized (Taron et al. 2023), and this type of FS reuse is also eligible for revenues from carbon market, due to differences in feedstock composition, combustion efficiency and carbon sequestration potential (Rowles et al. 2022).

Mahalaxmi's financial plans are available in the Supporting Information and Figure 7, where, unlike Nakuru, LIH and NLIH pay the same prices to install containments or connections: $2285 for a septic tank, expected to go to $3152 in 5 years; $519 for a single pit ($716 in 5 years); and $499 for sewer collection, to be $670 in 5 years. To operate containment, households spend $10/year for emptying septic tanks not connected to sewer; $5/year to empty septic tanks connected to sewer; $6/year to empty single pits; and a fixed household tax of $0.69/year for all to support sewer conveyance, which has a loss, unlike FS conveyance. The FSTP has an even more significant loss, which is covered by the municipality, indicating the need to charge a sanitation tax or tariff to improve treatment and cover the losses (Figure 7). It is to be noted that CAPEX is calculated based on the gap (in volume) between the existing infrastructure, for example, FS treatment capacity and the city's FS generation, it becomes evident that, in both cases, the FSTP capacity is significantly lower—or even non-existent—compared to the current FS generation. This discrepancy requires a higher initial investment to align with the improvement plan estimations and to enhance safety. The city may choose to make a one-time investment in a FSTP sized to meet the projected end-year volume estimation.

The long-term financial projections generated by CWIS-FiT are inherently sensitive to macroeconomic conditions, particularly inflation rates and capital cost escalation. While the tool allows users to define inflation and discount rates based on local conditions, the current version does not include a formal sensitivity or probabilistic analysis to quantify these uncertainties explicitly. As a result, the 20-year forecasts should be interpreted as scenario-based estimates conditional on stakeholder-agreed assumptions rather than as precise predictions when the tool is focused on early-stage planning rather than the project implementation stage. The integration of sensitivity analyses of financial outcomes under uncertainty will further strengthen

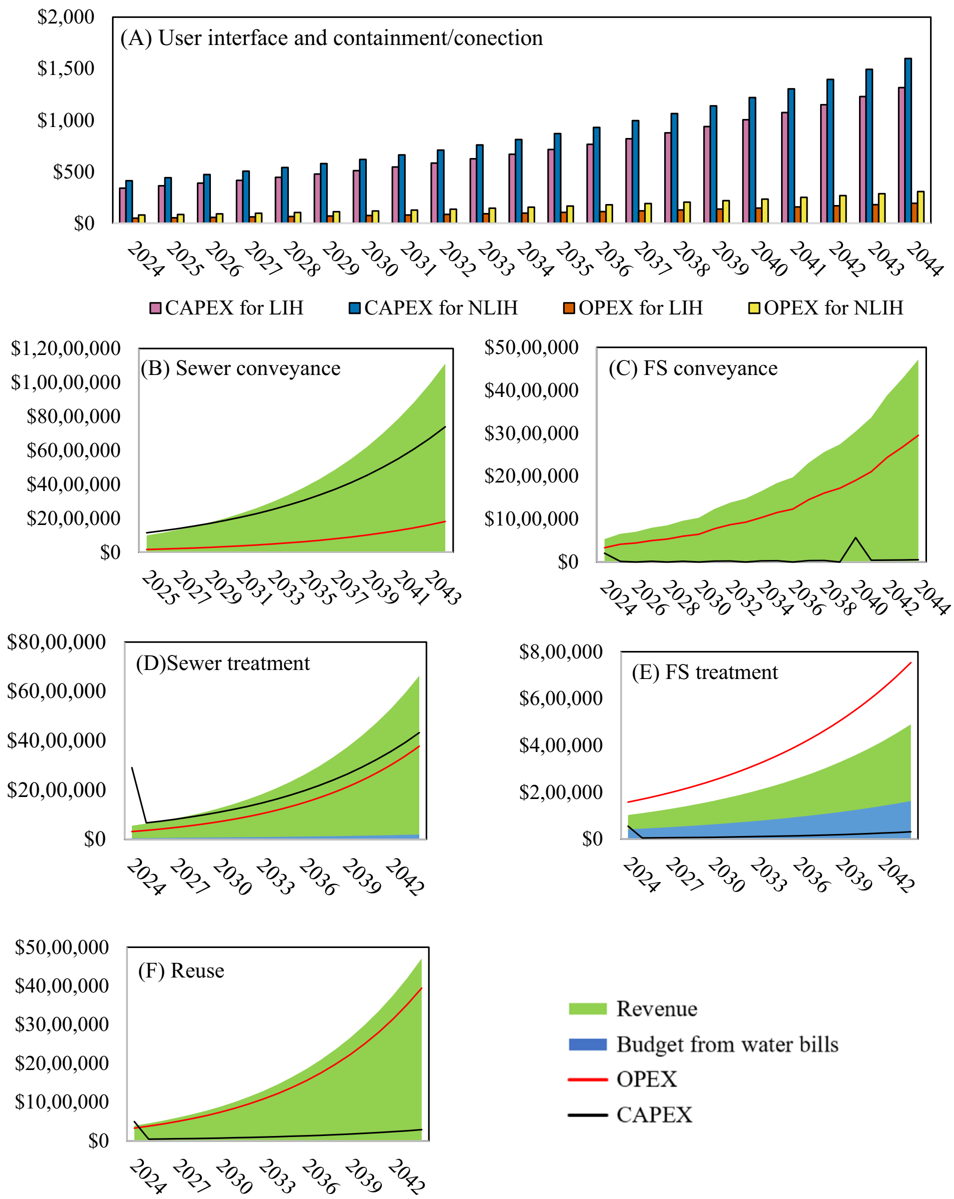


FIGURE 6 | Nakuru's financial plans. (A) User interface, containment and connection. (B) Sewer conveyance. (C) FS conveyance. (D) Sewer treatment. (E) FS treatment. (F) Reuse. CAPEX, capital expenditure; LIH, low-income household; NLIH, non-low-income household; OPEX, operational expenditure.

versions of the tool's applicability to investment planning and risk-informed decision-making.

The Life Cycle Costs (LCC) for all planned years, including both sewered and non-sewered sanitation systems, are presented in Table 5, showing household costs as well as profit or loss for conveyance, treatment and reuse. To estimate costs for an inclusive scenario, a 40% subsidy from sewered system to non-sewered system is applied, as non-sewered households empty their containers more frequently, thereby bearing 60% of the service costs in the existing scenario. Both tariffs were increased, though, to cover the operational costs of a new WWTP and to increase FSTP treatment to at least 90%, according to the standard established by stakeholders, which aligns with the national goal and SDG 6.

Using tariffs to cover OPEX for conveyance and treatment improves inclusivity of this indicator as a sustainability outcome. This can be visualized by comparing graphs for sewer conveyance in Table 5 between the two scenarios, where the loss is covered by revenue, leaving the CAPEX to be covered by national or external funds (Henriques et al. 2022; Marques and Monteiro 2023). For treatment and reuse, the inclusive scenario also aimed to cover operational expenses through sales. The losses presented in Table 5 indicate a need for national or external funds for infrastructure implementation, which is another indicator of sustainability (CAPEX covered by funds). It is also noteworthy to highlight the significance of the investment required to install a new WTTP (Basyal et al. 2023) and the expansion of faecal sludge reuse.

3.4 | CWIS Assessment

CWIS indicators are presented as per traffic light system representing performance of each indicator and ultimately reflecting

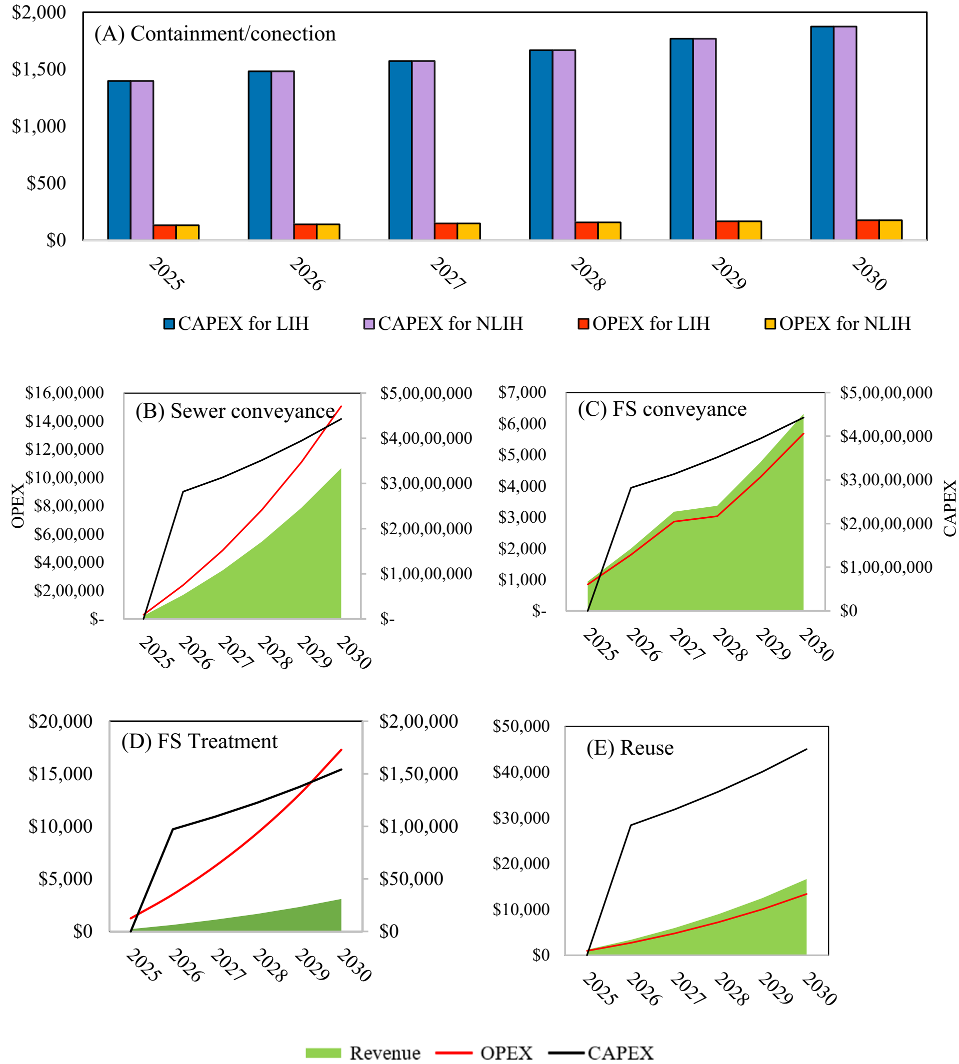


FIGURE 7 | Mahalaxmi's financial plans for each existing stakeholder. (A) Containment and connection. (B) Sewer conveyance. (C) FS conveyance. (D) FS treatment. (E) Reuse. CAPEX, capital expenditure; LIH, low-income household; NLIH, non-low-income household; OPEX, operational expenditure.

the overall outcome performance (Table 6). Indicators are evaluated based on their weight of importance and using maximum and minimum values/thresholds for red (low-performing), yellow (medium-performing) and green (high-performing) traffic lights.

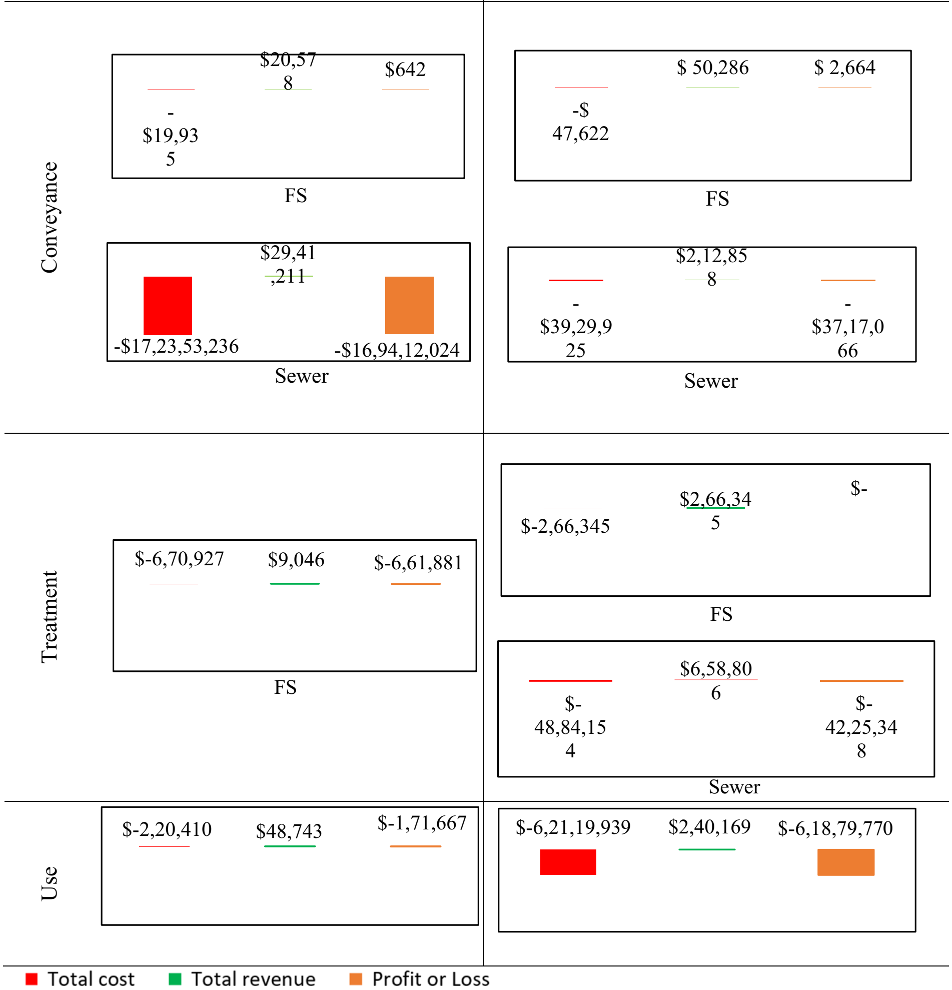
In Nakuru, all outcomes performance was evaluated as medium performing based on results from Equation (13) and considering threshold values for medium performance between 30% and 70%. On equity, the main gap is found in the sanitation workforce, which is composed of 74% men, who earn, on average, 16% more than women in similar work positions, while there are no women in decision-making positions. On safety, the partial coverage of workers with health insurance and the gaps between WW/FS generated and treated had low performance. On sustainability, the portion of WW/FS reused is still incipient (only 12%).

Nakuru's CWIS assessment was derived based on default standards and weights; however, for Mahalaxmi, stakeholders during the joint stakeholder meeting established thresholds tailored to the municipality's context.

In Mahalaxmi, stakeholders lowered thresholds for outcomes by 40%–60%. In terms of equity, they increased the gender gap to between 45% and 50%, resulting in low performance for women in the workforce (29%) and decision-making positions (0%). However, at the gender pay gap indicator, the tool showed that men earn less than women, as the small FSTP operator (men) earns 21% less than female workers in conveyance. Regarding equity, households connected to sewers empty their septic tanks less frequently, taking a longer time to fill up, resulting in lower expenses for households connected to sewers compared to those connected to NSS. The stakeholders' increase in weights for access to safe facilities for LI households and for women led to a high performance for this outcome. On safety, performance drops when institutionally, sanitation services are managed within general municipal functions rather than through clear regulations or a dedicated utility, resulting in limited earmarked budgets for workers' training and health or social insurance coverage. Additionally, at the technical level, the absence of a wastewater treatment plant and the limited capacity of the existing faecal sludge treatment facility mean that a large share of wastewater and faecal sludge generated in the municipality

TABLE 5 | Life cycle costs for existing and inclusive scenario at Mahalaxmi, Nepal.

Life Cycle Costs for existing and inclusive scenario at Mahalaxmi, Nepal						
SVC	LCC Scenarios (USD/ planned years)					
	Existing			Inclusive		
User interface/ containm	Monthly costs	Tariff	Empty fee	Monthly costs	Tariff	Empty fee
	NSS	0,69	8	NSS	1,76	9
	SS	0,69	5	SS	4,32	7



cannot be safely treated, directly constraining performance on treatment-related safety indicators. On sustainability, most of the OPEX is not covered because the taxes are insufficient and not specifically for sanitation services (embedded in housing) in Mahalaxmi municipality.

3.5 | Summary

The results of the tool's application in two distinct city contexts shows its comprehensiveness and versatility in applying tool for different objectives. In Nakuru, the tool could be applied to assess financial flows, cost recovery and sustainability across the whole sanitation value chain, including sewered treatment. Whereas, in Mahalaxmi, the absence of wastewater treatment infrastructure constrained sustainability performance, particularly for treatment-related indicators and demonstrated the tool's ability to explicitly reveal structural service gaps and estimate financial investment requirements for improving sanitation.

CWIS-Fit enables city planners and sanitation stakeholders to identify and trace poor performance in specific components of the sanitation value chain as well as financial shortfalls. For example, low budget allocation to worker's protection and training is directly linked to weak cost-recovery mechanisms and absence of sanitation-specific tariffs. During stakeholder discussions, these results informed concrete improvement options, including the introduction of tariffs, targeted subsidies for worker safety and phased investments or grants for installing infrastructure. CWIS-FiT can support not only in assessment of sanitation systems and services but also as a diagnostic and planning tool that helps stakeholders understand why CWIS outcomes fall short and where corrective infrastructure and non-infrastructure interventions are required.

TABLE 6 | CWIS assessment for Nakuru (default standards and weights), city and Mahalaxmi municipality for equity, safety and sustainability indicators.

	Nakuru			Mahalaxmi		
CWIS outcome indicators	**Thresholds for low, medium and high performance**	**Weight**	**Result**	**Thresholds for low, medium and high performance**	**Weight**	**Result**
Equity	30–70		64.3	40–60		64
% of LIH with access to safe facilities	50%–70%	13%	98%	70%–90%	20%	99%
% of women using safe facilities	50%–70%	13%	99%	70%–90%	20%	99%
Amount paid for non-sewer/amount paid for sewer services	100%–130%	13%	52%	100%–130%	12%	135%
Amount paid from LIH/amount paid for NLIH	100%–130%	13%	58%	100%–130%	12%	100%
% of women workers in decision-making positions	20%–30%	13%	0%	45%–50%	12%	0%
Gender pay gap in decision-making positions	0%–10%	0%	NA	0%–10%	0%	NA
% of women workers in the workforce	20%–30%	13%	26%	45%–50%	12%	29%
Gender pay gap in the sanitation workforce	0%–10%	13%	16%	0%–10%	12%	−21%
Safety	30–70		67	40–60		41.7
Training (% of OPEX for the whole SCV)	NA	17%	Yes	NA	17%	Partially
Workers covered by social/legal insurance	NA	17%	Yes	NA	17%	Partially
Workers covered by health insurance	NA	17%	Partially	NA	17%	Partially
Compliance with the worker's safety—PPE (USD/worker)	$15.00–$30.00	17%	33	$30.00–$50.00	17%	50
WW treatment capacity/total WW generated	70%–100%	17%	64%	90%–100%	17%	0%
FS treatment capacity/total FS generated	70%–100%	17%	90%	90%–100%	17%	15%
Sustainability	30–70		50	40–60		50
% of treated FS and WW treated that is reused	70%–100%	33%	12%	90%–100%	33%	100%
% of OPEX recovered by revenue	70%–100%	33%	257%	70%–100%	33%	68%
% of CAPEX covered by funds	70%–100%	33%	99%	70%–100%	33%	99%

The application of CWIS-FiT also highlighted the importance of institutional capacity and readiness in shaping sanitation service performance against CWIS framework and indicators. The tool assumes a minimum level of stakeholder willingness to collaborate and engage, data availability and institutional coordination to populate inputs and interpret results; thus, its effectiveness depends in part on local governance capacity. However, contexts with lower CWIS implementation maturity, limited regulatory clarity, fragmented mandates, or weak technical capacity do not invalidate the tool; instead, they make institutional and capacity gaps visible, enabling CWIS-FiT to serve as a structured lens for diagnosing readiness and sequencing reforms. As such, the tool remains applicable across different stages of CWIS maturity, provided its outputs are interpreted along with stakeholders' participation as context-sensitive signals of system readiness and transition needs.

4 | Conclusions

This work presents an innovative tool designed to support financial planning for achieving safely managed sanitation following the Citywide Inclusive Sanitation (CWIS) framework. It addresses the complexity of integrating non-infrastructure aspects and costs, sewered and non-sewered sanitation services and comparing costs for low-income and non-low-income households. By combining technical, financial and social indicators, the tool enables stakeholders to evaluate CWIS outcomes holistically and develop improvement plans tailored to equity, safety and sustainability. The tool also supports the tool user to incorporate local stakeholder priorities and adaptive standards for equity, safety and sustainability.

Applications in Nakuru, Kenya and Mahalaxmi, Nepal, were part of the tool development, testing and improvement. Tool applications in diverse urban contexts extend beyond case studies, offering a scalable approach that municipalities and private companies can use the tool to create scenarios and understand costs associated for achieving safely managed sanitation and CWIS outcomes. The tool integrates financial planning with equity, safety and sustainability outcomes, ensuring that investments in sanitation systems are inclusive. It highlighted the need to balance subsidies, tariffs and external funding to ensure financial sustainability without compromising equity and safety. The tool's capability to simulate financial analysis revealed gaps in cost recovery, particularly in treatment and conveyance services. Furthermore, the analysis highlighted gender disparities in workforce participation, suggesting that future planning must also consider social equity interventions.

CWIS-FiT highlighted recurring challenges relevant to cities in low and middle-income countries, such as: (1) data gaps—especially for non-infrastructure costs, workforce conditions and equity indicators; (2) financial projections reflected structural constraints: cities with limited treatment infrastructure or weak cost-recovery mechanisms systematically scored poorly on safety and sustainability, not as a modelling artefact but as an explicit signal of governance and service limitations; (3) traffic-light assessment proved valuable as diagnostic, identifying why outcomes fall short and where interventions along the sanitation value chain are needed, as well as a tool to evaluate greater inclusive scenarios.

A common challenge for both cities is distinguishing between secondary data for LI and NLI households, as most reports (including the Shit Flow Diagram) present results only for the entire city.

By directly linking financial planning with inclusive sanitation outcomes, the tool provides a practical pathway to advance several Sustainable Development Goals (SDGs), particularly SDG 6 on universal access to water and sanitation, SDG 10 on reducing inequalities, SDG 11 on sustainable cities and SDG 12 on responsible consumption and resource efficiency.

It is recommended that users be advised to allocate time for participatory data validation, treat financial forecasts as scenario-based inputs and link underperforming indicators to targeted policy, tariff, or investment actions. By emphasizing transparency, local ownership and learning-by-doing, CWIS-FiT can support cities in estimating costs while strengthening institutional readiness for equitable, safe and sustainable sanitation services.

Author Contributions

Camila Silva Franco: conceptualization, methodology, investigation, formal analysis, writing – original draft, visualization, funding acquisition. **Shirish Singh:** conceptualization, methodology, writing – review and editing, supervision, project administration. **Albert Ocharo:** investigation and data collection. **Timothy Mugo:** investigation and data collection. **Prajwal Shrestha:** investigation and data collection, writing – Review. **Kabita B. Shrestha:** investigation, writing – review. **Damir Brdjanovic:** conceptualization, resources, writing – review and editing, supervision, project administration, funding acquisition.

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Ethics Statement

Human participants: IHE—RECO 2024-aoc001.

Conflicts of Interest

The authors declare no conflicts of interest.

References

Asian Development Bank. 2021. "City-Wide Inclusive Sanitation: A Guidance Note. Asian Development Bank." https://www.adb.org/documents/city-wide-inclusive-sanitation-guidance-note.

Athena Infonomics. 2020. "EquiServe Tool." https://app.equiserve.io/.

Athena Infonomics. 2021. "Full List of CWIS Indicators."

Badal, B. 2020. "Historical Review of Mahalaxmi Municipality: An Integrated Development Perspective." *Rural Nepal Journal of Development Studies* 1, no. 2: 20–33. https://doi.org/10.3126/rnjds.v1i2.22424.

Basyal, I., K. B. Shrestha, S. Singh, B. R. Shrestha, K. R. Yendyo, and R. R. Shrestha. 2023. "Cost–Benefit Analysis of Sewered and Non-Sewered Sanitation Interventions in Mahalaxmi Municipality, Nepal." *ADBI Development Case Study* 2023, no. 1: 1–20. https://doi.org/10.56506/RARG9041.

CBS. 2021. *National Population and Housing Census Report 2021*. Central Bureau of Statistics, National Planning Commission.

Ćetković, J., M. Knežević, S. Lakić, et al. 2022. "Financial and Economic Investment Evaluation of Wastewater Treatment Plant." *Water* 14, no. 1: 122. https://doi.org/10.3390/w14010122.

Dodane, P.-H., M. Mbéguéré, O. Sow, and L. Strande. 2012. "Capital and Operating Costs of Full-Scale Fecal Sludge Management and Wastewater Treatment Systems in Dakar, Senegal." *Environmental Science & Technology* 46, no. 7: 3705–3711. https://doi.org/10.1021/es2045234.

Estu, L. K., B. Susanti, and F. Hadinata. 2021. "Operation and Maintenance Financial Feasibility Analysis of Centralized Domestic Wastewater Treatment System (Case Study: Palembang City Sewerage Project)." *Problemy Inżynierii Rolniczej – Infrastruktura i Ekologia Terenów Wiejskich* 30, no. 3: 484. https://doi.org/10.22630/PNIKS.2021.30.3.40.

Finney, B. A., R. A. Gearheart, J. Howell, et al. 1998. *A User's Manual FdR (Version 4.0 for MS-Windows): A Decision Support Model for Prefeasibility Analysis of Water and Wastewater Treatment Technologies Appropriate for Reuse*. IRC International Water and Sanitation Centre, Humboldt State University.

Franco, C. S., S. Singh, and D. Brdjanovic. 2025. "Sanitation Financial Tools (SFTs) for Citywide Inclusive Sanitation (CWIS): A Critical Review." *Journal of Environmental Management* 392: 126687. https://doi.org/10.1016/j.jenvman.2025.126687.

FSM Toolbox. n.d. "FSM Toolbox: Tools and Resources for Fecal Sludge Management." https://www.fsmtoolbox.com.

Furlong, C., S. Singh, N. Shrestha, et al. 2020. "Evaluating Financial Sustainability Along the Sanitation Value Chain Using a Financial Flow Simulator (eSOSView)." *Water Science and Technology* 82, no. 11: 2220–2233. https://doi.org/10.2166/wst.2020.456.

Furlong, C., S. Singh, N. Shrestha, et al. 2023. "Exploring the Usage and Impact of Urban Sanitation Tools Targeting Low- and Middle-Income Countries." *Frontiers in Environmental Science* 11: 1109306. https://doi.org/10.3389/fenvs.2023.1109306.

Henriques, D. S., S. T. Coelho, and L. Ribeiro. 2022. "Financial and Economic Viability of Wastewater Treatment Plants in Developing Countries: A Critical Review." *Water* 14, no. 1: 122. https://doi.org/10.3390/w14010122.

Hutton, G., and M. Varughese. 2017. *The Costs of Meeting the 2030 Sustainable Development Goal Targets on Drinking Water, Sanitation, and Hygiene*. Water and Sanitation Program, World Bank Group's Water Global Practice. https://openknowledge.worldbank.org/server/api/core/bitstreams/12d140fc-607b-5fa2-b966-40e872906946/content.

KNBS. 2019. *2019 Kenya Population and Housing Census*. Kenya National Bureau of Statistics.

Langergraber, G., and N. Weissenbacher. 2014. *Sustainable Sanitation. Practical Issues, 19: The CLARA Project*. EcoSan Club.

Li, Y., J. T. Trimmer, S. Hand, et al. 2022. "Quantitative Sustainable Design (QSD) for the Prioritization of Research, Development, and Deployment of Technologies: A Tutorial and Review." *Environmental Science: Water Research & Technology* 8: 2439–2458. https://doi.org/10.1039/d2ew00431c.

Marques, R. C., and A. Monteiro. 2023. "Financing Water and Sanitation Infrastructure in Portugal: Lessons From 25 Years of Investment." *Water* 16, no. 21: 3087. https://doi.org/10.3390/w16213087.

Mohideen, A. C., S. Singh, T. A. Chowdhury, and D. Brdjanovic. 2022. "Application of Financial Flow Simulator (eSOSView) for Analyzing Financial Viability and Developing a Sustainable Fecal Sludge Management Business Model in Kushtia, Bangladesh." *Frontiers in Environmental Science* 10: 863044. https://doi.org/10.3389/fenvs.2022.863044.

Ocharo, A. O. 2024. "Investigating an Integrated Financial Tool for Citywide Inclusive Sanitation (CWIS): A Case Study of Nakuru City, Kenya." Master's Thesis, IHE Delft Institute for Water Education, Delft, The Netherlands.

Oertlé, E., C. Hugi, T. Wintgens, and C. A. Karavitis. 2019. "Poseidon—Decision Support Tool for Water Reuse." *Water* 11, no. 2: 204. https://doi.org/10.3390/w11020204.

Rowles, L. S., V. L. Morgan, Y. Li, et al. 2022. "Financial Viability and Environmental Sustainability of Fecal Sludge Treatment With Pyrolysis Omni Processors." *ACS Environmental Au* 2, no. 5: 422–435. https://doi.org/10.1021/acsenvironau.2c00022.

Sainati, T., F. Zakaria, G. Locatelli, P. A. Sleigh, and B. Evans. 2020. "Understanding the Costs of Urban Sanitation: Towards a Standard Costing Model." *Journal of Water Sanitation and Hygiene for Development* 10, no. 2: 177–187. https://doi.org/10.2166/washdev.2020.093.

Sani Plan. 2016. *A Performance Improvement Planning Model: Approach Paper Manual Part 1*. PAS Project, CEPT University. https://pas.org.in.

Schrecongost, A., D. Pedi, J. W. Rosenboom, R. Shrestha, and R. Ban. 2020. "Citywide Inclusive Sanitation: A Public Service Approach for Reaching the Urban Sanitation SDGs." *Frontiers in Environmental Science* 8: 19. https://doi.org/10.3389/fenvs.2020.00019.

Strande, L., B. Evans, M. von Sperling, et al. 2023. "Urban Sanitation: New Terminology for Globally Relevant Solutions." *Environmental Science & Technology* 57, no. 38: 15771–15779. https://doi.org/10.1021/acs.est.3c04431.

Strande, L., M. Ronteltap, and D. Brdjanovic, eds. 2014. *Faecal Sludge Management: Systems Approach for Implementation and Operation*. IWA Publishing.

SuSanA. 2026. "SuSanASFD Portal. Sustainable Sanitation Alliance." https://sfd.susana.org/.

Taron, A., S. Singh, P. Drechsel, C. Ravishankar, and A. Ulrich. 2023. *Sewage Sludge: A Review of Business Models for Resource Recovery and Reuse (Resource Recovery and Reuse Series 23)*. International Water Management Institute (IWMI). https://doi.org/10.5337/2023.211.

Tilley, E., L. Ulrich, C. Lüthi, P. Reymond, and C. Zurbrügg. 2014. *Compendium of Sanitation Systems and Technologies*. 2nd ed. Eawag.

UN Millennium Project Water and sanitation needs assessment model: user guide, United Nations millennium project. 2005. MDG Needs Assessment Tools: User Guide. United Nations Millennium Project, United Nations Development Programme (2005) academiccommons.columbia.edu.

UN-HABITAT. 2020. *Informal Settlements' Vulnerability Mapping in Kenya: The Case of Nakuru Town Settlements*. UN-HABITAT.

United Nations. 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations.

Waziri, E. K. 2020. "Financial Assessment Tool for a City-Wide Inclusive Sanitation With the Island of Sint Maarten's Case Study." Master's Thesis, IHE Delft Institute for Water Education, Delft, The Netherlands.

World Bank. 2019. *The Online CWIS Costing & Planning Tool*. World Bank.

Zoungrana, M., H. A. Andrianisa, R. Yonaba, A. G. Mabia, S. Thiam, and B. Bonkian. 2024. "A GIS-Based Approach for Improving Urban Sanitation Planning and Services Delivery: A Case Study From Ouagadougou, Burkina Faso." *Habitat International* 102993.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Improvement plan example. **Figure S2:** User interface and containment inputs and financial planning from the perspective of LI and NLI households. **Figure S3:** Conveyance inputs and financial planning from public/private companies. **Figure S4:** Treatment inputs and financial planning from public/private companies. **Figure S5:** Use/disposal inputs and financial planning from public/private companies. **Figure S6:** Choosing technologies and checking CWIS outcomes. **Figure S7:** Inputting quantities and costs separately for LI and NLI households and SS and NSS. **Figure S8:** Workers equity and safety inputs. **Figure S9:** Business model sheet. **Figure S10:** Checking CWIS outcomes for each SVC component. **Figure S11:** (A) Nakuru City water coverage. *Source:* Water (2020). (B) Mapped informal settlements in Nakuru City. *Source:* UN-HABITAT (2020). **Figure S12:** SFD diagram for Nakuru City (NAWASSCO 2024). **Figure S13:** Field observation in Nakuru: Vacuum exhauster desludging at the WWTP, Manual emptiers transferring waste to mechanized transport, Rounded Briquettes from the Reuse plant and the briquettes on a local jiko (stove). **Figure S14:** Ongoing FGD and JSM in Nakuru. **Figure S15:** Location of Mahalaxmi municipality (ENPHO 2019). **Figure S16:** SFD diagram for Mahalaxmi municipality (CWIS TA Hub, South Asia, ENPHO, & KVWSMB 2019). **Figure S17:** (A) FSM system and (B) sewer system at Mahalaxmi (ENPHO 2019). **Figure S18:** Mahalaxmi FSTP. **Figure S19:** FGD in Mahalaxmi. **Table S1:** Disaggregated costs and revenue for each SVC component. **Table S2:** Details of the KII, FGD and JSM met in Nakuru. **Table S3:** Details of the KII, FGD and JSM met in Mahalaxmi. **Table S4:** Questionnaire template for interviews to fill tool's inputs.