Approach for scaling up citywide safely managed sanitation access and services: A study of Lusaka, Zambia

by

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Attaining global sanitation goals implies delivering safely managed services for all. This requires considerable financial resources, with funds often limited and inequitably allocated. Sanitation access, equity of public spending, affordability and financial viability of services are well documented. However, the challenges facing the delivery of citywide sanitation are not sufficiently addressed. Because planning is not responsive to the different urban realities within cities, uptake of current approaches at scale still lags, while conditions underpinning service sustainability are often missing from delivery frameworks.

This case study used mixed research methods to establish an approach that helps decision-makers compare citywide safely managed sanitation options to scale services in Lusaka. Two household surveys - area-level (596) and city-level (1495) and 37 key informant interviews complemented by secondary data informed the study. The aim was to understand the costs to deliver and sustain services, the enabling environment to facilitate the delivery and the community responsiveness to different services and modes of delivery.

A simplified approach prioritising the scaling-up of citywide services was established using multi-criteria analysis. Specifically, the analytical hierarchy process (AHP) provided the framework to compare sanitation options and summarise the effect of moving populations between sanitation systems across the city. Criteria were limited to cost, fit with the enabling environment, and community responsiveness of each option.

Results showed that a fully sewered system adoption is responsive to community needs and fits the enabling environment well but would be costly to implement. A fully non-sewered system does not fit well with the enabling environment but performs well on costs, as most people use on-site sanitation. A fully non-sewered system would be responsive to community needs, but communities have never experienced fully operational services. The analyses provided a path towards a solution comprising sewered and non-sewered options. Six pathways, a blend of services, were established that make

incremental improvements on an area-by-area basis by optimising the performance criteria of existing sewered and non-sewered services. The established pathways ensure citywide safely managed sanitation services, with the overall responsibility for services taken away from households to the public sector as a sole provider or on a delegated basis. The approach allows decision-makers to decide the optimal solution based on criteria prioritisation.

As the body of literature grows, with little traction for approaches, these results demonstrate the need to have adaptive planning by pulling together strands of existing approaches to meet sanitation needs in a specific context.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AfDB	African Development Bank
AHP	Analytical Hierarchy Process
AIC	Akaike Information Criterion
AIC	Average Incremental Cost
ANP	Analytical Network Process
AOR	Adjusted Odds Ratio
BC	Boundary Cases
BCR	Benefit-Cost Ratio
BMGF	Bill and Melinda Gates Foundation
BVO	Blended Variant Option
CapEx	Capital Expenditure
CBA	Cost-Benefit Analysis
CBO	Community-Based Organisation
CBS	Container-Based Sanitation
CE	Connection Efficiency
CEA	Cost-Effectiveness Analysis
CI	Confidence Interval
CLUES	Community-Led Urban Environmental Sanitation
COR	Crude Odds Ratio
CPI	Consumer Price Index
CSDA	City Service Delivery Assessment
CSO	Central Statistical Office (now Zambia Statistics Agency)
CSP	City Sanitation Planning
CWIS	Citywide Inclusive Sanitation
EIB	European Investment Bank
DA	Decision Analysis
DEWATS	Decentralised Wastewater Treatment System
DWWM	Decentralised Wastewater Management

FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
GBR	Great Britain
GoZ	The Government of Zambia
HCES	Household-Centred Environmental Sanitation
HILD	High-Income Low Density
IEC	Information, Education and Communication
IFIs	International Financing Institutions
IPL	Improved Pit Latrine
IRC	International Water and Sanitation Centre
JMP	Joint Monitoring Programme
KfW	German Development Bank
KII	Key Informant Interview
LCA	Lifecycle Cost Analysis
LCC	Lusaka City Council
LIHD	Low-Income High Density
LMIC	Low and Medium-income Country
LSIMP	Lusaka Sanitation Investment Master Plan
LSP	Lusaka Sanitation Program
LWSC	Lusaka Water and Sewerage Company (now Lusaka Water Supply and Sanitation Company)
MAUT	Multi-attribute Utility Theory
MCA	Multi-criteria Analysis
MCC	Millennium Challenge Corporation
MDG	Millennium Development Goal
MIMD	Medium-income Medium Density
MLGH	Ministry of Local Government and Housing
MWDSEP	Ministry of Water Development, Sanitation and Environmental Protection

NPV	Net Present Value
NUSS	National Urban and Peri-Urban Sanitation Strategy
NUWSSP	National Urban Water Supply and Sanitation Program
NWASCO	National Water and Sanitation Council of Zambia
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
OpEx	Operational Expenditure
OPSS	Open Planning of Sanitation Systems
OSS	On-Site Sanitation
PPP	Purchase Power Parity
PROMETHEE	Preference Ranking Organisation METhod for Enrichment Evaluations
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SDG	Sustainable Development Goal
SFD	Faecal Waste Flow Diagram
SLG	Service Level Guarantee
SSA	Sub-Saharan Africa
SSA	Strategic Sanitation Approach
SSD	Sewerage Services Department
ST	Septic Tank
TACC	Total Annualised Cost per Capita
TACH	Total Annualised Cost per Household
TEVETA	Technical Education, Vocational and Entrepreneurship Training Authority
UN	United Nations
UNICEF	United Nations Children's Fund
USA	United States of America
US$	United States Dollar
VIP	Ventilated Improved Pit

VfM	Value for Money
VTO	Vacuum Truck Operator
WaSH	Water, Sanitation and Hygiene
WB	World Bank
WHO	World Health Organisation
WPM	Weighted Product Method
WSM	Weighted Sum Method
WSS	Water Supply and Sanitation
WT	Water Trust
WWTP	Wastewater Treatment Plant
ZDHS	Zambia Demographic and Health Survey
ZEMA	Zambia Environmental Management Agency
ZMW	Zambian Kwacha

Glossary of Terms

Adjusted odds ratio control for other predictor variables in a regression model. It explains variability between the predictors and controls for confounding bias.

Access entails having sanitation facilities close to home, which can easily be reached and used when needed.

Approach is a framework or methodology for urban sanitation that aims at putting principles into action (Schertenleib et al., 2021).

Boundary cases are the synthetic (notional) sanitation options developed to assess their suitability against cost, enabling environment and community-level factors to plan for citywide services in Lusaka.

Community-scale secondary sewer networks are an area-level network of sewer pipes and inspection chambers that may include pumping stations that convey wastewater from households into the primary trunk network.

Compound refers to a cluster of household buildings within an enclosed space or defined plot boundary with shared services such as water, sanitation, stormwater and solid waste management.

Costs are direct, quantifiable cash flows or equivalent monetary means. For this study, these are the cash flows required to provide a sanitation service but not including fees.

Crude odds ratio is an odds ratio of an explanatory variable for predicting a dependent variable.

Faecal sludge is the raw or partially digested, slurry or semi-solid product without greywater coming from on-site sanitation technologies that have not been transported through a sewer.

Faecal sludge management is the safe collection, transport, treatment, disposal and/or reuse of faecal sludge.

Fees are the monetary value of a unit of a good or service fixed in advance based on the costs of producing the goods or delivering the service.

Full cost recovery is the recurrent income sufficient to cover the capital, operations and maintenance costs, the cost of capital, and the expected return on investment.

High-income low-density areas are predominantly planned, fully serviced areas with the least population density and a low proportion of renting households, associated with a high quality of life.

Household is "a person or group of related or unrelated persons living together in the same dwelling unit(s), who acknowledge one adult female or male as the head of the household, share the same housekeeping arrangements, and considered a single unit" (Zambia Statistics Agency et al., 2019, p 46).

Inclusive means everyone in the city and its areas, whether formally or informally settled, are included in services provided such as water, sanitation, solid waste and stormwater management.

Low-income high-density areas are often unplanned, spatially disorganised areas with a high population density, generally characterised by low incomes, a high proportion of renting households and associated with a low quality of life.

Medium-income medium-density areas are areas with at least basic services that may be planned and have a moderate population density, medium incomes with moderate quality of life.

Non-sewered sanitation is a system where partial excreta treatment at the point of generation occurs and/or is emptied and transported by manual or mechanical means to treatment.

On-site sanitation system is a system that stores human excreta in an in-situ containment, with partial in-situ treatment and/or for collection to treatment or to reuse or to safe disposal.

Non-sewered area is a location within a town or city with a sanitation system that allows partial excreta treatment occurring where it is generated or emptied and transported by manual or mechanical means to treatment.

Operation and Maintenance (O&M): operation entails activities resulting in using the sanitation system, ensuring the system works efficiently and orderly. Maintenance entails technical activities performed on a system keeping it in good working order, ensuring efficiency and effectiveness.

Open defecation is the disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other open spaces.

Percolation means the passage of effluent from sanitation containments through underground soil or rock.

Sanitation intervention is the provision of new or improved means of excreta management.

Sanitation system is a series of technologies and services for managing waste (or resources), i.e., for their collection, containment, transport, transformation, utilisation or disposal (Tilley et al., 2014).

Septage is a type of faecal sludge with partially digested faecal solids (and may have greywater) accumulating in septic tanks.

Service provider is a private or public company, institution or organisation, contracted to perform wastewater or faecal sludge management services.

Sewered area is a location within a town or city with a sanitation system that allows excreta collection for treatment and disposal through pipes.

Sewered sanitation is a system that collects excreta and wastewater through pipes for safe treatment and disposal.

Off-site sanitation system is a system where human excreta are flushed through sewer pipes to a wastewater treatment plant.

Sanitation surcharge is a fee surcharged on the monthly water bill and collected from each household with a utility connection to finance sanitation.

Sanitation value chain refers to the fit and combination of sanitation technologies in place and the quality of services provision within existing institutional arrangements (Spuhler and Lüthi, 2020).

Sanitation service coverage is the proportion of a given population serviced with sanitation services.

Socio-economic and demographic characteristics are the socio-economic characteristics of a population expressed statistically, such as age, sex, education level, income level, marital status, occupation and employment status, and household size.

Tool is an instrument applied in the context of one or more approaches to support the operationalisation of the approach (e.g. the Shit Flow Diagram) (Schertenleib et al., 2021).

Trunk sewers are the primary network of sewers that collect wastewater from community-scale secondary networks and convey the wastewater to treatment.

Chapter 1: Introduction

1.1 Introduction

The chapter gives a background to the urban sanitation situation and details some of the challenges within the planning paradigm. The chapter then highlights the space within which this research fits in the overall provision of citywide sanitation services by highlighting gaps in current scholarship. Finally, the chapter gives the rationale for the research and the thesis structure.

1.2 Background

1.2.1 Urbanisation and sanitation

Prevailing spatial and environmental challenges worldwide can be linked to the emergence of rapidly growing urban centres (Okari, 2019). The growth of these centres has led to uncontrolled urbanisation, especially in low and middle-income countries. As a consequence of this rapid urbanisation, the United Nations notes that "one in eight people globally and approximately 30% of urban residents in developing countries live in slum areas" (UN-HABITAT, 2016, p 2). Furthermore, around 7 billion people globally will live in urban areas by the year 2050 (Ritchie, H. and Roser, 2020), with the proliferation of slums remaining a critical factor in the persistence of poverty the world over (UN-HABITAT, 2016).

Urban areas experiencing rapid population growth are characterised by inadequate provision of services. The constrained services include water supply, sanitation, stormwater and solid waste management. The inadequacy of these services poses social, health and environmental risks to residents within these settings. In low and middle-income countries, the state of water, sanitation and hygiene (WaSH) is dire. In 2020, only 54% of the global population had access to a safely managed sanitation service, with current rates of progress needing to quadruple to meet 2030 targets (UNICEF and

WHO, 2021). Moreover, the proportion of the population without safely managed sanitation services in urban areas has increased (Schertenleib et al., 2021). Further, poor sanitation is one of the main contributors to the global diseases burden (Van Minh and Nguyen-Viet, 2011). Hence, providing adequate sanitation services is an urgent challenge facing many fast-growing urban areas (Andersson et al., 2016; Isunju, J. et al., 2011).

1.2.2 Challenges in sanitation service delivery

Despite increased investment in sanitation, results have fallen short of coverage and service delivery levels widely anticipated for many low and middle-income countries (Molden, 2013). Moreover, the challenges of sanitation service delivery are worsening in that the urban poor live in areas where municipalities lack capacity and often are not planning for service provision (Lüthi et al., 2010). In addition, the long-term failure of local governments to implement structural plans to enforce development control (Kampala City Council, 2002) has been a factor in the inadequacy of municipal services.

The emphasis on investments in expensive conventional sewerage systems in low-income countries has disadvantaged the development of appropriate approaches for managing excreta at the household and community levels (Evans, 2005). Moreover, strategies to extend sewer networks are constrained due to the high capital costs and the reluctance of municipalities to recognise the permanence of illegal settlements (Eales, 2008). In addition, the lack of planning controls in unplanned areas often characterised by increasing housing density also affects the development of sustainable excreta management systems (Isunju, J. et al., 2011).

Furthermore, affordability and the degree of security of tenure experienced in low-income settings are influential in the willingness of communities to invest in sanitation (Beall, 1995). Ostrom and colleagues argue that one underlying cause for the failure to sustain investments in infrastructure is the perverse incentives facing participants in the design, finance, construction, operation, maintenance, and use of the infrastructure (Ostrom et al., 1993). These incentives lead to unintended and undesirable outcomes contrary to the interests of sustaining the investments. As such, effective sanitation systems need to deliver the right incentives for all the actors involved. In addition, community participation in policy can be an opportunity to increase the chances of providing sustainable services to communities (Evans, 1995).

1.2.3 Urban sanitation planning

The United Nations Sustainable Development Goal (UN-SDG) Target 6.2 calls for access to adequate and equitable sanitation for all. Therefore, approaches that directly address user needs and demand (Sigel et al., 2012) are essential to improving the sanitation situation in low and middle-income countries. The situation can further improve with increased participation from households because participation is integral to sanitation planning approaches. Household participation can overcome the lack of sufficient demand for sanitation and may help develop long-term sustainability (Kennedy-Walker, Ruth et al., 2014).

Essential to urban sanitation planning considerations are the costs that occur during the life of systems to ensure adequate and sustainable sanitation (Ulrich et al., 2016; Fonseca et al., 2010). Detailed costing analyses are necessary for determining the most appropriate systems in a given context (Willetts et al., 2010). The analyses are needed early in the planning process to ensure sustained service delivery (Kennedy-Walker, R. et al., 2016). Furthermore, understanding the plausible determinants of sanitation costs is crucial for planning and may indicate where cost optimisation might be needed. As sanitation costs are susceptible to context (Daudey, 2018), cost assessments need to be transparent, detailed, and explicit to demonstrate the handling of uncertainty and data variation.

Overall, sanitation service provision is a complex undertaking in the face of scarce resources with several factors such as user behaviour, provision and production costs, context and incentives underpinning its success (Evans, 1995; Ostrom et al., 1993). For example, the building space, low income and land tenure are well-known barriers to sanitation provision in many low and middle-income countries (Rheinlander et al., 2015; Mazeau and Ramsay, 2011). Also, the environment enabling services is essential to ensure sustained sanitation delivery.

1.3 Statement of the problem and its significance

The development of approaches and tools to understand the different modes of sanitation services delivery has been progressive (Scott and Cotton, 2020). However, progress in safely managed sanitation service use by urban dwellers has been slow and uneven among different population segments (Schertenleib et al., 2021). Therefore, planning needs to provide solutions that respond to different urban realities for services to be inclusive. Despite several planning approaches and tools that suit various needs, their uptake at scale lags (Spuhler and Lüthi, 2020). Most are predominantly supply-led, with financial and technical support provided by promoters in implementation (Schertenleib et al., 2021). Also, the conditions underpinning sustainable services (i.e., the enabling environment) and users; their priorities and interests are often missing or overlooked in current conceptualisations of service delivery frameworks (Scott and Cotton, 2020). Therefore, the challenges for citywide sanitation are still not addressed sufficiently (Spuhler and Lüthi, 2020).

The lack of tools to holistically understand and select the effective combination of appropriate technologies, viable institutional options, and governance systems within context constrains service provision (Schertenleib et al., 2021). Therefore, providing appropriate options for the different areas within a city that deal with current challenges is an essential step towards a more holistic sanitation service approach. This research highlights the need for informative context-based decision-making and planning approaches to help overcome the current challenge to manage sanitation in rapidly urbanising cities safely. Thus, demonstrating a shift from a more ad-hoc focused to city-centred planning.

1.4 Study aim, scope and objectives

1.4.1 Aim

The overarching question the study seeks to answer is: How can the sector ensure the provision of safely managed sanitation services at scale in rapidly urbanising cities? This research aims to establish an approach to scale citywide safely managed sanitation services. The outcomes of this research could inform sanitation programming at the city level, resulting in inclusive services for all.

1.4.2 Scope

The research focuses on the context of a rapidly urbanising city with different population segments in low and middle-income countries using Lusaka, Zambia, as a case study. This research applied qualitative and quantitative methods through interviews, surveys, and secondary data review to establish an approach for scaling citywide sanitation services.

1.4.3 Research objectives

The specific objectives to achieve the aim are as follows:

i. To review existing sanitation costing approaches and establish the financial costs of sewer-based and faecal sludge management systems.
ii. To assess the environment enabling the delivery and sustaining of sewered and non-sewered sanitation services.
iii. To explore the factors influencing household sewer connectivity and access to safely managed faecal sludge management services.
iv. To establish an approach for generating strategic planning options to scale safely managed sanitation services citywide.

1.5 Rationale for the research

The emergence of rapidly growing urban centres in low and middle-income countries undermines the efforts of municipalities and utility providers in planning for and guiding the delivery of services. A holistic approach to planning and decision-making can be a driver to progress as it ensures sustainable management, given that financial resources for sanitation tend to be low (Daudey, 2018). It is worth exploring the complexities inherent in urban areas and factors inhibiting progress and service delivery. The sector needs to understand better the factors perpetuating the status quo. Situational analyses are needed to identify stakeholders and their roles and understand their interests, priorities, and incentives (Kennedy-Walker, Ruth, 2015). Therefore, urban planning approaches are a basis for establishing programming for successful sanitation interventions. Hence, analyses on how the approach informs decision-making would be relevant both for policy and practice, locally and beyond, in sanitation options selection for similar contexts.

1.6 Thesis theory of change approach

This research used a theory of change design process to inform the delivery of the intended societal impact. A theory of change approach is a structured and systematic study design process that brings together implementation elements by linking activities, outcomes, and the contexts of research uptake (Clappison, 2012; Connell and Kubisch, 1998). It also focuses on the intermediate steps between activities and impacts to help identify gaps and priorities, leading to more explicit goals and better planning to achieve them (Noble, 2019). The approach helped the researcher be explicit about the changes the research intends to bring about.

Furthermore, the approach determines the intended outcomes, the activities expected to be implemented to achieve the outcomes and the factors that may influence the implementation of activities and their potential to bring about desired outcomes (Connell and Kubisch, 1998). Figure 1-1 shows the theory of change logic model used in this thesis.

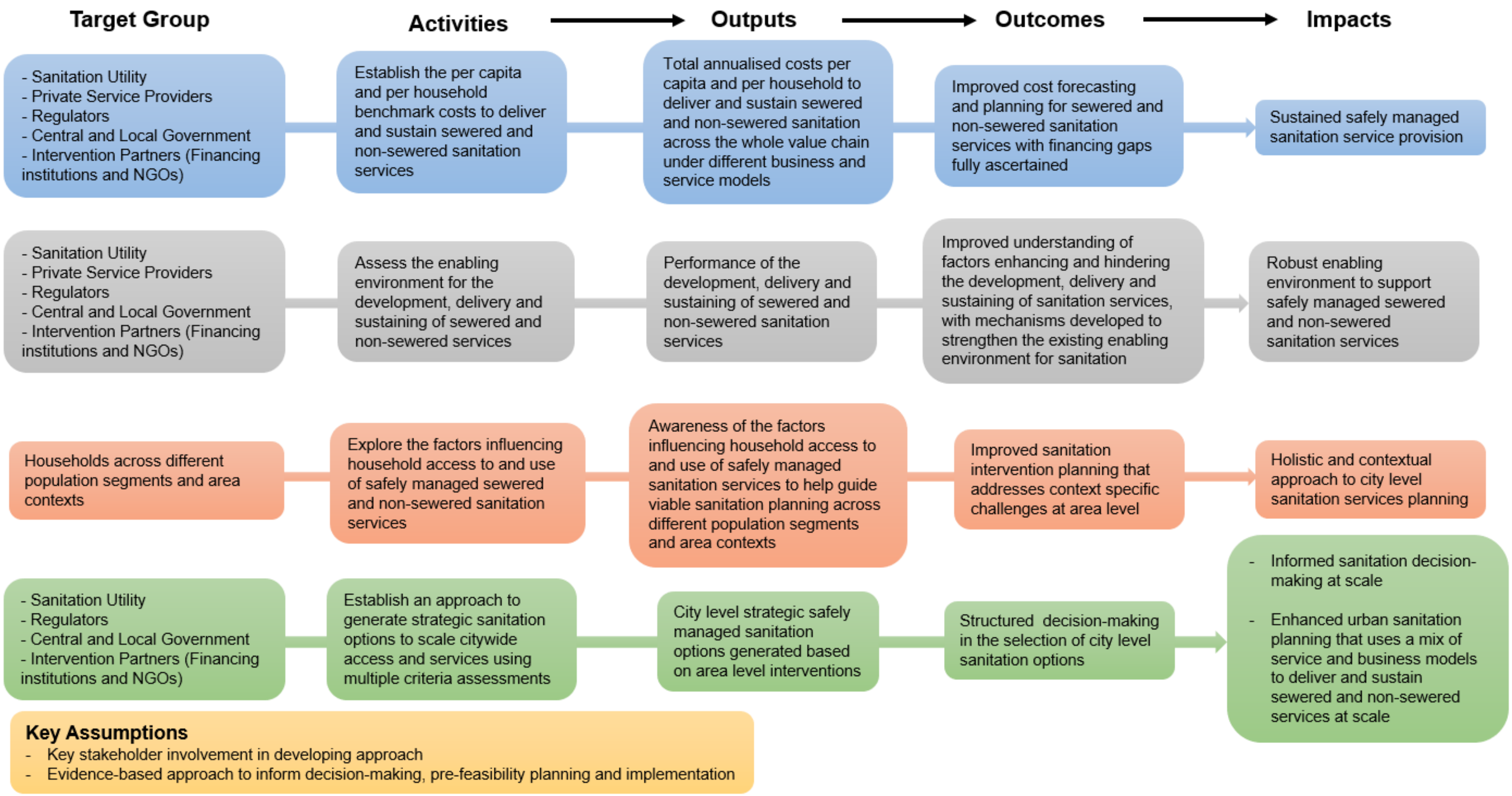

Figure 1-1. Thesis theory of change logic model

1.7 Thesis structure

This thesis is organised into ten chapters, broken down as:

- Chapter 1 gives the research background, aims, objectives and study rationale.
- Chapter 2 reviews the costing approaches in urban sanitation.
- Chapter 3 gives the study methodology.
- Chapter 4 is the financial cost analysis of sewer-based and faecal sludge management sanitation systems.
- Chapter 5 assesses the enabling environment for sewered and non-sewered sanitation services.
- Chapter 6 explores the factors influencing household sewer connectivity and access to safely managed faecal sludge management services.
- Chapter 7 establishes the approach to city-level safely managed sanitation optioneering.
- Chapter 8 generates the strategic options for citywide sanitation access and services.
- Chapter 9 describes the risks and resilience of the area-by-area optimised sanitation system options.
- Chapter 10 gives the general discussion on planning citywide sanitation.
- Chapter 11 gives the conclusions, limitations and recommendations.

Chapter 2: Systematic review of costing approaches in urban sanitation

2.1 Introduction

The previous chapter gave background to the research. This chapter focuses on exploring the literature to assess the approaches used to cost sanitation. This review was the first step in establishing the framing for this PhD research. The initial hypothesis was that lack of costing data was the highest barrier to good quality sanitation decision making. Therefore, this review was intended to establish the extent and quality of the literature on costing and assess whether reliable benchmarking costs could be generalised for planning purposes.

The review addressed the question: what approaches are used to cost urban sanitation? Findings from the review helped identify gaps in current costing approaches and the suitability of available approaches to inform the costing of citywide sanitation interventions (Chapter 4).

2.2 Methods

The review followed recommendations in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009) and guidance from the Campbell and Cochrane Economics Methods Group on including economic evidence in reviews (Shemilt et al., 2006).

2.2.1 Eligibility criteria

The review included all studies showing cost analysis data with no restriction on study design. Studies on any sanitation technology type and level of service, i.e., safely managed, basic and limited services, were included in the review. An attempt to identify all relevant peer-reviewed articles and grey literature studies published in the English language was made. No restrictions on publication date or status were imposed. The review excluded studies published as abstracts, reviews, commentaries, letters and editorials.

2.2.2 Information sources

All relevant peer-reviewed articles and studies were identified by searching electronic databases, scanning reference lists, and hand searching websites. The terms outlined in the search strategy were used to search titles and abstracts. For database searches, terms were separated by the Boolean logic AND/OR, while closed inverted commas were used for combined terms (Hart, 2001).

The databases Science Citation Index, Social Science Citation Index, Arts and Humanities Citation Index and Scopus were searched. Searches in Google Scholar, ProQuest open access dissertations and theses, ETHoS, and OpenGrey electronic databases were made to capture grey literature and reduce publication bias (Booth et al., 2016). The review also used the extraction of possible relevant studies by manually searching the reference lists of included studies. The World Bank's Open Knowledge Repository, IRC WaSH, Sustainable Sanitation Alliance and World Health Organisation websites were searched for grey literature. See Appendix A-1 for the full search strategy. An update of the literature in the final stages of the research was undertaken.

2.2.3 Search strategy

The database search used keywords and their corresponding subject headings. The search strategy below is an example of the search made in Scopus.

1. (method* OR methodolog* OR approac* OR techniqu* OR procedur* OR practic*) AND (cost* OR "estimat* cost" OR "structure cost*" OR apprais* OR "asses* cost") AND (sanitation OR toilet* OR latrine* OR "toilet facilit*" OR "fe*cal sludge" OR sewage OR "excreta disposal" OR "waste disposal" OR "wastewater" OR sewerage OR "rest room" OR bathroom OR lavator*) AND (urban OR "low-income" OR "peri-urban" OR slum* OR "informal settlemen*" OR cit* OR tow*)

2.2.4 Study selection

The articles and grey literature retrieved from the searches were exported into EndNote reference management software. The inclusion and exclusion criteria guided the screening process. The screening examined study titles, abstracts, and full-text articles. After excluding studies based on the titles and abstracts, full-texts were added to Endnote. Evaluation of full-text articles was necessary because abstracts only include limited descriptions of the study design and do not often provide sufficient methodological detail (Xu et al., 2014). The full-text EndNote library was then exported to QSR NVivo 12 data management software and Microsoft Excel 2016 for coding, analysis and synthesis.

Articles meeting the inclusion criteria were assessed on the approach used to cost sanitation. According to the PRISMA recommendation, the screening allowed for categorisation, summary, and reporting reasons for excluding studies (Moher et al., 2009). The list of excluded studies was maintained with reasons for exclusion (Appendix A-2).

2.2.5 Data collection process

The full texts were coded in NVivo and Excel according to the data items listed below:

- Characteristics of included studies, following: author; year; study type and design; study setting (country and area context, i.e., urban, peri-urban, informal settlement/slum);
- Description of the type of sanitation system[1] used;
- Costing approach/analysis used;
- Unit of analysis, i.e., cost per person, cost per unit, cost per household, cost ranges;
- Cost component(s) included;
- Study assumption(s); and
- Sensitivity analysis.

[1] A sanitation system is a context-specific series of technologies and services for the management of sanitary waste (or resources).

The data from all studies meeting the inclusion criteria were extracted and synthesised from the coding process.

2.2.6 Assessment for methodological quality

Each included study was evaluated to assess the quality and potential risk of bias in individual studies. The assessment used checklists developed for best evidence topics (BestBET) (Booth et al., 2016). It helps assess the methodological quality of cost studies. As the focus was on reviewing and evaluating the cost approaches of included studies, there was no combining of findings across individual studies. Therefore, there are no summary measures for this review; instead, tabulations and narrative summaries are the primary approaches to synthesising the data recommended by the Campbell and Cochrane Economics Methods Group (Shemilt et al., 2006). The review discussed gaps and limitations in the costing approaches for cost benchmarking.

2.3 Results

2.3.1 Study selection

The search strategy from the databases resulted in 4,041 titles and abstracts, while grey literature sources retrieved 43 documents. Screening was for the first 1000 records in the World Bank Open Knowledge Repository, IRC WaSH websites, and Google Scholar for the grey literature sources. From the screening process, 64 documents were eligible for further assessment. Of the eligible studies, 32 full-text documents met the inclusion criteria. Figure 2-1 provides a detailed overview, with Appendix A-2 giving the reasons for study exclusion.

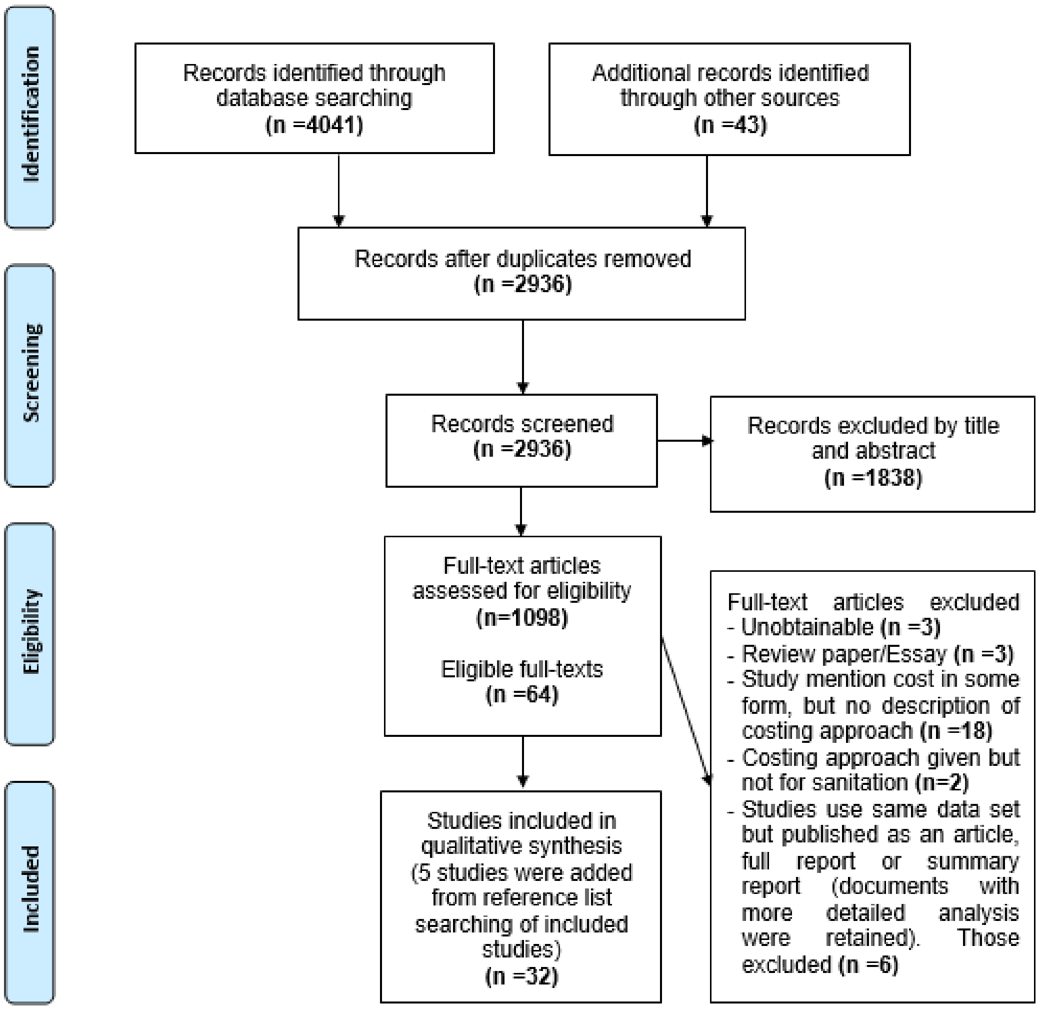

Figure 2-1. The process of including studies for review PRISMA flow chart (Moher et al., 2009)

2.3.2 Study type and settings

Most of the studies included followed an observational study design. The studies were either cross-sectional, case study or desk study based. Twenty studies took place in the urban or peri-urban settings; two in informal settlements; two in slums; one in a sub-district; with seven at a multi-country level. Table 2-1 summarises data collected on sanitation characteristics, the study context, the costing approach used, and the unit of analysis.

Table 2-1. Summary of data collected on sanitation characteristics, context, cost approach and unit of analysis

Author(s)	Sanitation characteristic	Context	Cost Analysis Approach	VfM Framework Analysis	Unit of Analysis
Alivelu et al., 2012	Not explicitly stated	Andhra Pradesh (Peri-Urban)	Disaggregated Costs		Costs capita^{-1} Costs capita^{-1} year^{-1}
Balasubramanya et al., 2017	FSM from on-site latrines	Bangladesh (Sub-district Rural)	NPV and Cost-Effectiveness Analysis	Costs to sustain actual outcomes	Costs household^{-1} Costs year^{-1}
Burr et al., 2011	Traditional and improved latrines (VIP, pour-flush & latrine with septic tank)	Andhra Pradesh, Burkina Faso, Ghana and Mozambique (Peri-Urban)	Disaggregated Costs		Costs toilet type^{-1} Costs capita^{-1} year^{-1}
Carrard et al., 2021	Household septic tanks with vacuum truck desludging and transportation to FSTP	Sri Lanka (Urban)	NPV lifecycle costs approach with integrated resource planning	Costs to sustain actual outcomes	Costs capita^{-1} year^{-1} Cost m^{-3} of FS
Chuan et. at., 2012	Flush toilets with sewerage, public and private flush toilets with septic tanks and pit latrines in urban areas and public dry toilets, pit latrines, shared latrines, UDDTs, and septic tanks in peri-urban areas	Yunnan Province (Urban & Peri-Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} Costs household^{-1} year^{-1}
Delaire et al., 2020	Compared the financial implications of different sanitation approaches such as sewerage, on-site sanitation, and CBS	Kenya (Kisumu, Malindi, Nakuru); Ghana (Kumasi); Bangladesh (Rangpur) – (Urban)	NPV Analysis	Cost efficiency of assumed outcomes and impacts	Aggregated costs Costs month^{-1} household^{-1} (CBS) Costs toilet^{-1}
Dodane et al., 2012	Sewer based system vs FSM system	Senegal (Urban)	Lifecycle costs approach		Costs capita^{-1} year^{-1}
Dube' et al., 2012	Traditional pit latrines (TPLs) and ventilated-improved pit (VIP) latrines	Burkina Faso (Urban)	Cost Estimates		Cost household^{-1} year^{-1}
Heng et al., 2012	Wet pit latrine + septic tanks and Sewerage connection to the wastewater treatment plant	Cambodia (Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} Costs household^{-1} year^{-1}
Hutton & Bartram, 2008	Household connection (partial treatment), Septic tank, Pour-flush, VIP and Simple pit latrine	Global, Regional and Country-level	Disaggregated Costs		Costs capita^{-1} year^{-1}
Hutton & Haller, 2004	Sewer connection, condominium sewer, Septic tank, Pour-flush, VIP and Simple pit latrine	Regional and Country-level	Incremental Cost Analysis	Cost differences between alternatives	Costs capita^{-1} Costs capita^{-1} year^{-1}
Hutton & Varughese, 2016	Latrines with a septic tank, Wet pit latrine, Septic tank with FSM and Sewerage with treatment	Global cost study of 140 countries	Aggregated Cost Estimates		Costs year^{-1}
Hutton, 2012	Septic tank (with and without off-site treatment); sewerage with wastewater management	Global, Regional and Country-level	Incremental Cost Analysis	Cost differences between alternatives	Costs year^{-1}
Isunju, 2013	Pit latrine-based FSM focused on containment and emptying	Tanzania & Uganda (Slums)	Cost Estimates		Cost
Kennedy-Walker et al., 2016	Pit latrine based faecal sludge management (FSM) focused on transfer stations and treatment	Zambia (Informal Settlement)	Net Present Value (NPV) and Average Incremental Cost (AIC)	Cost efficiency of assumed outcomes and impacts	Cost m^{-3} of FS Cost unit^{-1} Cost unit^{-1} year^{-1}
Klutse' et al., 2010	VIP toilet, Ecosan urine-diverting dehydration toilets (UDDT's), pour-flush toilet and the TPL's	Burkina Faso (Peri-Urban)	Cost Estimates		Costs toilet type^{-1} household^{-1}
Manga et al., 2020	Compared simplified sewerage, urine diversion dry toilet (UDDT) and Ventilated Improved Pit (VIP) latrine	South Africa (Informal settlement)	Net Present Value (NPV) and Average Incremental Cost (AIC) lifecycle costs approach	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} year^{-1}

Author(s)	Sanitation characteristic	Context	Cost Analysis Approach	VfM Framework Analysis	Unit of Analysis
Mayumbelo, 2006	VIP and the single vault UD toilet (Ecosan)	Zambia (Peri-Urban)	NPV	Cost efficiency of assumed outcomes and impacts	Costs capita^{-1} Costs capita^{-1} year^{-1}
McConville et al., 2019	Infrastructure investments and operating costs for faecal sludge and sewage treatment systems	Uganda (Kampala) – (Urban)	Lifecycle costs approach		Costs capita^{-1} year^{-1}
Nguyen et al., 2012	Community shared toilets, Wet pit latrine, Septic tank + soakaway, Septic tank + sewer and Septic tank + sewer + WWTP.	Vietnam (Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} Costs household^{-1} year^{-1} Cost capita^{-1} year^{-1}
Nyarko et al., 2011	Various pit latrine-based FSM	Ghana (Small towns)	Cost Estimates		Cost facility^{-1} Cost capita^{-1} Cost facility^{-1} year^{-1} Cost capita^{-1} year^{-1}
Remington et al., 2018	Household-level container-based sanitation (CBS)	Haiti (Urban)	Process Cost Analysis		Costs capita^{-1} year^{-1} Costs household^{-1} month^{-1}
Rodriguez et al., 2011	Community facilities, private sewerage, shared toilet, private septic tank & private communal sewerage	Philippines (Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} year^{-1} Costs capita^{-1} year^{-1}
Rodriguez et al., 2012	Shared wet pit, Shared: Toilet to the septic tank, Wet pit latrine, Toilet to the septic tank and Toilet to the sewer (with treatment)	Lao People's Democratic Republic (Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Cost household^{-1} Cost household^{-1} year^{-1}
Sainati et al., 2020	Faecal sludge management and sewerage treatment systems for the entire value chain	Multi-country, Multi-city (Urban)	Lifecycle costs analysis Novel Ball-Park Reporting Approach (NBPRA)	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} year^{-1} Costs capita^{-1} year^{-1}
Tilmans et al., 2015	Household CBS vs public CBS	Haiti (Urban slum)	Disaggregated Costs		Costs kg^{-1} of faeces
Ulrich et al., 2016	VIP latrine and UDDTs	Bangladesh, Nepal, India, Kenya, Tanzania, and Uganda	Disaggregated Costs		Cost facility^{-1}
Van Ryneveld, 1994	VIP latrine, Aqua privy with soakaway and Water-borne sanitation to the sewer system	South Africa (Urban)	Disaggregated Costs		Costs site^{-1} Cost site^{-1} year^{-1} Cost capita^{-1}
Von Munch, 2007	Latrine based excreta management system	Zambia (Peri-Urban)	NPV	Cost efficiency of assumed outcomes and impacts	Cost capita^{-1}
Willetts et al., 2010	Comparison of decentralised and centralised wastewater infrastructure alternatives	Vietnam (Peri-Urban)	Cost-Effectiveness Analysis, NPV and AIC	Cost efficiency of assumed outcomes and impacts and costs to sustain actual outcomes	Aggregated present value cost Cost m^{-3} water consumed Cost household^{-1}
Winara et al., 2011	Community facilities, private sewerage, shared toilets, private septic tanks & private communal sewerage	Indonesia (Urban)	Cost-Benefit Analysis	Cost efficiency of assumed outcomes and impacts	Costs household^{-1} year^{-1} Costs capita^{-1} year^{-1}
World Bank, 2012	VIP latrine, pour-flush latrine (PFL), Septic tank, PFL and shower/soakaway pit, VIP and shower/soakaway pit, Pits for PFL and shower/soakaway pit and Interceptor tank inside plot plus connection to the small-bore sewer	Burkina Faso (Urban) and Senegal (Low-income Peri-Urban)	Cost-Effectiveness Analysis	Costs to sustain actual outcomes	Costs capita^{-1} Costs capita^{-1} year^{-1}

2.3.3 Sanitation system characteristics reported

The sanitation systems assessed in reported studies varied (Table 2-1). Most of the studies compared service levels and the study setting. A comparison of sewer-based and various FSM-based systems was the outcome in 17 studies (Dodane, P. et al., 2012; Hutton, G. and Varughese, 2016; Rodriguez et al., 2011; Winara et al., 2011; Rodriguez et al., 2012; Chuan et al., 2012; World Bank, 2012; Nguyen et al., 2012; Heng et al., 2012; Hutton, G. and Bartram, 2008; Hutton, G. and Haller, 2004; Hutton, G., 2012; Willetts et al., 2010; Delaire et al., 2020; Manga et al., 2020; McConville et al., 2019; Sainati et al., 2020). One study assessed several latrine-based systems connected to the small-bore sewer system (World Bank, 2012).

Thirteen studies assessed various FSM-based systems: container-based sanitation (Tilmans et al., 2015; Remington et al., 2018); and septic tanks (Carrard et al., 2021). Others include latrine-based sludge management systems (Kennedy-Walker, R. et al., 2016; Klutse' et al., 2010; Isunju, J.B. et al., 2013b; Ulrich et al., 2016; Dube' et al., 2012; Von Münch and Mayumbelo, 2007; Nyarko et al., 2011; Burr, P. and Fonseca, 2011; Balasubramanya et al., 2017; Mayumbelo, 2006). One study did not explicitly state which sanitation systems were assessed (Alivelu et al., 2012).

This review utilised the Value for Money (VfM) framework (Prat et al., 2015) to interpret the costing approaches. Figure 2-2 shows how costs relate to inputs, outputs, outcomes, and impacts in implementing water, sanitation and hygiene (WaSH) projects and programmes. Studies that used the cost-effectiveness approach (e.g., World Bank, 2012; Hutton, G. and Bartram, 2008) looked at the costs to sustain the actual outcomes of the sanitation intervention. Studies that reported cost-benefit analysis and net present value (NPV) relate costs to efficiency in terms of assumed outcomes and, to a certain extent, the impacts of the implemented intervention. The studies on cost economy (e.g., Ulrich et al., 2016) relate costs to inputs. Finally, the incremental cost analysis studies (e.g., Hutton, G. and Haller, 2004; Hutton, G., 2012) determined the actual cost difference between alternatives.

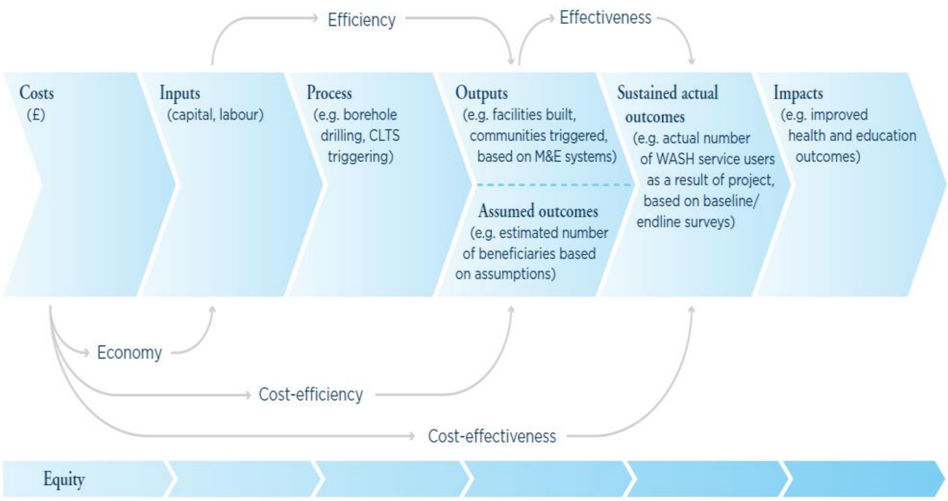

Figure 2-2. The Value for Money (VfM) framework analysis chain (Source: Prat et al. (2015))

This review also captured the value chain components assessed to show the extent of analysis in reported studies. The basis of the categorisation of costs is the value chain shown in Figure 2-3.

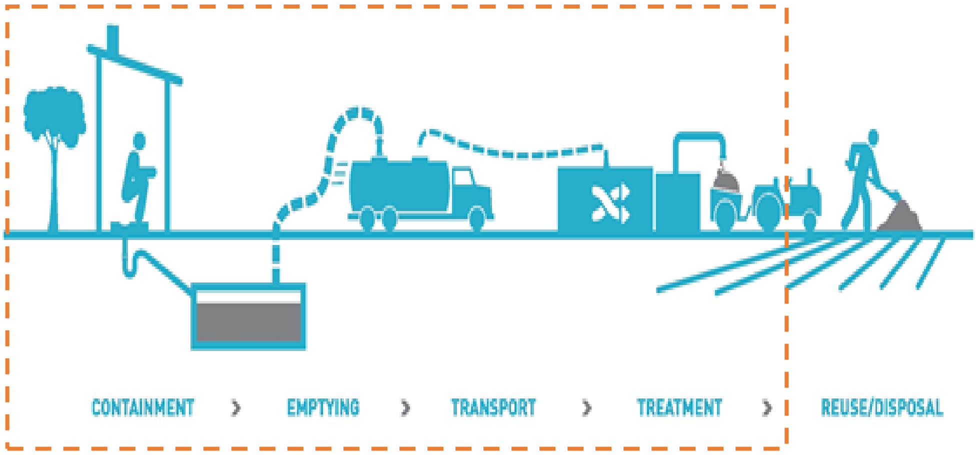

Figure 2-3. Sanitation value chain (Source: Bill and Melinda Gates Foundation, 2010)

2.3.4 Assessment of methodological quality

Appendix A-3 provides detailed information on the methodological assessment of included studies. No study reported any sample size calculation. Only four studies had obtained ethical approval (Balasubramanya et al., 2017; Carrard et al., 2021; Delaire et al., 2020; Isunju, J.B. et al., 2013a). Eight studies reported having performed a sensitivity analysis, with five studies (Dodane, P. et al., 2012; Kennedy-Walker, R. et al., 2016; Willetts et al., 2010; Mayumbelo, 2006; Carrard et al., 2021) showing how a change in a critical parameter influenced the overall cost analysis. For example, Hutton, G. and Haller (2004) performed a sensitivity analysis skewed to health costs and benefits in calculating Benefit-Cost Ratios (BCR) rather than on the costing approach for sanitation.

Only eight studies (Dodane, P. et al., 2012; Mayumbelo, 2006; Balasubramanya et al., 2017; Kennedy-Walker, R. et al., 2016; Carrard et al., 2021; Delaire et al., 2020; Manga et al., 2020; Sainati et al., 2020) included supplementary information to show the full cost analysis.

2.3.5 Costing approach or analysis used

All 32 included studies showed or reported some costs associated with sanitation. However, twelve of the studies had no specified method of cost analysis and presented the costs as estimates (Dube' et al., 2012; Klutse' et al., 2010; Isunju, J.B. et al., 2013b; Nyarko et al., 2011), as disaggregated costs (Ulrich et al., 2016; Alivelu et al., 2012; Burr, P. and Fonseca, 2011; Tilmans et al., 2015; Hutton, G. and Bartram, 2008; Vanryneveld, 1994) or as aggregated estimates (Hutton, G. and Varughese, 2016). Consequently, these results cannot be replicated; hence, making the cost data reported uncertain for benchmarking purposes. Figure 2-4 summarises all the cost analyses reported, with some studies reporting more than one approach.

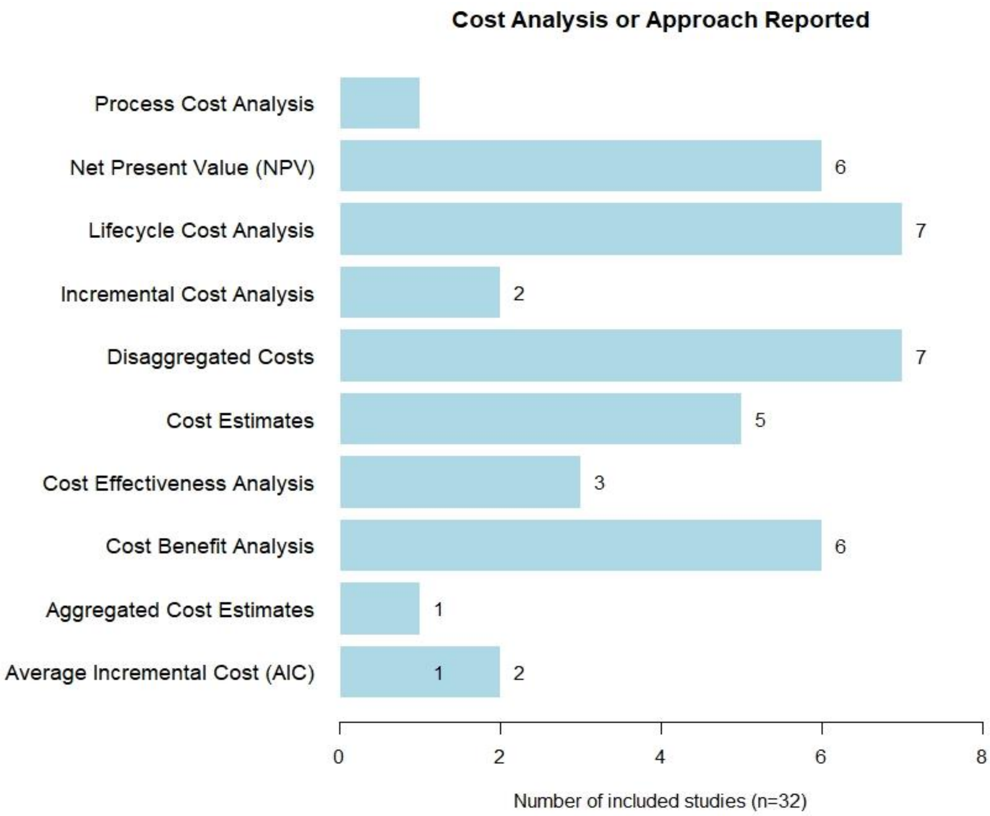

Figure 2-4. Summary cost analysis reported in included studies

The results show that the sanitation sector adopts no standard method or approach for reporting costs. For example, Dodane, P. et al. (2012) determined capital and operating costs using a lifecycle approach to compare the FSM and sewer-based sanitation systems in Dakar, Senegal. In Kampala, Uganda, McConville et al. (2019) used a similar approach to Dodane et al. (2012). However, even those these studies use a similar approach, the costs between these contexts are not directly comparable without accounting for the consumer price index and exchange rate. This scenario makes the comparison of cost studies across different contexts very challenging; hence, making cost studies of low utility for benchmarking. This is further exemplified in the study by Kennedy-Walker, R. et al. (2016), who used a lifecycle model to simulate emptying and transportation technologies over a 25-year design period. The analysis broke down the total faecal sludge cost per cubic meter into individual components (capital, maintenance, labour, fuel and oil and discharge costs). The study shows the costs per cubic meter of sludge which is incomparable with Dodane, P. et al. (2012) and McConville et al. (2019), who report costs per capita per year, with all three studies using a lifecycle approach (see Section 2.3.6).

Furthermore, the different costing approaches reported target different aspects of sanitation services delivery. For instance, Carrard et al. (2021) used a lifecycle-based spreadsheet model to calculate the NPV costs over 25 years in planning urban sanitation systems, accounting for financial exchanges required to achieve defined service outcomes. On the other hand, Delaire et al. (2020) used a conceptual approach to estimate the financial requirements for addressing existing service gaps by focusing on expenses that require financing. The different approaches to costing may not be suited to account for the requirements needed to holistically deliver and sustain sanitation services.

Some studies show differences in the extent of costing even when using a similar approach to deliver and sustain services across the value chain. For example, Sainati et al. (2020) introduce the Novel Ball-Park Reporting Approach (NBPRA). NBPRA uses the total annualised cost per household (TACH) as a standard metric for reporting the costs of urban sanitation systems. The approach generates plausible cost estimates for sanitation technologies and accommodates empirical data delivering partial services. Cost estimates generated for these partial sanitation systems can be synthesised to generate cost estimates for complete sanitation systems. This approach helps benchmark costs by synthesising partial services to complete systems.

On the other hand, Manga et al. (2020) used the TACH to compare full economic and financial costs for sewer-based and FSM options. The total annual capital, operation and maintenance costs and benefits associated with the sanitation technologies were converted to a present value. The present value helped derive the Average Incremental Cost (AIC) per household. Manga et al. (2020) show the financial and economic costs, while Sainati et al. (2020) show only the financial costs of sanitation service provision. Overall, Table 2-2 shows the sanitation cost components in reported studies.

Table 2-2. Sanitation cost components of included studies

Author	Cost Component Included			
Alivelu et al., 2012	Capital	Operational	Direct Support	Indirect Support
Balasubramanya et al., 2017	Capital	Operational	Maintenance	Cost of capital
Burr et al., 2011	Capital	Operational		
Carrard et al., 2021	Capital	Operational	Maintenance	Support
Chuan et al., 2012	Capital	Operational	Maintenance	
Dodane et al., 2012	Capital	Operational		
Delaire et al., 2020	Capital	Operational	Capital Maintenance	
Dube' et al., 2012	Capital	Operational	Maintenance	
Heng et al., 2012	Capital	Operational	Maintenance	Program
Hutton & Bartram, 2008	Capital	Operational	Maintenance	Surveillance
Hutton & Haller, 2004	Capital	Operational	Maintenance	Surveillance
Hutton & Varughese, 2016	Capital	Operational	Capital Maintenance	Program
Hutton, 2012	Capital	Operational		
Isunju et al., 2013	Capital	Operational	Maintenance	
Kennedy-Walker et al., 2016	Capital	Operational	Maintenance	
Klutse' et al., 2010	Capital	Operational	Maintenance	
Manga et al., 202)	Capital	Operational	Maintenance	Cost of capital
McConville et al., 2019	Capital	Operational		
Mayumbelo, 2006	Capital	Operational	Maintenance	
Nguyen et al., 2012	Capital	Operational	Maintenance	Program
Nyarko et al., 2011	Capital	Operational	Maintenance	
Remington et al., 2018	Capital	Operational		
Rodriguez et al., 2011	Capital	Operational	Maintenance	
Rodriguez et al., 2012	Capital	Operational	Maintenance	
Sainati et al., 2020	Capital	Operational	Maintenance	Cost of capital
Tilmans et al., 2015	Capital	Operational	Maintenance	
Ulrich et al. 2016	Capital			
Van Ryneveld, 1994	Capital	Operational		
Von Munch, 2007	Capital	Operational		
Willetts et al., 2010	Capital	Operational	Maintenance	
Winara et al., 2011	Capital	Operational	Maintenance	
World Bank, 2012	Capital	Operational		

The studies reported the costs of different sanitation components (Table 2-2) across the value to deliver and sustain services. The cost components required to deliver and sustain services include capital, operational, and maintenance expenditure. Other costs include the cost of capital and direct and indirect support costs. Klutse' et al. (2010), for example, calculated the toilet capital expenditure disaggregated into capital expenditure hardware (cost of labour, materials, and subsidies) and capital expenditure software (sensitising communities and training costs). Operational and minor maintenance expenditures were categorised as operation and maintenance costs.

On the other hand, Willetts et al. (2010) used an integrated resource planning approach drawing on cost-effectiveness analysis accounting for all capital, operational, and replacement costs and benefits across the different life cycles. The approach included life cycle costs, as annualised costs for the primary assets. Balasubramanya et al. (2017), for instance, used a spreadsheet-based model to identify a cost-effective option for transporting sludge and used capital and operational cost estimates of equipment to calculate the cost per household for transporting sludge. Annualised capital costs included the cost of capital, capital maintenance, and operational wear and tear over the operational period. These results highlight the differences in approaches and what is costed as some studies report only hardware costs while others report both hardware and software costs, making studies incomparable. Figure 2-5 summarises the cost components in reported studies.

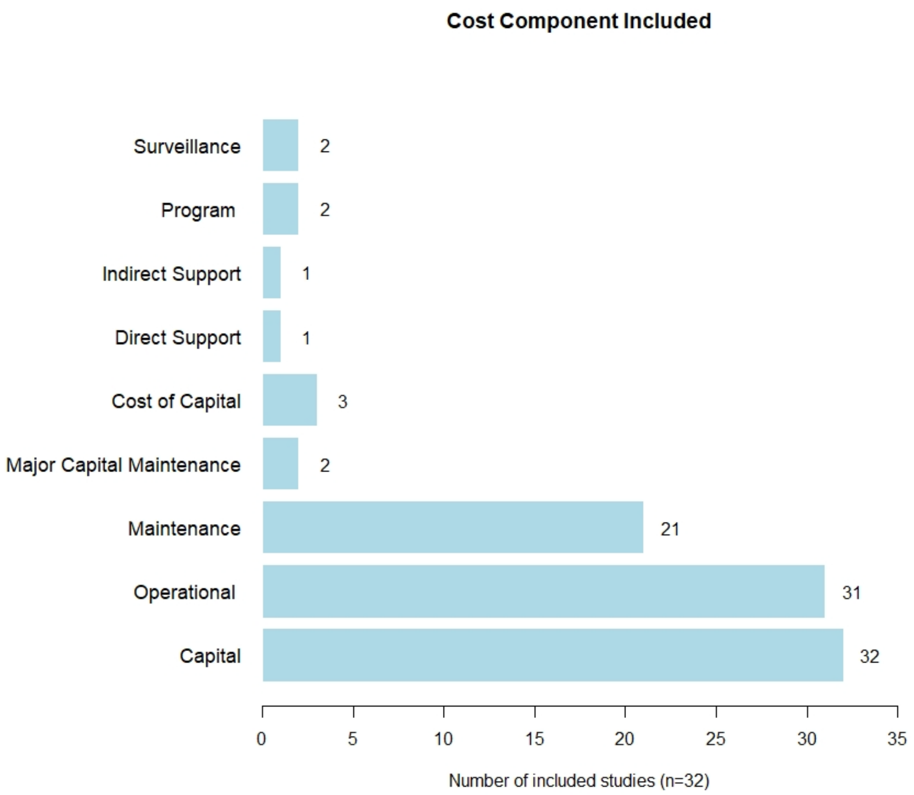

Figure 2-5. Summary of the cost components reported in the studies

For the different approaches reported across studies, Figure 2-5 further demonstrates no standard in the costing of sanitation components. Most studies reported the capital and operational expenditures for services. However, only two-thirds of studies reported costs to sustain services (maintenance). Some studies report costs on major maintenance (i.e., return an asset to its initial state), direct and indirect support. For example, Von Münch and Mayumbelo (2007) used a methodology for comparing costs based on the overall cost (NPV) of the entire sanitation systems capital and annual operating costs. The study only shows costs to deliver and operate services. However, other studies such as Rodriguez et al. (2011), Winara et al. (2011), Rodriguez et al. (2012), Nguyen et al. (2012), Chuan et al. (2012), and Heng et al. (2012) calculated the annualised investment costs (considering the estimated life of components), annual maintenance and operational costs, and indirect support costs. Therefore, not all studies consider the costs to sustain sanitation services.

Furthermore, the scale of costing and certainty of information sources differed across studies. The certainty of information sources is essential for the reliability of cost data. For example, Hutton, G. and Varughese (2016) used a quantitative cost model run at the country level for 140 low and middle-income countries. Cost data were gathered through an extensive search of the published peer-reviewed literature, project documents, and agency reports. In-country experts validated unit costs for larger countries with adjustments for discrepancies. In countries that lacked unit cost data, extrapolation from a similar country with data and adjustment for the difference in income level by purchasing power parities. Finally, the results were aggregated to give the regional and global totals or averages, weighted by country population size.

Hutton, G. and Bartram (2008) used a disaggregated cost approach with unit costs for capital investments per person covering the life of the technology with recurrent costs estimated on a cost per person per year basis. For example, annual operation and maintenance costs were 5–10% of capital costs for low-technology options and education for sanitation interventions at 5% of capital costs per year. However, as costs estimates from these studies are primarily not from empirical data and derived as percentages, these data are very uncertain and, therefore, challenging to develop benchmarking costs usable in other contexts to reflect the actual costs of service provision.

2.3.6 Unit of analysis

All 32 included studies reported at least a unit of analysis, with some reporting several units of analyses. Fifteen studies reported costs per capita year, whereas seven reported costs per capita. Six studies reported their analysis as costs per household, with nine reporting as costs per household per year. Kennedy-Walker, R. et al. (2016) reported their costs per cubic meter of faecal sludge emptied and transported, costs per unit of equipment purchased and shipped, and costs per unit per year. Figure 2-6 summarises all cost units of analyses reported.

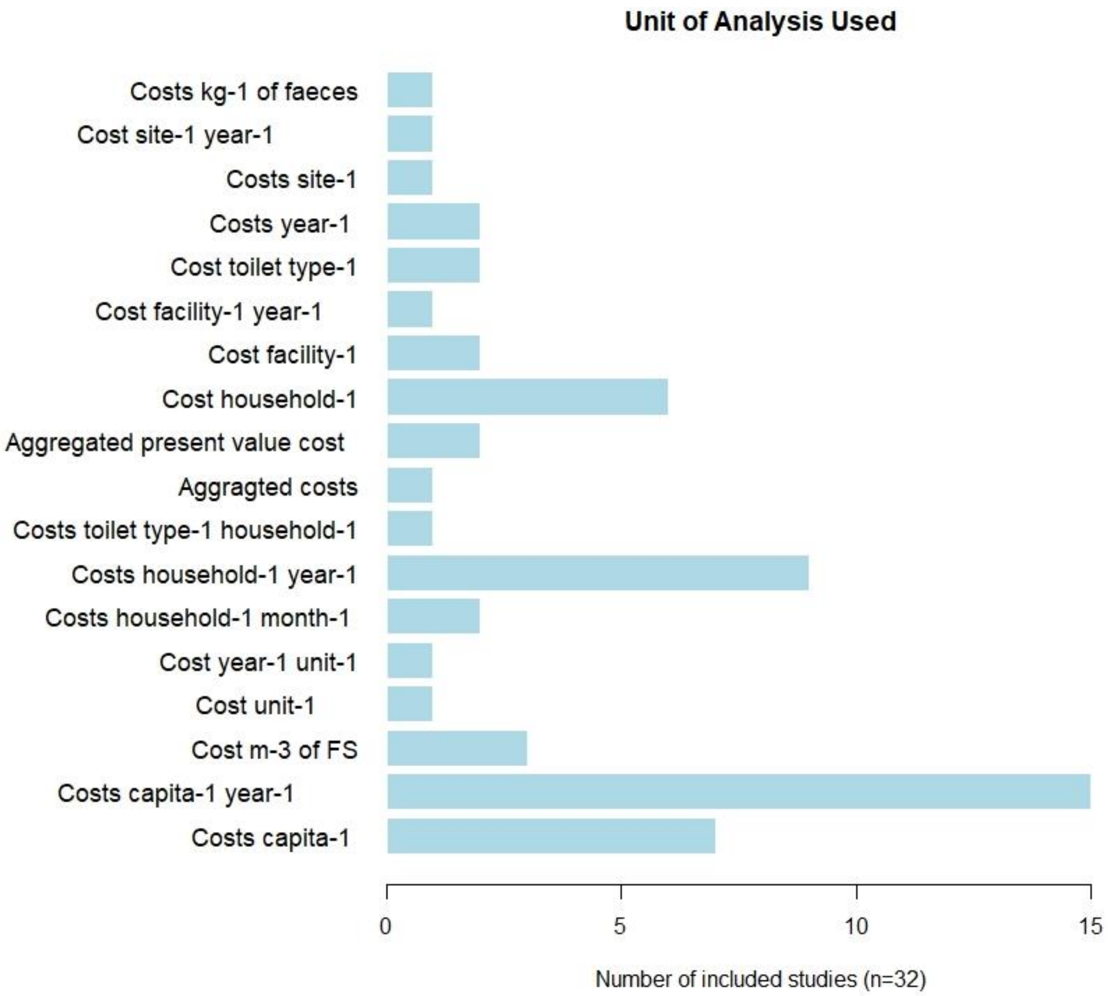

Figure 2-6. Summary of the unit of analysis of included studies

Reporting sanitation costs in different units of analyses (Figure 2-6) limits comparability across contexts and, overall, the utility of studies for cost benchmarking purposes. For example, Willetts et al. (2010) reported their analysis as aggregated present value cost and costs per cubic meter of water consumed in addition to costs per household. Two studies reported their analyses as costs per year (Balasubramanya et al., 2017; Hutton, G. and Varughese, 2016) and costs per facility (Nyarko et al., 2011; Ulrich et al., 2016). Vanryneveld (1994) reported costs per site and per site per year in addition to costs per capita, while Remington et al. (2018) reported their analysis as costs per household per month and per capita per year. Tilmans et al. (2015) reported costs per kilogram of faeces. These results underscore that the different costing approaches and units of analysis are challenging for cost comparisons across studies and contexts.

2.3.7 Sanitation value chain components included in studies

This review showed that emptying and collection are synonymous, as some studies indicated emptying, while others considered the term collection. Conveyance relates to wastewater transfer from the point of generation via a sewer line to a treatment facility. In addition, transport is indicative of the transfer of faecal sludge from on-site systems.

Table 2-3 summarises the costed sewerage service chain components. Results showed that all 18 studies cost the entire value chain from containment to treatment for sewer-based systems. For instance, Dodane, P. et al. (2012) and McConville et al. (2019) account for water closets, the sewer network, pumping stations, and WWTP costs.

Table 2-3. Summary of costed sewered service value chain components

Author	Containment	Conveyance	Treatment
Chuan et al., 2012	√	√	√
Delaire et al., 2020	√	√	√
Dodane et al., 2012	√	√	√
Heng et al., 2012	√	√	√
Hutton & Bartram, 2008	√	√	√
Hutton & Haller, 2004	√	√	√
Hutton & Varughese, 2016	√	√	√
Hutton, 2012	√	√	√
Manga et al., 2020	√	√	√
McConville et al., 2019	√	√	√
Nguyen et al., 2012	√	√	√
Rodriguez et al., 2011	√	√	√
Rodriguez et al., 2012	√	√	√
Sainati et al., 2019	√	√	√
Van Ryneveld, 1994	√	√	√
Willetts et al., 2010	√	√	√
Winara et al., 2011	√	√	√
World Bank, 2012	√	√	√

For non-sewered systems, results showed that only six out of 27 studies (22%) cost the entire value chain from containment to treatment. Dodane, P. et al. (2012) and McConville et al. (2019), for example, account for septic tanks, vacuum truck purchases, and building and operating FSTP costs. However, studies such as Kennedy-Walker, R. et al. (2016) only simulated the costs for manual and motorised emptying of latrines and the costs associated with transporting the faecal sludge to treatment. Containment and treatment costs are not included. Remington et al. (2018) analysed the cost for collecting, transporting, and treatment without considering containment. Dube' et al. (2012), Klutse' et al. (2010), Nyarko et al. (2011), and Ulrich et al. (2016) only considered containment in their analysis. Isunju, J.B. et al. (2013b) only considered emptying in their cost analysis, while Alivelu et al. (2012) did not report which service chain components were costed. Table 2-4 summarises non-sewered sanitation value chain components with costs in reported studies.

Table 2-4. Summary of costed non-sewered service chain components

Author	Containment	Emptying	Transport	Treatment
Balasubramanya et al., 2017		√	√	
Burr et al., 2011	√	√		
Carrard et al., 2021	√	√	√	√
Chuan et al., 2012	√			√
Delaire et al., 2020	√	√	√	√
Dodane et al., 2012	√	√	√	√
Dube', 2012	√			
Isunju, 2013		√		
Heng et al., 2012	√			√
Hutton & Bartram, 2008	√			√
Hutton & Haller, 2004	√			√
Hutton, 2012	√			√
Kennedy-Walker et al., 2016		√	√	
Klutse', 2010	√			
Manga et al., 2020	√	√	√	√
McConville et al., 2019	√	√	√	√
Mayumbelo, 2006	√		√	√
Nguyen et al., 2012	√			√
Nyarko et al., 2011	√			
Remington et al., 2018		√	√	√
Rodriguez et al., 2011	√			√
Rodriguez et al., 2012	√			√
Sainati et al., 2019	√	√	√	√
Tilmans et al., 2015		√	√	
Ulrich et al., 2016	√			
Von Munch, 2007	√		√	√
Winara et al., 2011	√			√
World Bank, 2012	√			√

The non-inclusion of all components of the sanitation value elements gives the costing as partial and incomplete elements needed to deliver and sustain services over the lifetime of the infrastructure and equipment deployed.

2.4 Discussion and conclusion

In general, the evidence from the review suggests that although sanitation cost studies have been undertaken, more needs to be done to make outputs from such studies of utility to stakeholders. Furthermore, although most of the studies reviewed show a costing approach in use, the quality of these studies varies, and the actual strength of evidence towards a standardised costing approach for cost benchmarking purposes in other contexts is weak. Hence, caution is needed in their interpretation due to some limitations.

Firstly, the evidence on costing approaches suggests that intended outcomes in the delivery of sanitation programming have led to different approaches to meet these outcomes. For example, cost-effectiveness approaches look to sustain the actual outcomes of an intervention, while cost-benefit analysis relate costs to efficiency in terms of assumed outcomes and, cost economy relate costs to inputs. Therefore, the various approaches used in the sector lead to different units of analysis, making comparisons across cost studies and contexts very challenging.

Secondly, most approaches do not give the highest level of detail in their computations as only eight studies included the complete analysis. Therefore, replicating some of the approaches may be challenging. Razzouk (2017) notes that multiple factors such as the quality of the measurement, level of detail, and accuracy affect cost estimation. For this reason, the description of methods and/or approaches used to measure and estimate costs need to be transparent, detailed, and accurate with a well-defined costing time frame.

Finally, only two-thirds of studies had included the costs to deliver, operate and maintain sanitation services. Therefore, the costing methods should justify excluding costs components and demonstrate the handling of uncertainty and data variation. As a result, there is a clear gap in the costing of elements for the entire value chain, especially for non-sewered sanitation, which may lead to poor service delivery outcomes when these costs are used as benchmarking costs.

The review was essential in identifying suitable approaches for costing city-level interventions in Lusaka (Chapter 4). Adopting the lifecycle approach to costing is helpful for the sector. The approach uses well defined and broad cost categories that facilitate a systematic process of identifying all costs involved in service delivery over the lifetime of infrastructure and equipment. Applying a lifecycle approach to costing sanitation services helps decision-makers understand the full costs of different sanitation systems and the financing gaps to ensure sustained service delivery (e.g., Carrard et al., 2021). In their lifecycle costing approach, Sainati et al. (2020) cluster the partial service types into technology categories internally consistent and externally comparable in technological terms for the entire value chain. The costs are normalised to comparable currency equivalent values based on the consumer price index using the purchasing power parity, annualised, and divided by the households or people served. This approach makes costs comparable when adjusted for the year and consumer price index between contexts.

In conclusion, the review showed that there is not enough rigorous standardised data on which planning cost estimates can be based. However, an emerging approach (TACH) would enable this. Therefore, this study adopts the Novel Ball-Park Reporting Approach (NBPRA) (Sainati et al., 2020) as the most suitable approach to benchmark costs for city-level interventions (Chapter 4).

The NBPRA considers full lifecycle costs annualised and expressed on a per-household or per-user basis - the TACH and total annualised cost per capita (TACC). TACH/TACC are cost indicators that express the cost of any sanitation system with varying life expectancy and technical characteristics. The cost conversion is to a standard reporting year, and currency is annualised to generate a comparable annual cost liability (Sainati et al., 2020). The cost is expressed as the expenditure needed to construct and maintain a sanitation system plus the annual operational budget.

The researcher decided to extend the work to cover other aspects of sanitation systems that could be used for planning purposes. The costing work was focused on establishing reliable estimates specifically for use in Lusaka.

Chapter 3: Methodology

3.1 Introduction

This chapter introduces the case study. It details the research approach and presents the research and data collection methods used to address each objective. It also gives details on how data were managed, analysed and the ethical considerations.

3.2 Introduction to the case study

3.2.1 Brief background to Lusaka city

Lusaka is the capital city and Zambia's political and economic centre. Lusaka city, located in Lusaka Province, is the smallest yet the most populous of the ten Zambian provincial centres. There are eight districts in the Province. The city has 33 Wards (Figure 3-1), which are heterogeneous, with areas having high to low population and housing density. In 2019, the estimated population in Lusaka city was around 2.4 million people (CSO, 2013). The city has a total area of 360 km^2, with an average 2018 population density of 7,017 people/km^2 (Kappauf et al., 2018). Lusaka has over 30 low-income urban areas (MLGH, 2015), accounting for around 70% of the entire city population. These low-income areas have become a prominent feature of Zambia’s urban landscape and are characterised by inadequate economic and social infrastructure (MLGH, 2015). In addition, inadequate housing and services generally characterise these areas (UN-HABITAT, 2007).

Lusaka lies at an elevation of 1200 to 1300 m above mean sea level with a gentle slope of about 0.14%, generally in the north-western direction (Tembo et al., 2017). The gentle slope makes the evacuation of stormwater slow, resulting in seasonal floods, especially in the southern and south-western parts of the city (Tembo et al., 2017). The challenge of stormwater evacuation also results in flooding of sanitation facilities. Furthermore, as Lusaka is predominantly sited on dolomite, which is prone to contamination (Bäumle et al., 2012), the flooding facilitates the widespread contamination of aquifers (Tembo et al., 2017).

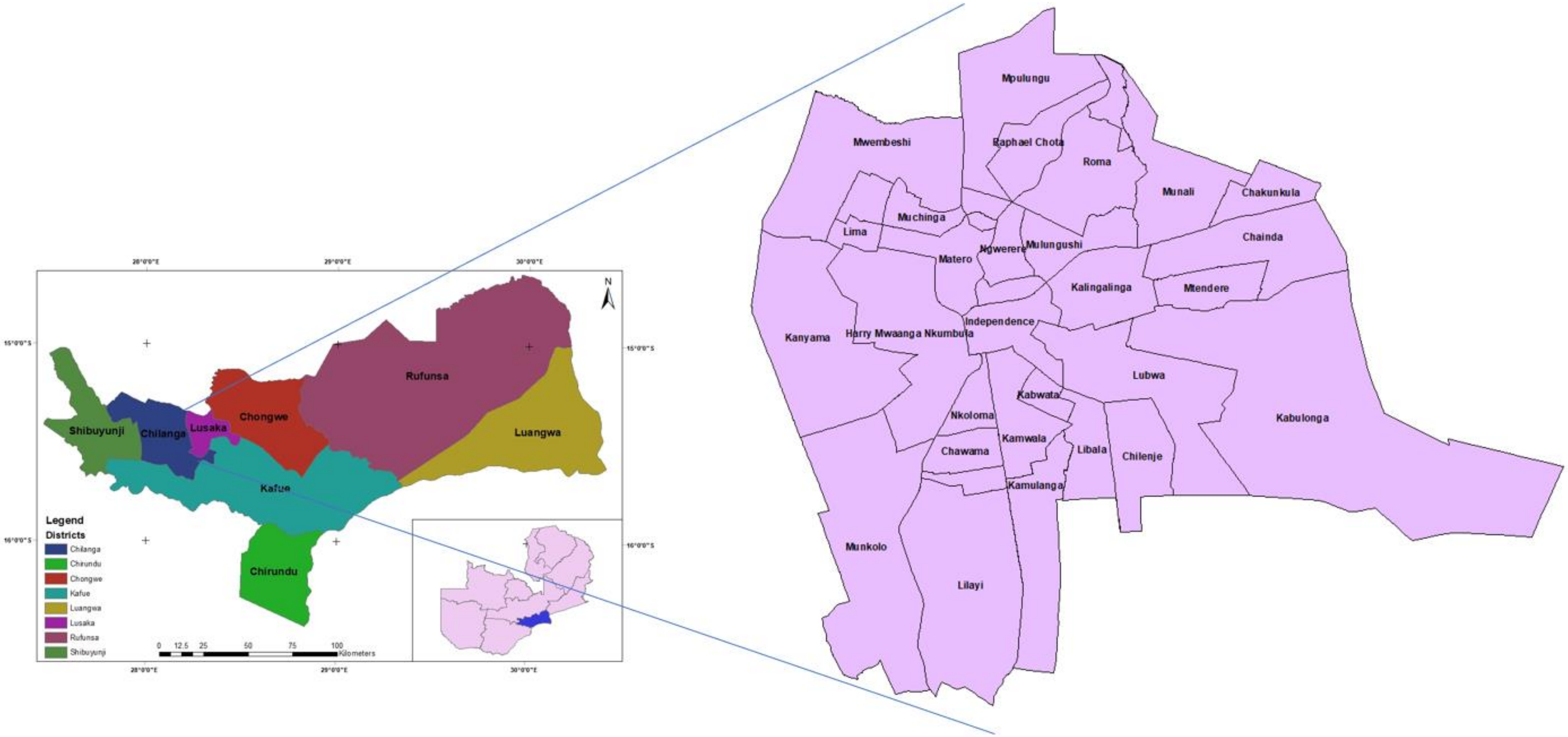

Figure 3-1. Map of Lusaka city in Lusaka Province, showing the location of its 33 Wards (Source: Authors own)

The city was selected as a case study because it has embraced citywide inclusive sanitation (CWIS) principles and plans to implement sewered and non-sewered interventions. In embracing CWIS, the mandate of the utility has changed from water and sewerage only to incorporate non-sewered services.

3.2.2 Summary of sanitation challenges in the city

Rapid urbanisation in Lusaka city has seen the growth of high-density unplanned low-income areas. As a result, the control of development and the associated provision of services is proving difficult in the city (LWSC, 2016a). For example, sanitation in Lusaka is heavily or partly financed by households as the government and utility "cannot afford" to subsidise sanitation improvements (LWSC, 2016a). The Lusaka Sanitation Master Plan (LSMP) notes that "*The challenges facing Lusaka city are those typically associated with development, such as population growth, high and rapid levels of urbanisation, lack of serviced land, and illegal settlements*" (MCC, 2011, p. 13).

Over 80% of households in Lusaka use on-site sanitation facilities, of which 22% have septic tanks, 10% have pour-flush latrines, 50% have improved pit latrines and traditional latrines (LWSC, 2016c). However, around 60% of the sludge generated from on-site facilities is not contained, with 35% directly discharged into the environment (Kappauf et al., 2018). Connections to the sewer network are less than 15% of households (LWSC, 2016a).

Wastewater management in sewered areas of Lusaka includes seven sewage treatment plants that allow excreta disposal from various locations in the city (LWSC, 2016a). However, most infrastructure is in a deplorable state. As a result, only 4% of the wastewater generated in the city is estimated to be safely managed (Kappauf et al., 2018). Some locations connected to the sewer network experience frequent blockages, resulting in sewage overflows (LWSC, 2016a). Figure 3-1 shows the faecal waste flow diagram (SFD), highlighting the sanitation situation in Lusaka.

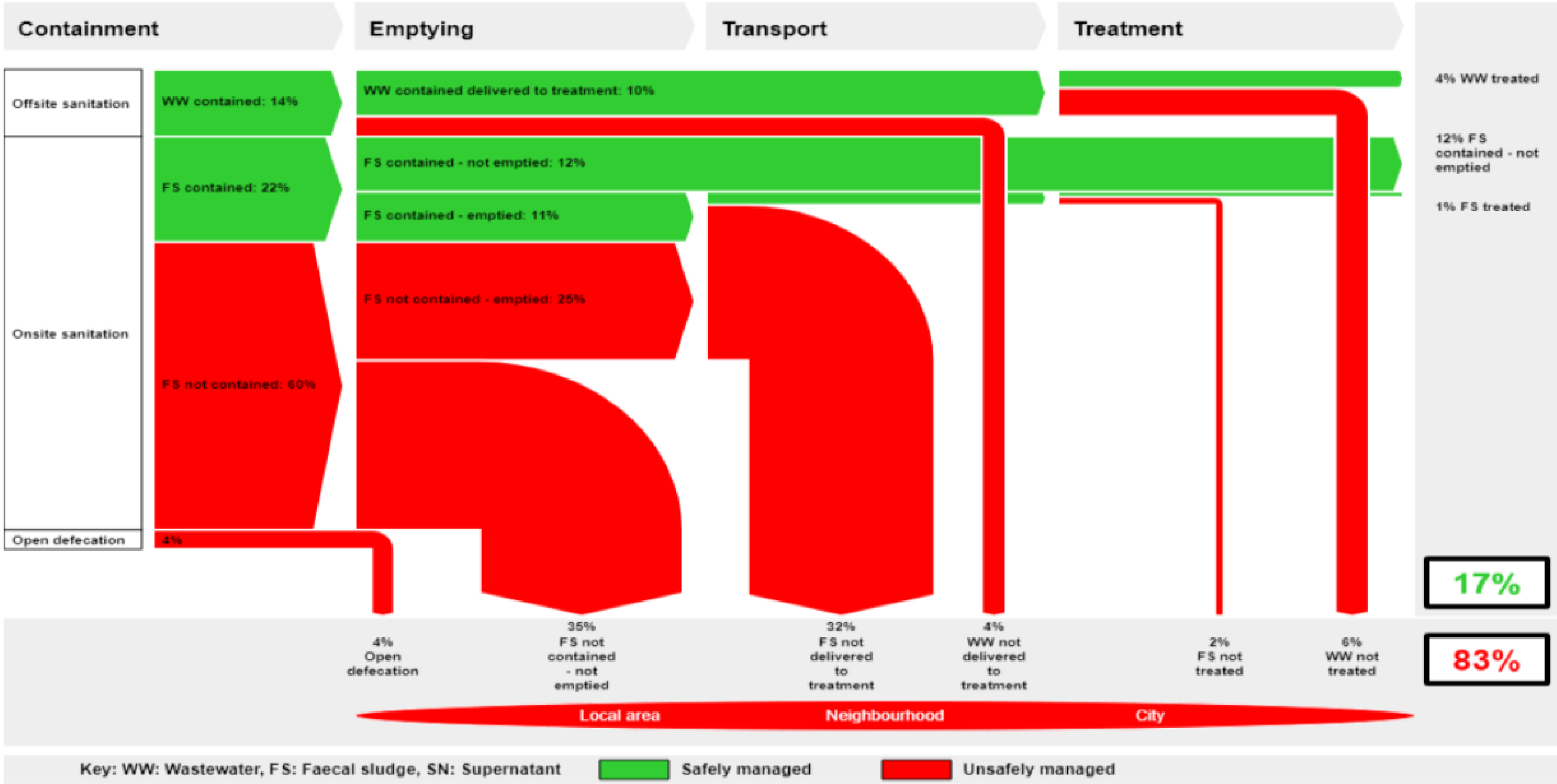

Figure 3-2. Faecal waste flow diagram (SFD) for Lusaka city (Source: Kappauf et al., 2018)

The seven wastewater treatment plants (WWTPs) include two conventional (active) and five waste stabilisation ponds (passive). The conventional WWTPs are Manchichi and Chunga, situated in the central and north-western parts of the city. The Manchinchi plant receives mostly residential, septage and some industrial wastewater. Both plants use conventional biological treatment using trickling filter unit processes, coupled with anaerobic digesters and sludge drying beds. (LWSC, 2016b). The passive plants include Matero, Ngwerere (North), Garden (Central), downstream of Manchichi, and Kaunda Square and Chelston (East).

In non-sewered areas, around 30,000 tonnes of faecal sludge is produced annually, with the majority remaining in pit latrines, buried or overflows during the rainy season, contributing to groundwater contamination (WSUP, 2018b). Emptying and transportation of sludge are through vacuum trucks and manual emptiers (Kappauf et al., 2018). Privately owned vacuum truck operators (VTOs) mainly empty septic tanks, transporting to treatment (LWSC, 2016a; Kappauf et al., 2018). However, the frequency of sludge collection is not entirely known and is still low (LWSC, 2016a). Two faecal sludge treatment plants (anaerobic digesters and drying beds) are located in Kanyama (West) and Chazanga (North). Furthermore, the septage facilities at Manchichi use anaerobic digestion and drying beds to treat waste from pit latrines and septic tanks from around the city.

3.3 Research data sources

The research used primary and secondary data sources. The aim was to collect data for different sanitation systems within the urban space. As such, informants at three decision-making levels informed the research. First, households were helpful as they managed and made decisions related to their sanitation situation. The community was the second level within which the sanitation systems are nested with data sought from community-based institutions and stakeholders. Finally, the city and country formed the third level and captured institutions and stakeholders involved in the broader planning, management and service provision. The primary data sources at the different decision-making levels informing the research are presented in Table 3-1.

Table 3-1. Primary data sources informing the research

Decision-making levels	Data sources
Household	1. Households in areas with community-based water and FSM service provider 2. Households in areas with utility water and sewerage service provision
Community	1. Community-based FSM service providers 2. Ward Development Committees 3. Pit emptiers 4. Contractor
City and country	1. Water and Sanitation utility 2. Local authority 3. Sanitation based NGOs 4. Vacuum Truck Operators 5. Regulators 6. Funding Agency

Stakeholder mapping identified the primary data sources who were individuals and organisations embedded within the sanitation sector. In addition to primary data sources, secondary data was collected from several informants and organisations at the community, city and country levels. The aim of collecting and using secondary data was to strengthen the primary data via triangulation.

3.4 Research approach

Different data collection methods were used to obtain data from stakeholders within the decision-making domains. The research used key informant interviews, household surveys and secondary data to understand the existing situation by exploring access, costs and the enabling environment for sewered and non-sewered services. Key informant interviews helped get a diversity of perspectives from informants (Barbour, 2001) on costs (Chapter 4) and the enabling environment (Chapter 5) as it describes events in their natural setting and is a subjective way of looking at life as it is lived (Lowhorn, 2007).

Furthermore, two cross-sectional household surveys informed the study. The first survey conducted by the researcher (DS1) - informed sanitation costing (Chapter 4). The second was a citywide sanitation mapping assessment by Lusaka Water Supply and Sanitation Company (LWSC) (DS3). The survey was used with permission from LWSC and informed costing (Chapter 4) and community-level responsiveness to sanitation (Chapter 6). Appendix B-1 shows the permission letters from LWSC and the local authority, Lusaka City Council (LCC). The surveys were helpful in understanding variability within a setting by examining multiple cases (Bryman, 2012). Thus, it enabled identifying sanitation characteristics within context, allowing comparisons between and within areas. In addition, the cross-sectional approach was an economical method with no loss to follow-up as participants were interviewed once (Sedgwick, 2014; Bryman, 2012; Kelley et al., 2003). Figure 3-2 shows the research objectives, data sources and data collection methods.

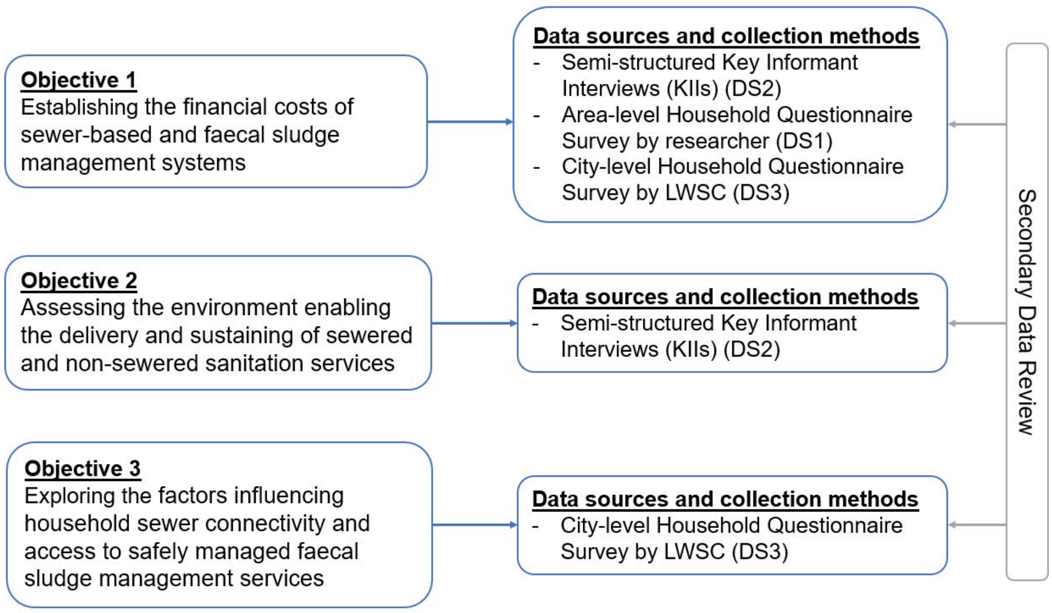

Figure 3-3. Mapping of research objectives, data sources (DS) and collection methods

3.4.1 Key informant sampling for interviews

The choice of informants for the interviews (DS2) was purposive (Kothari, 2004). These were actors involved in service delivery, promotion and funding of sanitation interventions. Purposive sampling helped identify and select information-rich cases through snowballing (Creswell, 2012; Palinkas et al., 2015; Patton, Michael Quinn, 1990).

Who and how participants were approached?

Identification of organisations and stakeholders followed a stakeholder mapping exercise. Contacts made during a scoping visit helped set up other informants using a snowballing technique (Bryman, 2012) by asking interviewees for further contacts. The local authority, utility, international non-governmental organisation (iNGOs), funders, regulators and Water Trust personnel were approached in their places of work or contacted by phone. Appointments were set for further discussion of the study. In addition, some participants, such as pit emptiers and community leaders, were approached within the community setting. A description of participants for which data was elicited is provided.

- ***Local Authority and Utility Personnel:*** Local authorities (LAs) are mandated to provide sanitation services. However, LAs have formed and delegated the function to commercial utilities (CUs) in urban areas. CUs are responsible for services solely or under a delegated management arrangement. Therefore, LA and utility personnel informed the study.

- ***Water Trust Personnel:*** Water Trusts mainly provide water in low-income, high-density urban settlements on a "delegated basis" from the utility. In two settlements in the city, the Trusts are responsible for operating FSM services, thus informing the study on costs and service delivery.

- ***Non-Governmental Organisations and Funders:*** these were individuals from organisations supporting sanitation infrastructure and services provision with project/program management and funding. They had an in-depth understanding of how sanitation projects and programs have been conceptualised and delivered.

- ***Vacuum Truck Operators:*** these were conversant with the costs of setting up and operating the transportation service of faecal sludge and septage. These services are available to all residents in the city.

- ***Pit Emptiers:*** these were conversant with running the day to day emptying of faecal sludge from on-site facilities in low-income, high-density areas.

- ***Contractors:*** these usually are contracted by funding institutions working with utilities to implement sanitation infrastructure projects. The contractors had first-hand information on setting up sanitation infrastructure; hence, they informed on infrastructure costs.

- ***Community Leaders***: Zambia uses a central and local government system. As such, Ward councillors, through their development committees, are key actors in implementing projects as they interface with communities. Members of the Ward Development Committee (WDC) had in-depth knowledge of the prevailing situation in their communities regards sanitation; hence, they informed the study.

3.4.2 Household survey sampling (survey by the researcher)

Participants in the survey were sampled to represent the population (Ritchie, J. et al., 2003); hence, a sampling frame was necessary. The sampling frame meant listing all the households in the areas to which generalisations can be made (Fowler, 2008; Acharya et al., 2013). However, such a list was not available. Therefore, the number of households sampled was statistically determined based on the estimated total number of households to achieve representativeness. Statistical parameters in sample size determination included:

i. **Distribution**: The selected sample was assumed to be normally distributed, following a normal density symmetric bell-shaped curve.
ii. **Confidence level**: A 95% level of statistical confidence was chosen for the sample. The significance level (α) was set at 0.05.
iii. **The margin of error (confidence interval)**: An interval estimate of the observed data likely containing the true value of the population mean.
iv. **Accuracy**: When determining the sample size needed for a given level of accuracy, a safe choice is a standard deviation of 0.5, which helps ensure the sample size is large enough.

Given that the target population was substantial, a sample size calculation was performed (Lwanga and Lemeshow, 1991).

$$\text{Sample Size} = \frac{(p) * (1-p) * Z^2}{C^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3-1)}$$

Where,

- p = accuracy expressed as a decimal was 0.5 for this sample.
- C = confidence interval of 0.04 (4%)
- Z = 1.96 for 95% confidence level

A sample of 600 households was determined. Sampling weights in each study area were assigned proportionately to the number of households (Table 3-2). The weights were multiplied by the sample size to determine the number of households surveyed in each area. The areas were divided into existing zones as per city zoning maps. The research team randomly picked numbers corresponding to a zone within the area to be surveyed (Singh, 2006).

Table 3-2. Study sample size based on the number of households

Study Area	No. of Households	Weights	Sample Size	Final Sample
Chazanga	29,935	0.312	187	181
Kalingalinga	8,356	0.087	52	56
Kanyama	35,682	0.372	223	238
Mtendere	22,074	0.230	138	121
Total	**96,047**	**1.000**	**600**	**596**

Five hundred and ninety-six households (99%) were interviewed, while four (1%) took no part as the household-head or an adult was unavailable.

3.5 Data collection procedures

3.5.1 Semi-structured interviews with key informants (DS2)

Semi-structured interviews were an appropriate data collection method as the questions were tailored to targeted stakeholders. The interviews capture the participant's perspectives, thoughts, and experiences in their own words (Liamputtong, 2013). The interviews collected data conversationally, enabling the researcher to exert minimal control (Murungi and van Dijk, 2014). The interviews aimed to collect information and views that were non-obtainable through direct observation (Patton, M.Q., 2002). A guide with a list of topics for discussion was designed. Appendix B-2 presents the key informant guide used.

Though interviews help obtain detailed data, they can be time-consuming since they allow for one informant at a time and produce a large amount of data (Harding, 2013). The method provided a medium to interview stakeholders with knowledge on sanitation service delivery in Lusaka. It drew on interviewees' perceptions towards sanitation service delivery.

3.5.2 Interview guide design

The use of interview guides helped ensure that the participants' time was effectively used (Kvale, 1994). Further, the guides aid analysis by making it easier to find and compare responses (Oppenheim, 2003; Harding, 2013). The guide was designed with a list of open-ended questions related to sanitation service delivery in Lusaka. The topics were in two broad categories:

1. ***Implementation information***

Firstly, the interviews sought to understand the selection of communities for intervention and if discussions were held for their input. Also, the local needs and priorities considered before implementation. Then, the reasons for selecting the technologies implemented and whether the adopted technology choices are responsive to the local context, such as the hydro-geological, social, financial, institutional and environmental. The interviews probed which institutions delivered the interventions, their financing, and the components funded. Then, the costs of the various sanitation components and the challenges faced in sanitation delivery.

2. *Service information*

The interviews elicited data on the services provided along the sanitation value chain and the assets and resources employed to provide the services. Then the costs in terms of capital, operational and maintenance expenditure for the components delivered. Finally, based on the specific technology and assets employed, how services are delivered, and the challenges faced.

3.5.3 Interview administration

The researcher administered the interviews face-to-face. The guide was flexible to accommodate unplanned questions following the flow of the discussion, and the asking followed no strict order. The questions were asked based on the informant's affiliation or roles, such as service provider, promoter or funder. Interviews were conducted in English, apart from the pit emptier interviews conducted in a local language, Nyanja. Following the example by Jones, M. (2001), the researcher used the group interview technique with the local authority personnel, pit emptiers and an iNGO because of its convenience in effectively using time and subsequently as a means of triangulating the individual truths. Thirty-seven individual/group interviews were conducted (Table 3-3). On average, an interview session lasted 45 minutes.

Table 3-3. Number of key informant interviews conducted

Key Informant	Interviews Conducted
Utility Personnel	**9**
Water Trust Personnel	**3**
Non-Governmental Organisations	**5**
Vacuum Truck Operators	**4**
Pit Emptiers	**8**
Contractor	**1**
Community Leaders	**1**
Local Authority Personnel	**2**
Funders	**2**
Regulator	**2**

Before conducting an interview, detailed information about the study was given to each participant, and consent was confirmed. Consent to audio record the interview was sought from each participant. The participants were informed about their right to stop the interview or withdraw their participation.

3.5.4 Household survey instrument (survey by the researcher – DS1)

The household questionnaire was the primary survey instrument used. The questionnaire mostly had closed-ended questions. The open-ended questions allowed qualitative insight and explanations from the respondents (Cohen et al., 2013). The questionnaire sought to establish existing socio-economic and demographic factors, sanitation practices and the costs for sewered and non-sewered services delivered. Appendix B-3 shows the household questionnaire.

The first section of the questionnaire was designed to build rapport with the respondents (Aday and Cornelius, 2006) and consisted of household identifiers such as house identification number, location coordinates, and the respondent's rights. The second section collected personal information on the respondents' socio-economic and demographic characteristics such as age, length of stay, education level, income, tenure status, and household size (Fowler Jr and Fowler, 1995; Scott et al., 2013).

The third section contained household sanitation characteristics such as the functionality of the sanitation system, adapted from Kvarnström et al. (2011), specifically on the sanitary quality of facilities, safety and availability. The WHO/UNICEF Joint Monitoring Program (JMP) guidelines for developing household surveys were referred to, particularly those focusing on sanitation access by technology and use arrangement (UNICEF and WHO, 2006).

The fourth section had aspects relating to sanitation facility construction (e.g. type of superstructure), access to water supply, costs borne and household sanitation practices such as emptying containments. Cost data elicited from households included capital investment, operation and maintenance. These aspects were split based on the type of sanitation system implemented, i.e.

sewered and non-sewered. Further, questions on the service provider and user satisfaction with the service provided were elicited.

3.5.5 Administration of the survey conducted by the researcher

Three research assistants were recruited and trained to familiarise them with the survey objectives, the questionnaire, administration techniques and expectations in the conduct of the survey. Visual aids were given to the assistants to help identify the different sanitation technologies. The assistants selected had prior experience in administrating questionnaire surveys. All had a background in social sciences and had a good command of English, Bemba and Nyanja (the most common local languages spoken in Lusaka). Before pre-testing the survey instrument, mock sessions were held where each assistant verbally translated the questionnaire from English to the local languages to the researcher. The intended meanings of the questions were checked to ensure there was no loss in meaning during translation. Pre-testing was done, with adjustments on the sequencing of some questions to improve clarity.

Before conducting the survey, the researcher visited each study area and engaged the local leaders in the Ward Development Committee (WDC) and local authority personnel. The researcher discussed the purpose of the research and obtained consent from the community leadership to conduct the survey. The researcher also presented a permission letter from LCC (Appendix B-1) to research the areas. The researcher and community leaders agreed on dates to conduct the survey. In each area, the WDC gave the research team a local guide who acted as a gatekeeper as they were familiar with the area and directed the team when conducting the survey.

From the first house selected, efforts were made to sample every third house on the right in every chosen street or road. All the households surveyed had identification numbers with the Global Positioning System (GPS) coordinates of each location recorded. GPS coordinates were collected using Garmin eTrex 10 handheld devices (Garmin Ltd., Olathe, KS, USA). The household head[2] was the primary target respondent. Where the household head was not available, an adult household member was approached. English was the preferred language of communication by the research team. When the respondent was not conversant with English, a local language was used to ask questions with the English equivalent response recorded. After giving information about the research and obtaining consent, the research team administered the household questionnaires face-to-face. Permission was sought from the respondent to view and to take a picture of the toilet facility. It took, on average, 25 minutes to complete the questionnaire interview.

During the survey administration, it became clear that some tenants were not conversant with the costs of the sanitation infrastructure and details related to the containment facility, such as the size (dimensions), when it was built and by whom. Therefore, the tenant who had the longest tenure in the compound was targeted. A diary was kept, which recorded observations made while undertaking the research.

3.5.6 Household survey instrument (survey by LWSC – DS3)

The Lusaka Sanitation Mapping Assessment, a cross-sectional survey at the city level by LWSC, gave the sanitation provision variables on access and services, the functionality of facilities to manage or convey waste, infrastructure quality, and sanitation practices. In addition, the study analysed the effect of socio-economic factors on sanitation service uptake or access from the city-level dataset. The aim was to establish whether valuable insights into these factors may influence the uptake and sustainability of sewered and non-sewered sanitation services. The survey had 1,495 household respondents. Appendix B-4 shows the variables analysed from the survey.

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[2] Household head is the female or male responsible for decision-making at the household level.

3.5.7 Secondary data sources

The aim of collecting and using secondary data was to triangulate (Carter et al., 2014), "validating information obtained through interviews by checking program documents and other written evidence that can corroborate what interview respondents report" (Patton, Michael Quinn 1999, p. 1195). Secondary data were solicited from stakeholders, and this included project and program design reports, financial records, payments certificates, and planning costs (where actual costs were not available). Other sources included policy and strategy documents, Acts of Parliament, master plans, and budgets. In addition, the literature on the expected lifetimes of the different sanitation infrastructure and equipment were searched using electronic databases.

3.6 Data management

The data from the household surveys were managed and analysed using IBM SPSS Statistics for Windows (Version 26.0. Armonk, New York: IBM Corporation) and R version 4.0.0 (R Foundation for Statistical Computing, Vienna, Austria). The open-ended questionnaire questions were first qualitatively analysed by thematic coding to identify key themes. Then, the themes were entered as variables and responses were recorded as categories in the data set.

The management of qualitative data from audio-recorded interviews firstly involved transcribing into Microsoft Word (Version 2016. Redmond, Washington: Microsoft Corporation). Additionally, field notes were also typed in Microsoft Word. Finally, the field notes and transcripts were imported into and organised using NVivo version 12 (QSR International Pty Ltd) for analysis.

3.7 Data analysis

Data were analysed in several ways to understand the costs of several sanitation system options, their fit with the enabling environment and the community responsiveness of these options. The sections below highlight the various aspects of the study analysed to meet the objectives. These include a description of the planning units, a description of the sanitation systems in

Lusaka, cost estimation of sanitation systems, assessment of the enabling environment for services and exploration of factors influencing service uptake.

3.7.1 Planning Units

In meeting the objectives, a key approach employed in this study was to characterise the city into units of analysis with common characteristics. The first step was to create a set of manageable planning units (PU). For example, planning on an individual household level would be too complex, and planning for the entire city would result in inefficiencies. Therefore, a decision was taken to segment the city into planning units which would be contiguous areas with similar characteristics relating to housing density and income levels of residents. The use of housing density and income levels gave each planning unit homogeneity as a basis for a less complex planning process. Accordingly, the study used the area descriptors defined in Table 3-4 below to represent the different urban realities in the city as a basis for planning.

Table 3-4. Definition of the different area descriptors typical of Lusaka city

Area	Description
Low-income high-density (LIHD)	These are often unplanned, spatially disorganised areas with a high population density, generally characterised by low incomes and a high proportion of renting households. The areas are also associated with a low quality of life. Typical population density is >6,000 people/km^2.
Medium-income medium-density (MIMD)	These areas have at least basic services and may be planned with a moderate population density. Medium incomes and moderate quality of life generally characterise these areas. Typical population density is 3,000 – 6,000 people/km^2.
High-income low-density (HILD)	These are predominantly planned, fully serviced areas with the least population density and a low proportion of renting households. The areas are also associated with a high quality of life. Typical population density is <3000 people/km^2).

Adapted from Turok (2020)

3.7.2 Description of the sanitation systems in Lusaka

A set of ‘standard’ sanitation system types useful for all the subsequent planning work was established. It is recognised that there may be slight differences in the design of infrastructural systems from place to place. However, if a set of general approaches to sanitation can be defined, these can be used in high-level planning.

i. **Conventional and simplified sewer systems**

Conventional sewers are an extensive network of underground pipes conveying wastewater sometimes combined with stormwater from households to treatment, using gravity or pumps for relatively flat terrain. A flow gradient must be guaranteed to maintain self-cleansing flows, which necessitate deep excavations with sewers laid beneath road sections at depths of 1.5-3 meters to avoid damage by traffic loads (Tilley et al., 2014).

Simplified sewers collect wastewater from households in small-diameter pipes laid at shallow depths and relatively flat gradients. Simplified sewerage is conceptually equivalent to conventional sewerage but with design features adapted to the local context (Tilley et al., 2014). The sewerage technology can be laid at a 5% gradient using 100 mm diameter sewer pipes. Unlike conventional sewerage laid in central road sections, the sewers are generally laid in the front or back yard. Simplified sewers have a flexible design suitable for dense unplanned urban areas.

The system components include household toilets and connections, sewer networks, pumping stations, active and passive wastewater treatment plants (WWTPs). The capital costs for the water closet include material and labour costs for the superstructure and the capture technology. The service life of the water closets was assumed to be 20 years (Piper, 2004; Hashemi et al., 2015). The capital costs for the house sewer connections included material and labour costs for access chambers, uPVC pipes and fittings, and concrete covers. The service life of the house sewer connections was assumed to be 20 years (Dodane, P.H. et al., 2012). The capital costs for the sewer network included material and labour for concrete access and other chambers, uPVC piping and fittings, and sewer interceptors. The design life of the uPVC-based conventional sewer network was assumed to be 35 years (Whittle, AJ and Tennakoon, 2005; Whittle, Alan et al., 2013; Folkman, 2014; Makris et al., 2020). The service life for the simplified sewer network was assumed to be 25 years (Bakalian et al., 1994; Manga et al., 2020).

The capital costs for pumping stations included material and labour costs for the pumping house civil works, pipework and fittings, access chambers. Other installations included submersible pumps with control systems and standby power generators in some places. Pumping station service life was assumed to be 25 years (Jones, G.M. et al., 2006). Capital costs for treatment included active conventional centralised WWTP and passive waste stabilisation ponds. The service life of the active and passive WWTPs was assumed to be 50 and 35 years (Tsagarakis et al., 2003; Mara, 2013; Shilton et al., 2008).

Annual operating and maintenance costs for the conventional and simplified systems included the sewer network, pumping stations and the active and passive WWTPs (e.g. fuel for the pumping station and vehicles, electricity, vehicle repair, repair materials, management costs, taxes and labour).

ii. **Faecal sludge management (FSM) systems**

Septic tanks collect excreta and consist of a water-tight settling tank. Settling and the inherent anaerobic process reduces the solids and organics, but treatment is only moderate, with effluent needing to be dispersed using a soak pit or leach field or transported to another treatment technology (Tilley et al., 2014). The septic tank system was assumed to have a service life of 25 years (Hill and Frink, 1980; Noss and Billa, 1988; McGauhey and Winneberger, 1964; Lowe and Siegrist, 2008). The capital costs of the septic tank system included the costs of the substructure (tank) and toilet facility.

An improved pit latrine is a structure fully covered by a slab or platform fitted with a squatting hole or seat without exposing the pit content other than through the squatting hole or seat (WHO and UNICEF, 2014). Lining the pit prevents collapse and anchors the superstructure. On average, latrines have a solids accumulation rate of 40-60 litres capita^{-1} year^{-1} (Tilley et al., 2014). The improved pit latrine was assumed to have a service life of 20 years (Brouckaert et al., 2013; Tilley et al., 2014). The capital costs of the latrine included the costs of the superstructure, lined pit with semi-impermeable walls and labour.

Beyond the household, the capital costs for the FSM system included emptying tools, flatbed trucks, land, buildings, equipment and faecal sludge treatment plants (FSTPs), using a decentralised wastewater treatment approach of a bio-digester and unplanted drying beds. The emptying tools and trucks had a service life of 0.5 and 10 years, respectively. Vacuum truck operators (VTOs) empty and transport faecal sludge and septage for treatment at the septage facility. The service life of the vacuum trucks ranges from 4-10 years (key informant interviews). The FSTPs were assumed to have a service life of 20 years (Baig et al., 2017; Gutterer et al., 2018), while the septage treatment plant was assumed to have a service life of 50 years.

The FSM system annual operating and maintenance costs included emptying from the containment, transporting and treatment. The costs involved were fuel, labour, chemicals, marketing, management, vehicle repair, vaccinations, electricity, and taxes.

3.7.3 Analysis of the financial costs of faecal sludge management and sewer-based sanitation systems

The analyses were for the main components of the FSM and sewer-based sanitation systems. The primary and secondary data sources were analysed for costs to construct and operate different sanitation technologies and systems. The survey conducted by the researcher informed on costs in low-income areas, while the survey by LWSC and key informants informed on costs in medium and high-income areas and costs on collection and treatment aspects.

Using the NBPRA (Sainati et al., 2020), a spreadsheet model was used to generate and present the entire sanitation value chain costs. The approach is standardised based on technological homogeneity, acceptable service, a full costing approach, and the reference business model (Sainati et al., 2020). The analyses followed the steps:

1. Determining capital, operating and maintenance costs for the different systems from empirical and secondary data sources. Household-level costs from the surveys were extracted as median values due to the non-normality of the data set (Hedges and Olkin, 1984). The interview transcripts were analysed for costs, and the data was extracted into the spreadsheet model. Project reports, payment certificates, financial records and planning costs (where the actual costs could not be obtained) were analysed. The documents helped triangulate the cost data from the KIIs and the household surveys.
2. The costs were converted to a standard reporting year and currency to generate a comparable annual cost liability to facilitate the parametric cost estimation. The currency conversion generated costs in United States Dollars ($2018 in this case), based on the consumer price index using purchasing power parity from the World Bank Database.
3. Annualisation was applied and expressed as the annual cost of owning, operating, and maintaining the sanitation system over its entire lifetime. Table 3-5 presents the costing input and output parameters, while Table 3-6 presents the equations used to calculate costs.

Table 3-5. Parameters used to cost sanitation systems

Parameter	Symbol	Unit
Number of people per served	N_p	capita
Number of people per household	N_{p-h}	Household
Infrastructure/Equipment lifetime	t	years
Discount rate[1]	n	%
Purchasing Power Parity for output year (i.e., reference currency to $2018)	PPP_{2018}	Nominal
Consumer Price Index for input year	CPI_{year}	Nominal
Consumer Price Index for output year	CPI_{2018}	Nominal
Input currency to US$ conversion factor	C_F	Nominal
Input capital cost per component[2]	$InCapEx_{comp}$	Currency/component
Input operating cost per component[3]	$InOpEx_{comp}$	Currency/component
Annualised capital cost	$CapEx_{av}$	$2018
Annual operating cost	$OpEx_a$	$2018
Total Annualised Cost	ToT_{AC}	$2018

[1]Assumed to be 5% for all cost calculations
[2]Components include infrastructure and buildings, land, and equipment
[3]Components include staffing, consumables, taxes, administrative charges and other OpEx

Table 3-6. Equations to calculate the lifecycle costs of sanitation systems

Calculation	Unit	Equation
Input currency to US$ conversion factor, $\mathbf{C_F}$	Nominal	$\mathbf{C_F} = PPP_{2018} * \left(\frac{CPI_{year}}{CPI_{2018}}\right)$
CapEx output value, $\mathbf{CapEx_{comp}}$	$2018	$\mathbf{CapEx_{comp}} = \frac{InCapEx_{comp}}{C_F}$
Annual OpEx output value, $\mathbf{OpEx_a}$	$2018	$\mathbf{OpEx_a} = \frac{InOpEx_{comp}}{C_F}$
Annualised CapEx value, $\mathbf{CapEx_{av}}$	$2018	$\mathbf{CapEx_{av}} = \frac{CapEx_{comp} * n(1+n)^t}{(1+n)^t-1}$
Total annualised cost, $\mathbf{ToT_{AC}}$	$2018	$\mathbf{ToT_{AC}} = \sum_{n=1}^{i} CapEx_{av} + \sum_{n=1}^{i} OpEx_a$ n = CapEx and OpEx sys. component
Total annualised cost per capita, **TACC**	$2018	$\mathbf{TACC} = \frac{ToT_{AC}}{N_p}$
Total annualised cost per household, **TACH**	$2018	$\mathbf{TACH} = \frac{ToT_{AC}}{N_{p-h}}$

The lifecycle costs are reported as total annualised costs per capita and per household, calculated by dividing the annual cost by the estimated number of people and households served. Thus, costs are reported as US$ 2018 per person per year and per household per year.

Financial flows and cost drivers

The cash flows among stakeholders (users and service providers) were analysed using a spreadsheet model to evaluate the allocation of costs (or financial burden) associated with different systems. These included the financial burden to construct and operate the different sanitation systems. For example, households pay a sewerage charge based on their water consumption at 30% of the monthly water consumed for residents connected to the water supply system. The charge helped establish the financial burden borne by households and the extent to which they fund the operations.

For FSM systems, the time it takes for the containment to fill depends on several factors such as the number of users, size, soil characteristics and anal cleansing material used (Pickford, 1995). The variability in factors means that it can take different periods before the containment is full and when maintenance is required (Burr, P.W., 2014). Based on responses from households, the filling time for both latrines and septic tanks was from 6 months to more than 36 months. This study assumed that a private latrine or septic tank took three years to fill while those shared took two years. The emptying fees paid by the household were estimated based on values reported by households and those given by the WT's based on a bundled tariff of 12, 24 or 32 sixty-litre barrels emptied. The emptying fees paid by households to VTOs varied. Furthermore, as sanitation costs are susceptible to local contexts, the parameters driving the costs were established.

3.7.4 Assessment of the enabling environment for sewered and non-sewered services

Content analysis was used to analyse the key informant qualitative dataset and the secondary data sources. The analysis involved interpreting the meaning of the data by evaluating consecutive data sections and assigning them to categories on a coding frame (Flick, 2013; Schreier, 2012). The interview transcripts and field notes were deductively coded into themes in NVivo relating to the enabling environment for sewered and non-sewered services. From the coded data and categories created, dominant themes were revealed in helping understand the influence of the enabling environment on service delivery.

The positionality of the interviewee was checked for bias as positionality is subjective based on the individual's reality as they select the information relayed to the researcher (Jones, M., 2001). In addition, the approach was taken to enhance the internal validity of the data by employing the strategy of informant triangulation, that is, by checking how many other informants supported the assertion or narrative. The coded data under each theme were then analysed, and the strength of evidence for each theme was checked by counting the number of data points supporting the theme.

The City Service Delivery Assessment (CSDA) framework (Blackett and Hawkins, 2019; Peal, Andy et al., 2014) was used to assess the enabling environment for sanitation services. The assessment is structured around three functions - enabling, delivering, and sustaining. Enabling function looks at the policy, legal and institutional environment. The delivering function looks at the resources and mechanisms available to improve sanitation. Finally, the sustaining function looks at the operating environment, funding and personnel needed to provide ongoing and sustainable sanitation services. Each function has three building blocks, of which one focuses on inclusion (Blackett and Hawkins, 2019).

Each building block has indicators (specific questions) assigned a score during the assessment process. Sewered and non-sewered services were assessed separately across the sanitation value chain elements. The performance of sewered and non-sewered service development and delivery were scored on a scale of 0 (hindering) to 1 (enhancing). Appendix D-1 to D-5 shows the assessment criteria used.

3.7.5 Exploration of factors influencing household sewer connectivity and access to safely managed faecal sludge management services

The study used the JMP definition of safely managed sanitation to measure access. Safely managed sanitation considers the use of improved facilities not shared between households with the excreta safely disposed of in-situ or transported and safely treated off-site (UNICEF and WHO, 2017). Improved sanitation facilities hygienically separate human excreta from human contact (UNICEF and WHO, 2006). They include flush/pour-flush to a piped sewer system, septic tanks, ventilated improved pit latrines, compositing toilets or pit latrines with slabs (UNICEF and WHO, 2015). The JMP classifies the use of shared sanitation as a limited service. Shared facilities are prevalent in compounds where several households share water, sanitation and solid waste management services.

Descriptive statistics were used to analyse household socio-demographic and WaSH characteristics. The association between household socio-demographics and WaSH characteristics was evaluated using bivariate logistic regression to identify a set of predictors for connecting to the sewer network and using a safely managed emptying service. In selecting variables for stepwise regression, crude odds ratio (COR) with 95% confidence intervals (CI) were computed between each explanatory (predictor) and the outcome variable. The threshold for inclusion into the multivariate logistic regression model were variables resulting in $p<0.25$.

In this study, eligible explanatory factors for connecting to the sewer network were household income, living arrangements (owner vs renting), water supply availability, living on a compound plot, type of facility access (private vs shared). Other factors included length of household stay, household head level of education, household size, type of urban setting, gender of household head and the number of people using the facility. For using a safely managed emptying service, eligible predictors were household income level, living arrangements, water supply availability, not living on a compound plot, type of facility access (private vs shared). Other factors included length of household stay, household head level of education, household size, type of urban setting, gender of household head, type of sanitation facility (improved vs unimproved) and plot/containment accessibility.

This study defines a household as "A person or group of related or unrelated persons living together in the same dwelling unit(s), who acknowledge one adult female or male as the head of the household, share the same housekeeping arrangements….." (Zambia Statistics Agency et al., 2019, p 46). The income threshold used was ZMW 2,893 (US$ 276), the average income for urban households in Lusaka according to the 2015 Living Conditions Monitoring Survey (CSO, 2015, p 79). Based on survey and key informant interview data, the household size in LIHD and MIMD areas was six members, with five members in HILD areas.

Using the Akaike Information Criterion (AIC), eligible predictors were computed via backward stepwise regression to determine factors that significantly contributed to sewer connectivity (Yes vs No) and use of a safely managed emptying service (Yes vs No). The AIC is a mathematical test designed to explore different working hypotheses and selects the best model that fits the data it describes (Portet, 2020). The p-value threshold for input into the model to determine the adjusted odds ratio (AOR) was 0.25, at 0.05 significance level and 95% CI. The AOR and corresponding CI are reported. The results are presented in text and tables.

3.8 Ethical considerations

The study was approved by the University of Leeds Maths and Physical Sciences and Engineering Ethics Committee (MEEC 18-036) and ERES Converge Institutional Review Board (2019-JUN-014) in Lusaka. Appendix B-4 shows the approval letters. Before participant enrolment, an information sheet describing the research was read out before the researcher asked for written consent to participate. Participants received no compensation, and anonymity was ensured using identification codes with no names recorded.

Chapter 4: Financial cost analysis of sewer-based and faecal sludge management sanitation systems

4.1 Introduction

This chapter reports the costs of implementing, operating and sustaining FSM and sewer-based systems in Lusaka. Costs are reported using a standard metric, the total annualised cost per household (TACH) and per capita (TACC), described in Section 3.7.3. Annualised costs include both capital and operational and maintenance liabilities. In addition to disaggregation by system type, costs are reported separately for systems in a range of different urban settings typical of Lusaka. For this analysis, the study used the area descriptors defined in Table 3-4 and summarised below:

- Low-income high-density (LIHD) being areas that are often unplanned with a high population density, generally characterised by low incomes, and a high proportion of renting households;
- Medium-income medium-density (MIMD) being areas that may be planned, with at least basic services, having a moderate population density and generally characterised by medium incomes; and
- High-income low-density (HILD) areas are predominantly planned, fully serviced, and have the least population density, with a low proportion of renting households.

Using these disaggregated results, exploring the drivers of cost for urban sanitation in Lusaka is possible.

In addition to describing the total costs of various systems in the different urban settings, data are presented on the extent to which these costs are borne and/or recouped from stakeholders (users and service providers). Overall cost recovery may be a factor that could have a bearing on levels of coverage and quality of service in each case.

4.2 Costs of sewer-based systems

There are both conventional and simplified sewers in Lusaka using different treatment technologies. This section sets out the total cost liabilities for constructing, operating and sustaining each type of system. Cost data are estimated primarily based on planning data in reports, with some empirical cross-checking. Since actual cost data were not available for most sewersheds in Lusaka, estimates are used, including ranges to indicate the level of uncertainty.

The costs of each sewerage system are summarised in Table 4-1 for costs per capita and Table 4-2 for costs per household. Cost data are broken down, with specific costs allocated for the household collection system (the water closet and sewer connection), the emptying and transport system (in this case, the sewer network) and treatment. The costs of the sewer network are further broken down into costs of the secondary sewers at the community scale and the trunk network collecting sewage from communities and conveying it to treatment.

The costs presented are for four sewerage systems which include:

- Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant (S1);
- Conventional sewers connecting to waste stabilisation ponds (S2);
- Simplified sewers with communal septic tanks, connecting to a trickling filter and anaerobic sludge treatment plant (S3); and
- Simplified sewers connecting to waste stabilisation ponds (S4).

Table 4-1. Total annualised cost per capita of a complete service for conventional and simplified sewerage systems in Lusaka (US dollar 2018 equivalent)

System Type	Sewer shed	Urban Setting	Annualised Cost (US$ 2018 capita^{-1} year^{-1})										TACC[3] ($2018)
			Containment[1]	Emptying and Transport (Collection)						Treatment			
				Secondary sewers			Trunk sewers						
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	CapEx	OpEx	Total	
Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant (S1)	Western	S1-LIHD	**33**	23	7	**30**	7	2	**9**	9	17	**26**	**98**
		S1-MIMD	**40**	10	4	**14**	7	2	**9**	9	17	**26**	**89**
	Central	S1-LIHD	**33**	8	3	**11**	7	1	**8**	9	17	**26**	**78**
		S1-MIMD	**40**	8	3	**11**	7	1	**8**	9	17	**26**	**85**
		S1-HILD	**49**	19	5	**24**	7	1	**8**	9	17	**26**	**107**
Conventional sewers connecting to waste stabilisation ponds (S2)	Eastern	S2-LIHD	**36**	18	8	**26**	3	1	**4**	6	3	**9**	**75**
		S2-MIMD	**40**	6	2	**8**	3	1	**4**	6	3	**9**	**61**
		S2-HILD	**49**	25	7	**32**	3	1	**4**	6	3	**9**	**94**
Simplified sewers with DWWM[2] through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant (S3)	Western	S3-LIHD	**33**	26	8	**34**	7	2	**9**	9	17	**26**	**102**
		S3-MIMD	**40**	19	4	**23**	7	2	**9**	9	17	**26**	**98**
	Central	S3-LIHD	**33**	23	7	**30**	7	1	**8**	9	17	**26**	**97**
Simplified sewers connecting to waste stabilisation ponds (S4)	Eastern	S4-LIHD	**42**	36	9	**45**	3	1	**4**	6	3	**9**	**100**

[1]Containment includes the costs for a water closet and single sewer connection
[2]DWWM (decentralised wastewater management) using communal septic tanks, with simplified sewers moving the waste from household/compound plots and discharging it into the tanks from which wastewater is conveyed through conventional trunk sewers for further treatment.
[3]TACC (total annualised cost per capita) was obtained, dividing the total annual capital and operational liabilities by the number of people using the system (see Section 3.7.3 for the detailed calculation procedures)

Table 4-2. Total annualised cost per household of a complete service for conventional and simplified sewerage systems in Lusaka (US dollar 2018 equivalent)

System Type	Sewer shed	Urban Setting	Annualised Cost (US$ 2018 household^{-1} year^{-1})										TACH[1] ($2018)
			Containment	Emptying and Transport (Collection)						Treatment			
				Secondary sewers			Trunk sewers						
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	CapEx	OpEx	Total	
Conventional sewers connected to a trickling filter and anaerobic sludge treatment plant (S1)	Western	S1-LIHD	**198**	138	42	**180**	42	12	**54**	54	102	**156**	**588**
		S1-MIMD	**240**	60	24	**84**	42	12	**54**	54	102	**156**	**534**
	Central	S1-LIHD	**198**	48	18	**66**	42	6	**48**	54	102	**156**	**468**
		S1-MIMD	**240**	48	18	**66**	42	6	**48**	54	102	**156**	**510**
		S1-HILD	**245**	114	25	**139**	42	6	**48**	54	102	**156**	**588**
Conventional sewers connected to waste stabilisation ponds (S2)	Eastern	S2-LIHD	**216**	108	48	**156**	18	6	**24**	36	18	**54**	**450**
		S2-MIMD	**240**	36	12	**48**	18	6	**24**	36	18	**54**	**366**
		S2-HILD	**245**	125	35	**160**	18	6	**24**	36	18	**54**	**483**
Simplified sewers with DWWM through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant (S3)	Western	S3-LIHD	**198**	156	48	**204**	18	12	**54**	54	102	**156**	**612**
		S3-MIMD	**240**	114	24	**138**	42	12	**54**	54	102	**156**	**588**
	Central	S3-LIHD	**198**	138	42	**180**	42	6	**48**	54	102	**156**	**582**
Simplified sewers connected to waste stabilisation ponds (S4)	Eastern	S4-LIHD	**252**	216	54	**270**	18	6	**24**	36	18	**54**	**600**

TACH[1] was obtained dividing the total annual capital and operational liabilities by the number of households using the system (see Section 3.7.3)

The costs presented in Table 4-3 are allocated to the household or individuals with working connections, representing the current total cost allocation.

Table 4-3. Household collection (containment) capital costs for different urban settings in Lusaka (US dollar 2018[3] equivalent)

Urban settings/sanitation component	Capital costs
LIHD areas	
- Water closet[4]	542-753
- Sewer connection[4]	276-480
MIMD areas	
- Water closet	1,142
- Sewer connection	276
HILD areas	
- Water closet	1,142
- Sewer connection	276

Costs for a water closet range from $542-753 in LIHD areas, while a sewer connection ranges from $276-480 (US dollar 2018 equivalent). The equivalent total annualised costs for the household-level collection system are $33-42 capita^{-1} year^{-1} (Table 4-1) or $198-252 household^{-1} year^{-1} (Table 4-2). LIHD areas average six members per household. In most cases, facilities in LIHD areas are standalone structures, detached from the living unit due to several households (on average four) living on a compound plot.

On average, the cost for a water closet is $1,142, with sewer connection costs of $276 in both MIMD and HILD areas. MIMD households, on average, have six members. The equivalent total annualised costs are $40 capita^{-1} year^{-1} or $240 household^{-1} year^{-1} in MIMD areas (Table 4-1 and Table 4-2). On average, households in HILD areas have five members, corresponding to annualised costs of $49 capita^{-1} year^{-1} or $245 household^{-1} year^{-1}.

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3 Average 2018 US dollar to Zambia kwacha exchange rate was $1 to ZMW10.498 (Source: Bank of Zambia: https://www.boz.zm/average-exchange-rates.htm).

4 Costs indicated are median ranges. Appendix C-2 shows minimum and maximum containment costs

Water closets costs in MIMD and HILD areas were estimated based on information from the Head of FSM at the water and sanitation utility, LWSC. Costs for a sewer connection differ depending on who makes the connection. For in-house connections done by LWSC, the distance from the facility to the secondary network connecting point determines the cost. However, a domestic connection by LWSC costs on average $276. For externally funded community-scale sewer networks implemented by contractors, connection costs tend to be higher. The projects usually cover the connection costs, with households paying a connection fee. For example, in Mtendere LIHD area, households paid a connection fee of $17, with a connection costing $480. Appendix C-1 shows the water closet and sewer connection costs.

The costs of collection (i.e., community-scale secondary and trunk sewers) and treatment are now considered. S1[5] has total collection costs of $19-39 capita^{-1} year^{-1} across all urban settings with treatment costs of $26 capita^{-1} year^{-1}. Annualised capital costs for collection ($15-30 capita^{-1} year^{-1}) are higher when compared to operational costs ($4-9 capita^{-1} year^{-1}). For treatment, annualised capital costs are lower than operational costs ($9 capita^{-1} year^{-1} compared to $17 capita^{-1} year^{-1}). Electro-mechanical equipment with high energy and maintenance requirements in treatment drives operational costs. The TACC for a full service is $78-98 in LIHD areas, $85-89 in MIMD areas and $107 in HILD areas (Table 4-1). Costs for the community-scale secondary sewers by area are presented in Appendix C-3, with trunk sewer costs in Appendix C-5.

S2[6] has total collection costs of $12-36 capita^{-1} year^{-1} across all urban settings. The total treatment costs are $9 capita^{-1} year^{-1}. The capital costs for collection ($6-25 capita^{-1} year^{-1}) are substantially higher than operational costs ($2-8 capita^{-1} year^{-1}). Total capital costs for treatment are twice as high as operational costs ($6 capita^{-1} year^{-1} compared to $3 capita^{-1} year^{-1}). Waste stabilisation ponds are passive treatment systems with lower operational costs than active

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[5] Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant
[6] Conventional sewers connecting to waste stabilisation ponds

systems using energy-driven equipment. The TACC for a full service is $75 in LIHD areas, $61 in MIMD areas and $94 in HILD areas (Table 4-1).

S3[7] has total collection costs of $32-43 capita^{-1} year^{-1} with treatment costs of $26 capita^{-1} year^{-1}. The capital costs for collection ($26-33 capita^{-1} year^{-1}) are over three times higher than operational costs ($6-10 capita^{-1} year^{-1}). The TACC in LIHD areas is $97 to $102 and $98 in MIMD areas (Table 4-1).

System type S4[8] has total collection costs of $45 capita^{-1} year^{-1} with treatment costs of $9 capita^{-1} year^{-1}. The capital costs for collection ($36 capita^{-1} year^{-1}) are four times higher than operational costs ($9 capita^{-1} year^{-1}). The TACC in the LIHD area is $100 (Table 4-1).

Overall simplified sewer systems had higher costs than conventional systems. In LIHD areas, simplified sewers were $99 capita^{-1} year^{-1} compared to $88 capita^{-1} year^{-1} for conventional sewers with trickling filter treatment. Similarly, in MIMD areas, simplified costs were higher than conventional sewerage ($98 capita^{-1} year^{-1} compared to $89 capita^{-1} year^{-1}). For the system using ponds, costs for the conventional system in LIHD areas were $75 capita^{-1} year^{-1} compared to $100 capita^{-1} year^{-1} for the simplified system.

Caution is needed in comparing these data. The costs of simplified sewer systems are higher but should be viewed with context. For instance, simplified sewers with communal septic tanks contribute 25-35% to total collection costs for the system connecting to a trickling filter treatment plant (Appendix C-4). Low connectivity was a factor for community-scale secondary conventional and simplified networks with comparable capital costs. For example, a comparison of conventional sewers in Northmead ($538,007 CapEx) and simplified sewers in Kalingalinga ($553,000 CapEx) show that Northmead has a higher number of connections (495) compared to Kalingalinga (156).

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7 Simplified sewers with communal septic tanks through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant

8 Simplified sewers connecting to waste stabilisation ponds

Consequently, the per capita costs in Northmead are lower (\$18 capita^{-1} year^{-1}) compared to Kalingalinga (\$45 capita^{-1} year^{-1}). See Appendix C-3 and C-4. Generally, capital costs for the community-scale secondary networks for conventional sewerage were higher for similarly sized simplified sewerage networks when costs of communal septic tanks are not considered.

4.3 The influence of connection efficiency on total system costs

The total annualised costs were modelled to ascertain how they varied with changes in the rate of connections (or connection saturation). Costs were modelled at 100% sewer connection efficiency (CE) with all households within an area assumed connected to the sewer network. Table 4-4, costs per capita and Table 4-5, costs per household, present the modelled costs for a full service assuming 100% connection efficiency.

Results show that at lower connectivity rates, sewer costs are higher. At 100% connection efficiency, sewer costs reduce. For community-scale conventional sewerage with pumping, cost reductions range from \$1.3-9.5 capita^{-1} year^{-1} in LIHD areas. In MIMD areas, cost reductions range from \$1.3-19.4 capita^{-1} year^{-1}, with costs in HILD areas ranging from \$8-18.3 capita^{-1} year^{-1}. For non-pumped systems, the costs reduce by \$0.3 capita^{-1} year^{-1} in LIHD areas. In MIMD areas, cost reductions range from \$0.6-3.3 capita^{-1} year^{-1} and \$3.9-6 capita^{-1} year^{-1} in HILD areas. See Appendix C-9 and C-10 on the influence of connection efficiency on costs for community-scale secondary sewer networks.

For pumped simplified sewers at 100% connection efficiency, cost reductions range from \$6.7-9.5 capita^{-1} year^{-1}. In non-pumped systems, the reduction in costs were \$6 and \$20.5 capita^{-1} year^{-1}. Data are presented in Appendix C-11 and C-12. Full sewer connectivity is assumed in the planning for citywide services (Chapter 8), which is the outcome intended for any new investments.

Table 4-4. Total annualised cost per capita of a complete service for conventional and simplified sewerage systems assuming 100% connection efficiency in Lusaka (US dollar 2018 equivalent)

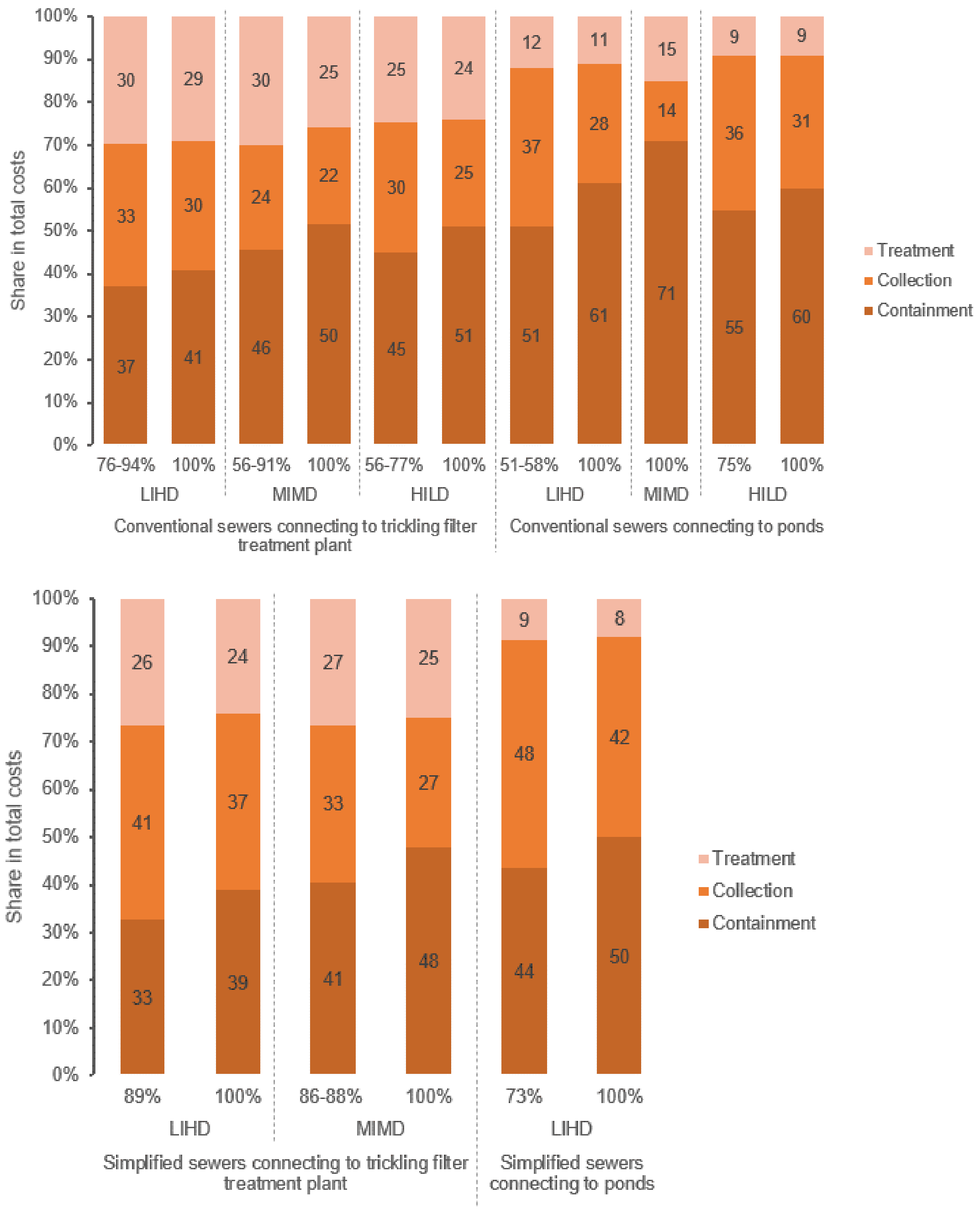
System Type	Sewer shed	Urban Setting	Annualised Cost (US$ 2018 capita^{-1} year^{-1})										TACC ($2018)
			Containment	Emptying and Transport (Collection)						Treatment			
				Secondary sewers			Trunk sewers						
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	CapEx	OpEx	Total	
Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant (S1)	Western	S1-LIHD	**33**	19	5	**24**	5	2	**7**	9	17	**26**	**90**
		S1-MIMD	**40**	9	4	**13**	5	2	**7**	9	17	**26**	**86**
	Central	S1-LIHD	**33**	7	3	**10**	6	1	**7**	9	17	**26**	**76**
		S1-MIMD	**40**	7	2	**9**	6	1	**7**	9	17	**26**	**82**
		S1-HILD	**49**	14	3	**17**	6	1	**7**	9	17	**26**	**99**
Conventional sewers connecting to waste stabilisation ponds (S2)	Eastern	S2-LIHD	**36**	10	4	**14**	2	1	**3**	6	3	**9**	**62**
		S2-MIMD	**40**	6	2	**8**	2	1	**3**	6	3	**9**	**60**
		S2-HILD	**49**	18	5	**23**	2	1	**3**	6	3	**9**	**84**
Simplified sewers with DWWM[2] through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant (S3)	Western	S3-LIHD	**33**	18	4	**22**	5	2	**7**	9	17	**26**	**88**
		S3-MIMD	**40**	15	3	**18**	5	2	**7**	9	17	**26**	**91**
	Central	S3-LIHD	**33**	16	4	**20**	6	1	**7**	9	17	**26**	**86**
Simplified sewers connecting to waste stabilisation ponds (S4)	Eastern	S4-LIHD	**42**	19	5	**24**	2	1	**3**	6	3	**9**	**78**

Table 4-5. Total annualised cost per household of a complete service for conventional and simplified sewerage systems assuming 100% connection efficiency in Lusaka (US dollar 2018 equivalent)

System Type	Sewer shed	Urban Setting	Annualised Cost (US$ 2018 household^{-1} year^{-1})										TACH ($2018)
			Containment	Emptying and Transport (Collection)						Treatment			
				Secondary sewers			Trunk sewers						
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	CapEx	OpEx	Total	
Conventional sewers connected to a trickling filter and anaerobic sludge treatment plant (S1)	Western	S1-LIHD	**198**	114	30	**144**	31	11	**42**	54	102	**156**	**540**
		S1-MIMD	**240**	53	23	**76**	31	11	**42**	54	102	**156**	**514**
	Central	S1-LIHD	**198**	43	17	**60**	35	6	**42**	54	102	**156**	**456**
		S1-MIMD	**240**	42	12	**54**	35	6	**42**	54	102	**156**	**492**
		S1-HILD	**245**	69	18	**87**	35	6	**42**	54	102	**156**	**530**
Conventional sewers connected to waste stabilisation ponds (S2)	Eastern	S2-LIHD	**216**	60	24	**84**	12	6	**18**	36	18	**54**	**372**
		S2-MIMD	**240**	36	12	**48**	12	6	**18**	36	18	**54**	**360**
		S2-HILD	**245**	92	26	**118**	12	6	**18**	36	18	**54**	**435**
Simplified sewers with DWWM through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant (S3)	Western	S3-LIHD	**198**	108	24	**132**	31	11	**42**	54	102	**156**	**528**
		S3-MIMD	**240**	90	18	**108**	31	11	**42**	54	102	**156**	**546**
	Central	S3-LIHD	**198**	96	24	**120**	35	6	**42**	54	102	**156**	**516**
Simplified sewers connected to waste stabilisation ponds (S4)	Eastern	S4-LIHD	**252**	114	30	**144**	12	6	**12**	36	18	**54**	**462**

4.4 Distribution of costs across the value chain for sewered systems

Figure 4-1 shows the distribution of costs across the value chain at current and 100% connection efficiency for sewered systems. Modelling at 100% sewer connection efficiency was to ascertain how the share in costs varies with current connection rates for the different systems.



The figure shows a combination of actual and modelled data

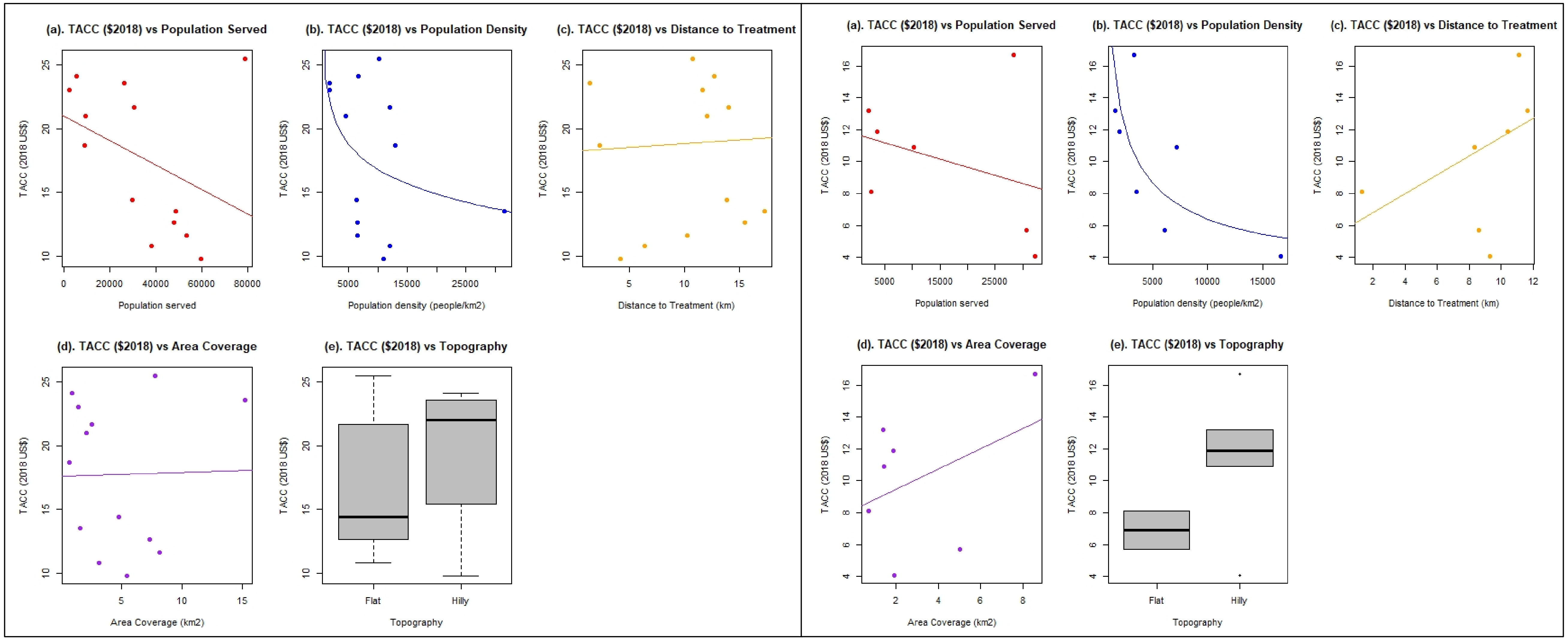
Figure 4-1. Distribution of costs across the value chain for sewered systems at current and 100% connection efficiency (Top) conventional and (Bottom) simplified

Results show that the costs of containment dominate. Due to the locational context and household socio-economic status, containments vary considerably in their construction and finished quality. It is useful to note that the cost of containment for sewerage usually comprises the bathroom - which, as it falls within the house, is more likely to be assumed as a legitimate expense by householders than the other costs. Overall costs for sewerage reduce at a 100% connection efficiency for all systems analysed. Treatment had the least contribution to total costs at 24-27% for active treatment (trickling filters) and 8-9% for passive treatment (ponds).

4.5 Factors influencing the costs of sewered systems

For planning purposes, analysis of cost drivers is meaningful when sewer connectivity rates are high as costs are sensitive to connectivity rates (Section 4.3). Figure 4-2 presents an analysis of potential cost drivers at 100% connection efficiency. The data are presented separately for pumped and non-pumped systems. This analysis examined the influence of population density, the population served, area coverage, topography and distance to treatment on TACC for community-scale conventional networks. Simplified pumped and non-pumped networks had five data points. Hence, no meaningful relationships could be drawn from these data.

The number of connections is directly correlated to the population served. As the population served increases, costs correspondingly reduce for pumped and non-pumped systems (Figure 4-2). At 100% connection efficiency, higher population densities reduce per capita costs, which is more prominent in non-pumped systems (Figure 4-2). The costs of the community-scale secondary networks have an inverse relationship with the population density. An increase in the connection efficiency increases the population served, with population density rising at the same area coverage. Using linear regression (with $p<0.1$), the relationship between population density and TACC was significant ($p= 0.078$) for non-pumped systems. See Appendix C-14 for analysis outputs. The results highlight that with higher sewer connection efficiency, the population density reduces the per capita and the per household costs of sewerage.



Pumped System **Non-pumped System**

Modelled costs at 100% connection efficiency

Figure 4-2[9]. TACC against selected factors for pumped (Left) and non-pumped (Right) community-scale secondary conventional sewers at 100% connection efficiency (a) population served, (b) population density, (c) distance to treatment, (d) area coverage, and (e) topography

[9] The scale of the y-axis on the Figures are different

Results show that the spread (scale) of the network is a function of the area coverage than the number of connections or people served (Figure 4-2). Area coverage is a factor for the capital investment costs of sewerage networks. In Figure 4-2, community-scale secondary networks with costs of \$25.5, 23.6 and \$16.7 capita^{-1} year^{-1} serve substantial populations. However, they have low population densities due to extensive area coverage. The networks are extensive with corresponding high capital costs overall. See Appendix C-3 on the capital costs for community-scale secondary networks for Lilanda-Chunga-George, Chamba Valley, Rhodes Park and Rhodes Park East.

Data presented in Figure 4-2 generally show that systems with pumping have higher costs when compared to non-pumped systems (see Appendix C-9, C-10 and C-13). Capital costs increase with flat or very hilly topography, leading to increased pumping stations to convey wastewater to treatment. The increase in pumping stations results in higher capital and energy costs. Further, pumping could be a result of the distance to treatment. Areas farther away from treatment require pumping to convey the sewage. For pumped networks (Figure 4-2), there is seemingly a weak direct relationship between distance to treatment[10] and TACC. The effect of pumping likely confounds the strength in the direct relationship between costs and distance to treatment. In non-pumped networks (Figure 4-2), there is a stronger direct relationship between the distance to treatment and TACC. Costs increase as the distance to treatment increases.

For simplified systems, the use of communal septic tanks influenced costs. The communal septic tanks account for 25 to 35% of total sewerage costs. Further, the type of treatment technology in use also influences costs. Treatment plants using electro-mechanical equipment had higher investment and operational liabilities. Costs were almost three times more than the passive pond treatment system (\$26 capita^{-1} year^{-1} compared to \$9 capita^{-1} year^{-1}).

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10 When analysing the cost against distance to treatment; the cost contribution of each secondary network relative to the trunk sewer was made proportional to the distance to treatment

4.6 Costs of faecal sludge management (FSM) systems

Several FSM options using various treatment technologies are available in Lusaka. This section sets out the total cost liabilities for constructing, operating and sustaining each type of system. Cost data are estimated primarily based on planning data with some empirical cross-checking.

The costs of each FSM system option deployed are summarised in Table 4-6 as costs per capita and Table 4-7 as costs per household. Cost data are broken down, with specific costs allocated for containment (improved pit latrines or septic tanks), the emptying and transport service, and treatment.

The costs presented are for three FSM systems which include:

- Manual emptying with truck transport dumping into faecal sludge treatment plants (FSTPs), using anaerobic digesters and unplanted drying beds (O1);
- Mechanical desludging of pit latrines and dumping into FSTPs - anaerobic digesters with unplanted drying beds (O2); and
- Mechanical emptying and transport using vacuum trucks and dumping into an anaerobic digester plant with sludge drying (O3).

Table 4-6. Total annualised cost per capita of a complete service for FSM systems in Lusaka (US dollar 2018 equivalent)

System type	Technology	Urban Setting	Annualised Cost (US$ 2018 $capita^{-1}$ $year^{-1}$)							TACC (US$2018)
			Containment[1]	Emptying & Transport			Treatment			
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	
Manual emptying with truck transport dumping into a FSTP using bio-digester with drying beds (O1)	IPL[2]	O1-LIHD	**13**	1	18	**19**	5	1	**6**	**38**
			28	1	17	**18**	8	4	**12**	**58**
			21	4	12	**16**	2	9	**11**	**48**
	ST[3]	O1-LIHD	**22**	1	18	**19**	5	1	**6**	**47**
			31	1	17	**18**	8	4	**12**	**61**
Mechanical desludging; dumps into an FSTP using anaerobic sludge treatment (O2)	IPL	O2-LIHD	**21**	4	13	**17**	2	9	**11**	**49**
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	O3-LIHD	**21**	1	8	**9**	11	5	**16**	**46**
			21	2	9	**11**	11	5	**16**	**48**
			21	2	11	**13**	11	5	**16**	**50**
	ST	O3-LIHD	**22**	1	8	**9**	11	5	**16**	**47**
			22	2	9	**11**	11	5	**16**	**59**
			22	2	11	**13**	11	5	**16**	**51**
			31	1	8	**9**	11	5	**16**	**56**
			31	2	9	**11**	11	5	**16**	**58**
			31	2	11	**13**	11	5	**16**	**60**
		O3-MIMD	**48**	1	8	**9**	11	5	**16**	**73**
			48	2	9	**11**	11	5	**16**	**75**
			48	2	11	**13**	11	5	**16**	**77**
		O3-HILD	**72**	1	8	**9**	11	5	**16**	**97**
			72	2	9	**11**	11	5	**16**	**99**
			72	2	11	**13**	11	5	**16**	**101**

[1]Includes capture technology and infrastructure: [2]Improved Pit Latrines: [3]Septic Tanks

Table 4-7. Total annualised cost per household of a complete service for FSM systems in Lusaka (US dollar 2018 equivalent)

System type	Technology	Urban Setting	Annualised Cost (US$ 2018 household^{-1} year^{-1})							TACH (US$2018)
			Containment[1]	Emptying & Transport			Treatment			
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	
Manual emptying with truck transport dumping into bio-digesters with drying beds (O1)	IPL	O1-LIHD	**78**	6	108	**114**	30	6	**36**	**228**
			168	6	102	**108**	48	24	**72**	**348**
			126	24	72	**96**	12	54	**66**	**288**
	ST	O1-LIHD	**132**	6	108	**114**	30	6	**36**	**282**
			186	6	102	**108**	48	24	**72**	**366**
Mechanical desludging; dumps into an FSTP using anaerobic sludge treatment (O2)	IPL	O2-LIHD	**126**	24	78	**102**	12	54	**68**	**296**
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	O3-LIHD	**126**	6	48	**54**	64	31	**95**	**275**
			126	12	54	**66**	64	31	**95**	**287**
			126	12	66	**78**	64	31	**95**	**299**
	ST	O3-LIHD	**132**	6	48	**54**	64	31	**95**	**281**
			132	12	54	**66**	64	31	**95**	**293**
			132	12	66	**78**	64	31	**95**	**305**
			186	6	48	**54**	64	31	**95**	**335**
			186	12	54	**66**	64	31	**95**	**347**
			186	12	66	**78**	64	31	**95**	**359**
		O3-MIMD	**288**	6	48	**54**	64	31	**95**	**437**
			288	12	54	**66**	64	31	**95**	**449**
			288	12	66	**78**	64	31	**95**	**461**
		O3-HILD	**360**	6	48	**54**	64	31	**95**	**509**
			360	12	54	**66**	64	31	**95**	**521**
			360	12	66	**78**	64	31	**95**	**533**

The costs presented in Table 4-8 are allocated to households using improved pit latrines (IPL) and septic tanks (ST), representing the current total cost allocation. Costs for IPL range from $452-995 in LIHD areas, with septic tank costs ranging from $881-1,238. In most cases, septic tanks in LIHD areas have no baffle wall for effective primary treatment and no infiltration structure for secondary treatment. The equivalent total annualised costs for IPL systems range from $13-28 capita^{-1} year^{-1} (Table 4-6) or $78-168 household^{-1} year^{-1} (Table 4-7). The equivalent total annualised costs for septic tank systems range from $22-31 capita^{-1} year^{-1} (Table 4-6) or $132-186 household^{-1} year^{-1} (Table 4-7). Detailed costs are presented in Appendix C-2.

Table 4-8. FSM system containment capital costs for different urban settings in Lusaka (US dollar 2018)

Urban setting and sanitation system component	Capital costs
LIHD areas	
- Improved pit latrines (IPL)[11]	452-995
- Water closet with a septic tank (ST)[11]	881-1,238
MIMD areas	
- Water closet with a septic tank (ST)	1,905
HILD areas	
- Water closet with a septic tank (ST)	2,381

The costs for septic tanks average $1,905 in MIMD areas and $2,381 in HILD areas. In MIMD and HILD areas, septic tanks usually have infiltration structures. The equivalent total annualised costs in MIMD areas are $48 capita^{-1} year^{-1} or $288 household^{-1} year^{-1} (Table 4-6 and Table 4-7). In HILD areas, the annualised costs are $72 capita^{-1} year^{-1} or $360 household^{-1} year^{-1}.

Now considering the costs of collection (emptying and transport) and treatment. O1[12] uses pushcarts to haul manually emptied faecal sludge in 60-litre containers to the nearest road and trucked to treatment. Latrines and septic tanks are emptied this way in some LIHD areas. Capital costs for emptying and

11 Costs indicated are median ranges. Appendix 4.3 shows minimum and maximum costs
12 Manual emptying with truck transport dumping into bio-digesters with drying beds

transport ($1-4 capita^{-1} year^{-1}) are three times lower than operational costs ($12-18 capita^{-1} year^{-1}). Manual emptying is labour intensive with a minimum six-man team, accounting for over 50% of total operational costs.

Treatment capital costs ($2-8 capita^{-1} year^{-1}) are not substantially different from the operational costs ($1-9 capita^{-1} year^{-1}). Treatment is passive; hence, it has low operational liabilities. The total annualised costs for emptying and transport ($16-19 capita^{-1} year^{-1}) are higher than treatment ($6-12 capita^{-1} year^{-1}). The results show that emptying and transport drive costs in this business model. TACC for a full-service range from $38-58 for IPL and $47-61 for septic tanks (Table 4-6). Detailed costs are presented in Appendix C-6 and C-7.

O2[13] is for latrines accessible by motorised transport that are mechanically desludged. Capital costs for emptying and transport ($4 capita^{-1} year^{-1}) are three times lower than operational costs ($13 capita^{-1} year^{-1}). Treatment capital costs are substantially lower than operational costs ($2 capita^{-1} year^{-1} compared to $9 capita^{-1} year^{-1}). Operational liabilities are drivers of cost in this business model. The TACC for a full service is $49 (Table 4-6).

O3[14] is mostly for septic tank systems across all urban settings. Capital costs for emptying and transport ($1-2 capita^{-1} year^{-1}) are four times lower than operational costs ($8-11 capita^{-1} year^{-1}). Fuel, staffing and truck maintenance costs are substantial costs drivers in this business model (see Appendix C-6). Most of the vacuum trucks deployed are second-hand; as such, the trucks require frequent maintenance. The average emptying and transport costs are 1.4 times lower than treatment costs ($11 capita^{-1} year^{-1} compared to $16 capita^{-1} year^{-1}). TACC for vacuum truck operated (VTO) systems range from $47-60 in LIHD areas, $73-77 in MIMD areas and $97-101 in HILD areas (Table 4-6).

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13 Mechanical desludging units dumping into anaerobic sludge treatment plants

14 Mechanical emptying and transport, dumping into a trickling filter (aerobic) treatment plant

4.7 The influence of operating emptying and transport services at full capacity on total system costs

Costs were modelled to ascertain how they varied at current and higher service coverage levels. Modelling was to the point at which emptying and transport services run at full operator capacity. Table 4-9 and 4-10 present the modelled costs assuming full-service capacity for emptying and transport.

Results show that system costs are higher at current emptying and transport service levels, while at full operator capacity, costs reduce. For manual emptying with truck transport, costs for direct staffing (for emptiers), fuel, maintenance, tools and other consumables increase when operating at full capacity. Investment and other fixed operating costs[15] remain the same. Emptying staff costs are 60% of the revenue generated in this business model. Staffing costs increase with increased service coverage as emptiers are paid on commission for every containment emptied. Overall, emptying and transport costs reduced considerably (\$10-13 capita^{-1} year^{-1} compared to \$16-19 capita^{-1} year^{-1}), highlighting inefficiencies at current levels of coverage. For treatment, there is a marginal reduction in costs of \$1 capita^{-1} year^{-1}. As coverage increases, investment and fixed operating costs remain unchanged except the solid waste and sludge transfer service costs.

For mechanical emptying and transport by VTOs, only fuel and vehicle maintenance costs increase with more households served. The investment and other fixed operating costs remain unchanged. These include staffing, vehicle taxes and insurance and disposal licences. Overall, emptying and transport costs for VTOs reduce slightly. The scenario shows that current levels of coverage are closer to full operational capacity (\$8-11 capita^{-1} year^{-1} compared to \$9-13 capita^{-1} year^{-1}). For treatment, the trickling filter and sludge plant receive water-borne sewage, and the addition of households from FSM services results in a marginal reduction in costs of \$0.5 capita^{-1} year^{-1}.

[15] The fixed operating costs include management costs, taxes, vaccinations and marketing.

Table 4-9. Total annualised cost per capita for FSM systems assuming emptying and transport services are operating at full capacity in Lusaka (US dollar 2018 equivalent)

System type	Technology	Urban Setting	Annualised Cost (US$ 2018 $capita^{-1}$ $year^{-1}$)							TACC (US$2018)
			Containment	Emptying & Transport			Treatment			
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	
Manual emptying with truck transport dumping into a FSTP using bio-digester with drying beds (O1)	IPL	O1-LIHD	**13**	1	12	**13**	4	1	**5**	**31**
			28	1	12	**13**	6	5	**11**	**52**
			21	2	8	**10**	2	9	**11**	**42**
	ST	O1-LIHD	**22**	1	12	**13**	4	1	**5**	**40**
			31	1	12	**13**	6	5	**11**	**55**
Mechanical desludging dumps into an FSTP using anaerobic sludge treatment (O2)	IPL	O2-LIHD	**21**	2	13	**15**	2	9	**11**	**47**
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	O3-LIHD	**21**	1	7	**8**	11	5	**16**	**45**
			21	2	7	**9**	11	5	**16**	**46**
			21	2	9	**11**	11	5	**16**	**48**
	ST	O3-LIHD	**22**	1	7	**8**	11	5	**16**	**46**
			22	2	7	**9**	11	5	**16**	**47**
			22	2	9	**11**	11	5	**16**	**49**
			31	1	7	**8**	11	5	**16**	**55**
			31	2	7	**9**	11	5	**16**	**56**
			31	2	9	**11**	11	5	**16**	**58**
		O3-MIMD	**48**	1	7	**8**	11	5	**16**	**72**
			48	2	7	**9**	11	5	**16**	**73**
			48	2	9	**11**	11	5	**16**	**75**
		O3-HILD	**72**	1	7	**8**	11	5	**16**	**96**
			72	2	7	**9**	11	5	**16**	**97**
			72	2	9	**11**	11	5	**16**	**99**

Table 4-10. Total annualised cost per household for FSM systems assuming emptying and transport services are operating at full capacity in Lusaka (US dollar 2018 equivalent)

System type	Technology	Urban Setting	Annualised Cost (US$ 2018 household^{-1} year^{-1})							TACH (US$2018)
			Containment	Emptying & Transport			Treatment			
			CapEx	CapEx	OpEx	Total	CapEx	OpEx	Total	
Manual emptying with truck transport dumping into bio-digesters with drying beds (O1)	IPL	O1-LIHD	**78**	6	72	**78**	24	6	**30**	**180**
			168	6	72	**78**	36	30	**66**	**312**
			126	12	48	**60**	12	54	**66**	**252**
	ST	O1-LIHD	**132**	6	72	**78**	24	6	**30**	**240**
			186	6	72	**78**	36	30	**66**	**330**
Mechanical desludging units dumping into anaerobic sludge treatment plant (O2)	IPL	O2-LIHD	**126**	12	78	**90**	12	54	**66**	**282**
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	O3-LIHD	**126**	6	42	**48**	64	28	**92**	**266**
			126	12	42	**54**	64	28	**92**	**272**
			126	12	54	**66**	64	28	**92**	**294**
	ST	O3-LIHD	**132**	6	42	**48**	64	28	**92**	**272**
			132	12	42	**54**	64	28	**92**	**280**
			132	12	54	**66**	64	28	**92**	**290**
			186	6	42	**48**	64	28	**92**	**326**
			186	12	42	**54**	64	28	**92**	**332**
			186	12	54	**66**	64	28	**92**	**344**
		O3-MIMD	**288**	6	42	**48**	64	28	**92**	**428**
			288	12	42	**54**	64	28	**92**	**434**
			288	12	54	**66**	64	28	**92**	**446**
		O3-HILD	**360**	6	42	**48**	64	28	**92**	**500**
			360	12	42	**54**	64	28	**92**	**506**
			360	12	54	**66**	64	28	**92**	**518**

4.8 Distribution of costs across the value chain for FSM systems

Figure 4-3 shows the distribution of costs for FSM systems across elements of the value chain at current and modelled service coverage (SC).

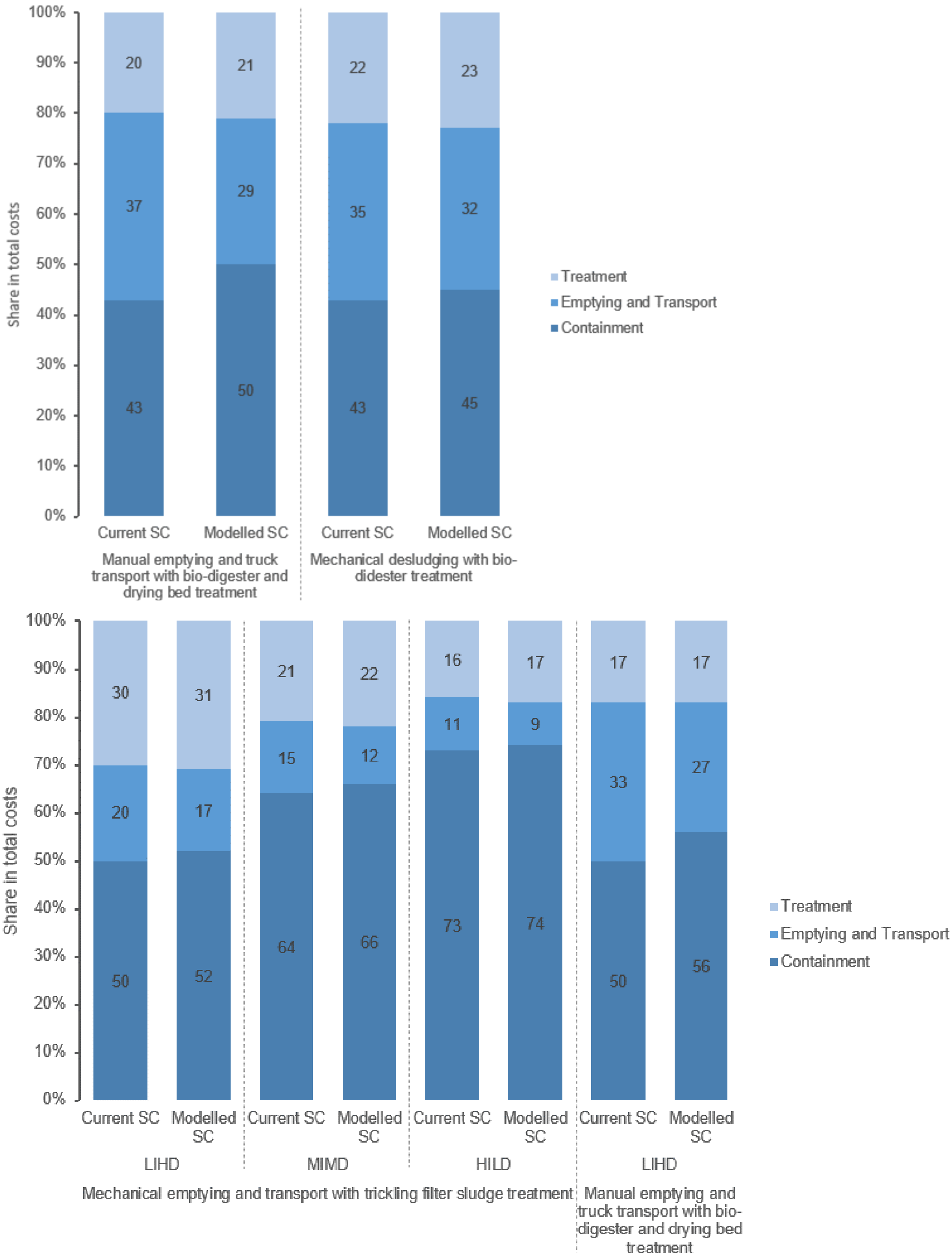


Figure 4-3. Distribution of costs across the value chain for FSM systems at current and modelled service coverage (Top) Improved pit latrines and (Bottom) Septic tanks

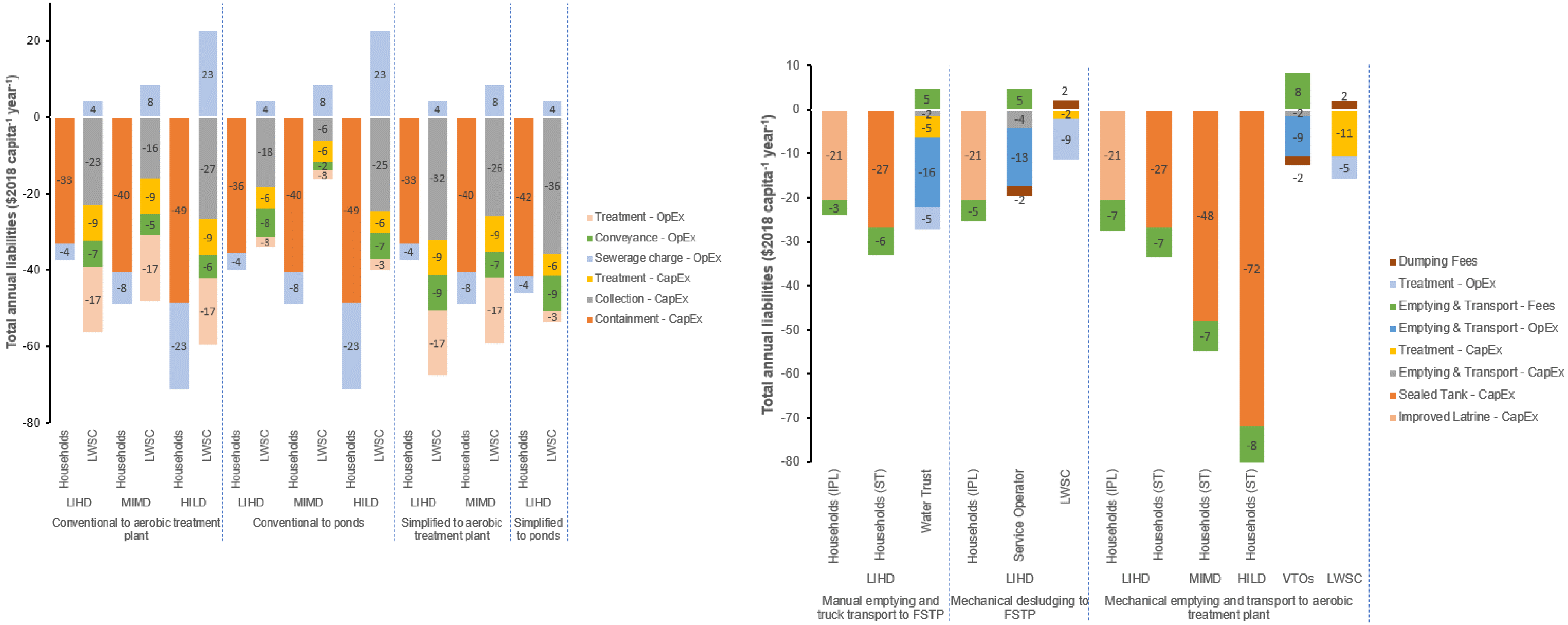
The results highlight that containment costs dominate and are highest in HILD areas. Current service costs for manual emptying and mechanical desludging systems are not substantially different (Figure 4-3). The manual emptying and transport system shows a considerable reduction in costs at higher service coverage, highlighting inefficiencies of the current system. VTOs account for the least cost (11-20%) at current service coverage across urban settings. At higher service coverage, cost reductions are marginal (2-3%) as VTOs operate closer to full-service capacity.

4.9 Factors influencing costs of FSM systems

The type of containment technology (septic tank vs IPL) influences costs. Septic tanks generally have higher costs. The type of treatment technology used influences costs. Systems using FSTPs have lower costs (\$6-12 capita^{-1} year^{-1}) than active aerobic sludge treatment (\$16 capita^{-1} year^{-1}). The planning and layout of treatment facilities also influence costs. For example, in Kanyama, operational treatment costs increased by 76% (\$5,674 annually) for sludge transfer as the FSTP is not integrated. The bio-digester and drying beds are in different locations. Service costs in Kanyama are higher (48%) than Chazanga (10%), with an identical treatment system that is integrated.

4.10 Financial flows within the sewered and FSM systems

Figure 4-4 shows the allocation of costs to stakeholders for systems analysed. Data on household payments were collected from the regulator, the utility, households and service providers. The payments were compared to the reported costs to provide services. For sewered systems, a sewerage tariff (30% of the water bill) is levied to households beyond the water closet and sewer connection cost. The analysis is based on fixed charge household water bills, with corresponding fixed charges for sewerage. FSM service providers levy a fee to households based on the volume of waste emptied. Containments are emptied every three years on average. The charges for sewerage and FSM fees are reported in Appendix C-8.



Sewered system **FSM system**

Figure 4-4. Total annual capital and operating liabilities (including charges/fees) to stakeholders for sanitation systems analysed (Left) Sewered and (Right) FSM

For sewered systems, the stakeholders considered were households and the sanitation utility, LWSC. For FSM, stakeholders include households and Water Trusts in selected LIHD areas providing manual emptying, trucking and treatment services. Others include VTOs providing mechanical emptying and transport services across all urban settings. The faecal sludge and septage emptied by VTOs are dumped at treatment plants operated by LWSC.

For sewered systems across urban settings, costs of containment (water closets and sewer connections) dominate. HILD households pay the most for services, while LIHD households pay the least (Figure 4-4). A substantial portion of finances, usually from households, flows to the private sector to construct sanitation infrastructure (water closets). Water closets have a substantial share in total costs for containment. LWSC does not fully recover its costs. In HILD areas, LWSC recovers their operational liabilities with partial recovery of investment for conventional sewers connected to ponds. In MIMD and LIHD areas, cost recovery for operations is low. Results show that for sewered systems, current tariffs are inadequate to cover costs fully.

For FSM, containment costs also dominate for all systems across urban settings. Most of the financial flows within the system move from households to the private sector due to the high capital investment of on-site facilities (Figure 4-4). HILD households bear the most burden compared to MIMD and LIHD households. All the service providers do not recover their operational liabilities. Water Trusts (WTs) providing manual emptying, transport, and treatment have very high liabilities, with water sales reportedly subsidising FSM operations.

VTOs recover around 68% of their costs from household fees (\$7-8 capita^{-1} year^{-1} revenue against costs of \$11 capita^{-1} year^{-1}). VTOs revealed that they do not break even servicing households. They rely on commercial and industrial entities to break even. The payment of dumping fees by VTOs (\$2 capita^{-1} year^{-1}) to LWSC hinders full cost recovery for their operational liabilities (\$9 capita^{-1} year^{-1}). For VTOs, it would be less challenging to make the businesses profit-making when incentivised. The dumping fees recover some costs for LWSC -

operational treatment costs. Overall, there is considerable money outside formal public service delivery. The private sector extracts a substantial part of the money from the sanitation system with little carried by them for operations.

The business models have implications on “price efficiency” for LIHD households. Manual emptying with trucking services by the WT uses a bundle-based tariff.[16] Households using VTO services are on average serviced by 6-8 m^3 capacity trucks, with the lowest fees levied at $114 per truckload emptied. The service offered by the WT on average empties 3.84m^3 at an equivalent fee ($114). Compared to the WT bundle-based tariff model, the VTO service offers value for money to households. However, emptying faecal sludge from latrines using mechanical means is challenging due to the state of latrines. Most latrines are not designed and built for emptying. Further, the disposal of solid waste in the pits alters the characteristics of the pit contents, which thicken over time, rendering mechanical emptying challenging.

4.11 Summary of key findings and their interpretation

Costs are essential for sanitation planning. The Novel Ball-Park Reporting Approach (NBPRA) (Sainati et al., 2020) helped report the costs for sanitation in Lusaka. The approach was helpful for two reasons. Firstly, cost characterisation by technical options, i.e., sewered vs non-sewered and sub-systems within these categories. Secondly, to ascertain the cost performance of options over their lifetime across the entire value chain. The plausible cost estimates for the various options help set out their suitability as the technology of choice in specific areas, as noted by Daudey (2018). This is useful when comparing options to scale sanitation. In addition, the approach helps overcome the challenge of reporting costs as incomplete estimates and as partial elements of the value chain.

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[16] The bundle-based tariff is such that emptying of containments by the Water Trust is offered in three bundles of 12x60-litre ($33); 24x60-litre ($43); and 32x60-litre ($57). A customer selects a bundle or combination of bundles to empty their containment.

The costs of sanitation provision vary considerably across Lusaka. Taking current levels of connection efficiency for sewered systems, the TACH ranges from $366-588 for conventional and $582-687 for simplified sewerage. Summary data are presented in Table 4-11. For latrine-based systems, the TACH ranges from $228-348. The TACH for septic tank systems ranges from $282-533. Overall, the costs of containment dominate for sewered and non-sewered systems. Sewerage containments across the value chain contribute 37-55% to total costs. Latrine-based containments contribute 42-43%, while septic tanks contribute 48-72% in total costs.

Table 4-11. Aggregated annualised cost per capita (TACC) and per household (TACH) for sewered (including trunk sewers) and FSM systems in Lusaka (US dollar 2018 equivalent) at current efficiency levels

Sewer-based System		**Urban Setting**	**TACC ($2018)**	**TACH ($2018)**
Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant		LIHD	78-98	468-588
		MIMD	85-89	510-534
		HILD	107	588
Conventional sewers connecting to waste stabilisation ponds		LIHD	75	450
		MIMD	61	366
		HILD	94	483
Simplified sewers with DWWM through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant		LIHD	97-102	582-612
		MIMD	98	588
Simplified sewers connecting to waste stabilisation ponds		LIHD	100	687
FSM-based System	**Technology**	**Urban Setting**	**TACC ($2018)**	**TACH ($2018)**
Manual emptying with truck transport dumping into bio-digester with drying beds	IPL	LIHD	38-58	228-348
	ST		47-61	282-366
Mechanical desludging units dumping into an anaerobic sludge treatment plant	IPL	LIHD	49	296
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	LIHD	46-50	275-299
	ST	LIHD	47-60	281-359
		MIMD	73-77	437-461
		HILD	97-101	509-533

Table 4-12 shows costs for services modelled at 100% sewer connection efficiency and FSM collection services at full operator capacity. Costs reduce when sewered and FSM systems operate at high efficiency and/or coverage. At 100% sewer connection efficiency, the TACH ranges from \$360-540 for conventional and \$462-546 for simplified systems. For latrine-based systems, the TACH ranges from \$180-312. The TACH for septic tank systems ranges from \$240-518. Results show that costs for sewered systems are more sensitive to connection efficiency/service coverage than FSM systems (cost reductions of \$6-96 household^{-1} year^{-1} compared to \$15-48 household^{-1} year^{-1}). The cost data for the planning in Chapters 7 and 8 are based on Table 4-12.

Table 4-12. Aggregated annualised cost per capita (TACC) and per household (TACH) for sewered systems (including trunk sewers) at 100% connection efficiency and FSM systems with collection services are at full capacity

Sewer-based System		**Urban Setting**	**TACC (\$2018)**	**TACH (\$2018)**
Conventional sewers connecting to a trickling filter and anaerobic sludge treatment plant		LIHD	76-90	456-540
		MIMD	82-86	492-514
		HILD	99	530
Conventional sewers connecting to waste stabilisation ponds		LIHD	62	372
		MIMD	60	360
		HILD	84	435
Simplified sewers with DWWM through conventional trunk sewers to a trickling filter and anaerobic sludge treatment plant		LIHD	86-88	516-528
		MIMD	91	546
Simplified sewers connecting to waste stabilisation ponds		LIHD	78	462
FSM-based System	**Technology**	**Urban Setting**	**TACC (\$2018)**	**TACH (\$2018)**
Manual emptying with truck transport dumping into bio-digester with drying beds	IPL	LIHD	31-52	180-312
	ST		40-55	240-330
Mechanical desludging units dumping into an anaerobic sludge treatment plant	IPL	LIHD	47	282
Mechanical emptying and transport, dumping into an anaerobic digester plant with sludge drying (O3)	IPL	LIHD	45-48	266-294
	ST	LIHD	46-58	272-344
		MIMD	72-75	428-446
		HILD	96-99	500-518

From the analysis, two factors were essential in influencing the overall costs of sewer-based systems. Firstly, the number of sewer connections (connection efficiency) is a primary driver influencing costs than population density. The higher the connection efficiency, the lower the cost, as costs are spread among more households than a higher population density with low connection efficiency. Instead, population density is an essential driver of costs, with considerable cost reductions at higher sewer connection efficiencies. This is seen when system costs are modelled for higher connection efficiency than current connection efficiency (see Section 4.3). Therefore, the emphasis within the enabling environment through policy instruments and sound regulation is to ensure systems operate closer to 100% sewer connectivity for cost efficiency.

Secondly, results showed that simplified sewers were more sensitive to connection efficiency than convention sewers. This contradicts findings by Cairns-Smith et al. (2014), who note that simplified sewer systems are less susceptible to higher per capita costs due to insufficient connections to the network. For non-pumped systems in LIHD areas, simplified sewers had higher cost reductions (\$6-20.5 capita^{-1} year^{-1}) compared to conventional systems at \$0.3 capita^{-1} year^{-1} (see Section 4.3). Conventional systems have a higher investment outlay than simplified sewers for similarly sized systems. For example, in LIHD areas, simplified community-scale sewers with communal septic tanks were cheaper (\$18 capita^{-1} year^{-1}) than conventional sewerage (\$24 capita^{-1} year^{-1}) at 100% connection efficiency. This confirms what is generally reported in the literature (e.g. Bakalian et al., 1994; Mara et al., 2001) on simplified sewers being cheaper to deliver.

The way simplified sewerage is delivered influences costs. The delivery modes use a decentralised system with sewers discharging into communal septic tanks or directly into trunk sewers. The combination of simplified sewers and communal septic tanks was a factor, with the latter contributing up to 35% in total sewerage costs. The septic tanks bear on overall costs by increasing infrastructure and operational costs for desludging. Therefore, the decision-maker needs to consider these factors as the impact on costs and the long-term operational sustainability of services.

The costs of FSM-based systems are not influenced by population density. These findings are in line with Manga et al. (2020). However, the service coverage of emptying and transport (E&T) services influences costs. When E&T services operate at full capacity (higher service coverage), overall system costs reduce compared to lower coverage (see Section 4.7). The proposition is to plan periodic desludging services instead of waiting for containments to fill up, thus increasing E&T cycles for service providers. This increases cost efficiency as services operate at full capacity, an incentive for profitable services. The service model for non-sewered services is to have customers pay for services as they do for sewerage which is monthly via the water bill but reflecting the cost of service provision.

Cost recovery for sewerage services was highest in HILD areas where operational liabilities are fully covered. Cost recovery is low in LIHD and MIMD areas. For FSM systems, cost recovery is low across all the options. However, the VTO business model shows better performance and can generate profits for the private sector operating the service if incentivised. For sewered and FSM services, most of the finances within the system flow to the private sector.

Overall, sewer-based systems had higher investment and lower operational liabilities than FSM systems for all analysed options. Cost characterisation and segregation by components clarified the plausible cost drivers. For example, sewers were dominated by capital costs, while for FSM (emptying and transport), operational costs were dominant. This is useful when considering investments at scale as it gives the trade-offs for each system option for decision-makers to align with their priorities. For instance, it is balancing between high initial investment and low operational liabilities for sewers or low initial investment and high operational liability FSM, as evidenced from the cost analysis. The results have implications on the system suited for the different urban settings when costs are considered.

Chapter 5: Assessment of the enabling environment for sewered and non-sewered sanitation services

5.1 Introduction

This chapter presents findings on the enabling environment for sanitation in Lusaka based on key informant interviews and secondary data review. The aim was to explore the influence of the enabling environment on services. It is the second of three results chapters following the methodology in Section 3.7.4.

The City Service Delivery Assessment (CSDA), described in the methodology (Section 3.7.4), was used to assess the enabling, delivering, and sustaining functions of the enabling environment for sanitation services (Blackett and Hawkins, 2019; Peal, Andy et al., 2014). Sewered and non-sewered services were assessed separately for the entire sanitation value chain. For sewered systems, the assessment sought to understand whether the enabling environment enhances or hinders the construction, connection to, and operation of services. For non-sewered services, the assessment sought to understand how services are set up, operated and the extent to which the environment enhances or hinders use.

Results offer insights into the state of the enabling environment and highlight the factors enhancing or hindering sewered and non-sewered service access. Understanding the enabling environment for sanitation will help inform plans and approaches to scale citywide services in Lusaka (Chapters 7 and 8).

5.2 Enabling environment for sewered sanitation services

The CSDA helped interrogate the capacity of the enabling environment to enhance service development and commitment to sustain sewered services. The assessment focused on factors enhancing or hindering construction, connection to and operation of sewer systems in Lusaka.

5.2.1 Enabling function

Table 5-1 summarises the findings on current policies, planning and budgetary arrangements for sewered services in Lusaka. Figure 5-1 shows the analysis of the extent to which current arrangements enhance or hinder services. Appendix D-1 presents the assessment criteria used. The methodology is described in Section 3.7.4. The following questions were addressed:

i. Is the provision of sewerage services (including household connections) adequately supported by an appropriate, widely-known, acknowledged and available national or local policy?
ii. Is responsibility for sewerage service delivery clearly assigned to an entity with well-defined roles, responsibilities and mandates?
iii. Are there national and/or local legislation and regulatory mechanisms for sewerage services, backed by any necessary complementary codes, specifications, schedules?
iv. Are service levels and targets for the accessibility of, and connections to, sewerage specified in current approved plans?
v. Are there annual and medium-term budget lines for sewerage, including software, hardware expansion, operation, and maintenance?
vi. Is the policy, planning, and budgeting process to provide sanitation services inclusive?

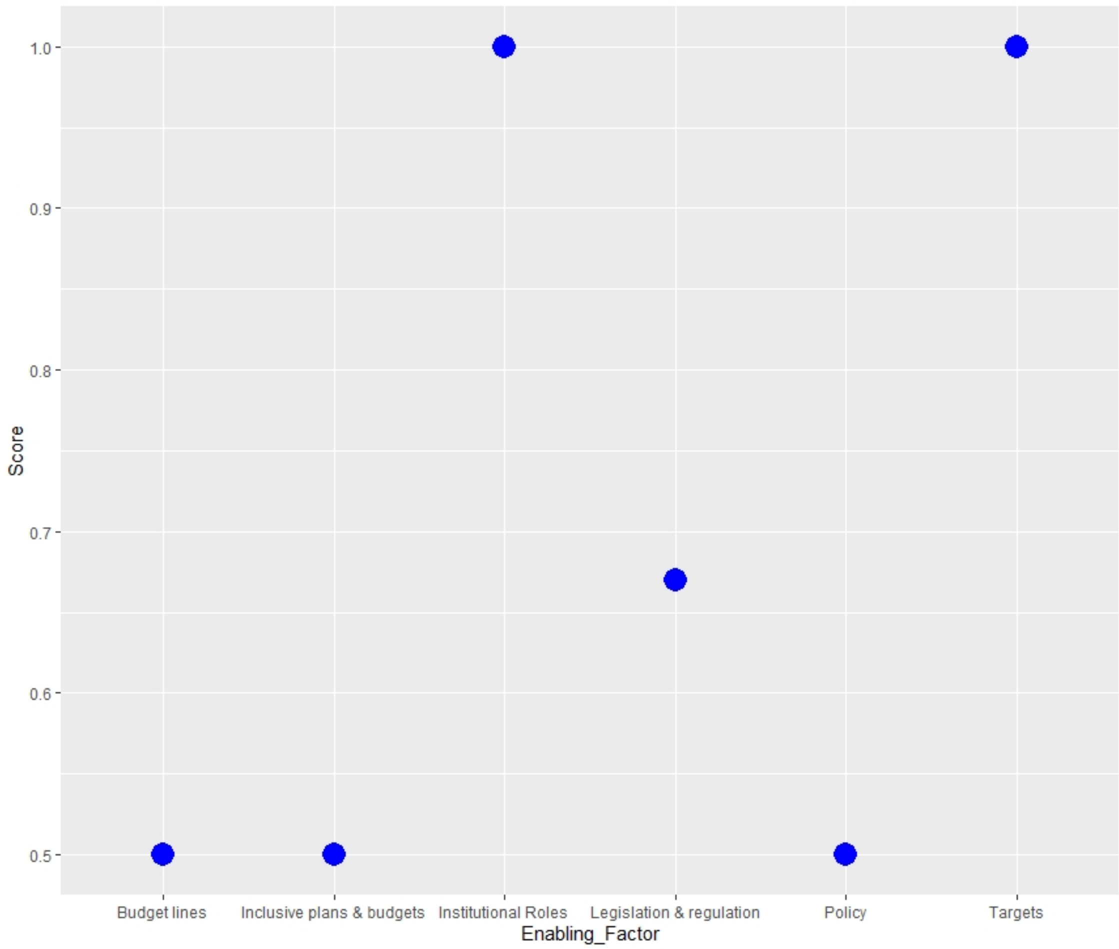

Figure 5-1. Analysis of policies, planning and budgetary arrangements for sewered services in Lusaka (Author's own)

Table 5-1. Summary of findings on current policies, planning issues and budgetary arrangements for sewered services in Lusaka

Enabling function		Evidence for sanitation value chain element		
		Water closets and house connections	**Sewerage**	**Treatment**
Policy and Legislation	**Policy:** Is the provision of sewerage services (including household connections) adequately supported by an appropriate, widely-known, acknowledged and available national or local policy?	- The National Water and Sanitation Policy (2020) is a guiding document for services provision. However, the guiding principles are broad and not explicit in addressing connectivity and overall sewerage services. - The National Urban and Peri-Urban Sanitation Strategy (2015) specifies that households are responsible for building water closets, internal piping works and connecting to the sewers. Service providers are responsible for reaching the network to the property boundary and conveying wastewater to treatment.		
	Institutional roles: Is responsibility for sewerage service delivery clearly assigned to an entity with well-defined roles, responsibilities and mandates?	- LCC[1] has the mandate to enforce sewer connections in areas where LWSC provides sewers.	- LWSC[2] is responsible for providing - constructing and operating - sewered services. - NWASCO[3] regulates the provision of sewered services. - ZEMA[4] monitors the discharge of effluent into the environment	
	Legislation/Regulation: Are there national and/or local legislation and regulatory mechanisms for sewerage services, backed by any necessary complementary codes, specifications, schedules?	- The Public Health Act (1995) specifies mechanisms for house connections in sewered areas.	- The Water Supply and Sanitation Act (1997) empowers NWASCO to regulate LWSC in providing sewerage services. - The Environmental Management Act (2011) empowers ZEMA to regulate wastewater discharges into the environment. - There are currently no standards for designing, constructing, operating and maintaining sanitation facilities and sewerage infrastructure.	
Planning and budgeting	**Targets:** Are service levels and targets for the accessibility of, and connections to, sewerage specified in current approved plans?	- 57% of the population using sewerage services by 2035 - The maximum service level is sewers across all urban settings with minimum service levels of sewers in HILD areas and septic tanks in LIHD and MIMD areas. - No performance indicator and benchmark for sewer connections or connection efficiency in the performance monitoring framework set by NWASCO	- The service level guarantee (SLG) specifies the maximum number of sewer flooding per connection in the year	- SLG's specify the quality of discharged wastewater from treatment
	Budget lines: Are there annual and medium-term budget lines for sewerage, including both software and hardware expansion, operation and maintenance?	- LWSC budget lines for 2018-2022 to extend sewerage are dependent on financing institutions and the government with no funds allocated from internally generated resources. - The bulk of the budget is for hardware (sewers and treatment expansion and upgrades) with software components not specified.		
Inclusion	**Planning and budgeting:** Is the policy, planning and budgeting process to provide sanitation services inclusive?	- Inclusion is mentioned in policy but not explicitly or is weakly required in the planning and budgeting process.		**N/A**

[1]Lusaka City Council (LCC)
[2]Lusaka Water Supply and Sanitation Company (LWSC)
[3]National Water Supply and Sanitation Council (NWASCO)
[4]Zambia Environmental Management Agency (ZEMA)

Policy

The National Water Supply and Sanitation Policy (2020) sets out the provision of sanitation services. The policy outlines planning and resources allocation priorities to achieve satisfactory service provision (MWDSEP, 2020). However, the guiding principles are broad and do not explicitly specify the elements of the sanitation value chain. Therefore, the implementation of the policy is subject to the interpretation of regulatory institutions and service providers. The National Policy on Environment (2009) sets out "to develop sanitation master plans ….. and improve water-borne sanitation systems using appropriate technology" (MTENR, 2009, p. 29). However, the policy falls short on extending services as it calls only to improve existing schemes.

Zambia's Vision 2030 specifies treatment hardware along the sanitation value chain through "rehabilitation and reconstruction of sewer treatment facilities in all major towns and cities" (GRZ, 2006, p 35). However, the Vision is silent on the construction and operation of sewer collection systems. Furthermore, the National Urban and Peri-Urban Sanitation Strategy 2015-2030 (NUSS) explicitly relegates to households the responsibility to construct water closets and connect to the sewer network (MLGH, 2015). Utilities are responsible only for reaching the network to the property boundary and conveying wastewater to treatment.

Institutional roles

The National Sanitation Policy of 2020 outlines the institutional roles for stakeholders in the sector. Lusaka City Council (LCC) is the city's local governing authority and has the sanitation mandate. LCC assumes the lead in the sanitation planning process in partnership with Lusaka Water Supply and Sanitation Company (LWSC) (MLGH, 2015). The National Water Supply and Sanitation Council (NWASCO) regulates sanitation services and defines service levels. On institutional roles, personnel from LWSC stated:

> *'One challenge is …. the function we [LWSC] are doing was under LCC …. The mandate to provide services was shifted from LCC to LWSC but not the authority to enforce…..'*

The lack of a mandate to enforce does not incentivise LWSC in ensuring households connect to sewers. LWSC manages an information database for LCC's sanitation planning and enforcement of the Public Health Act (MLGH, 2015).

Legislation and Regulation

Figure 5-2 presents the existing institutional and regulatory framework for water supply and sanitation (WSS). The Local Government Act (1991) confers sanitation provision on the LCC, which it delegates to LWSC. NWASCO establishes and enforces standards for sanitation services and providers; and the design, construction, operation and maintenance of facilities (Water Supply and Sanitation Act, 1997). The Zambia Bureau of Standards (ZABS) has developed guidelines for managing on-site domestic wastewater services. However, there are currently no standards for the design, construction, operation and maintenance of sanitation facilities (ZABS, 2019, p. 27).

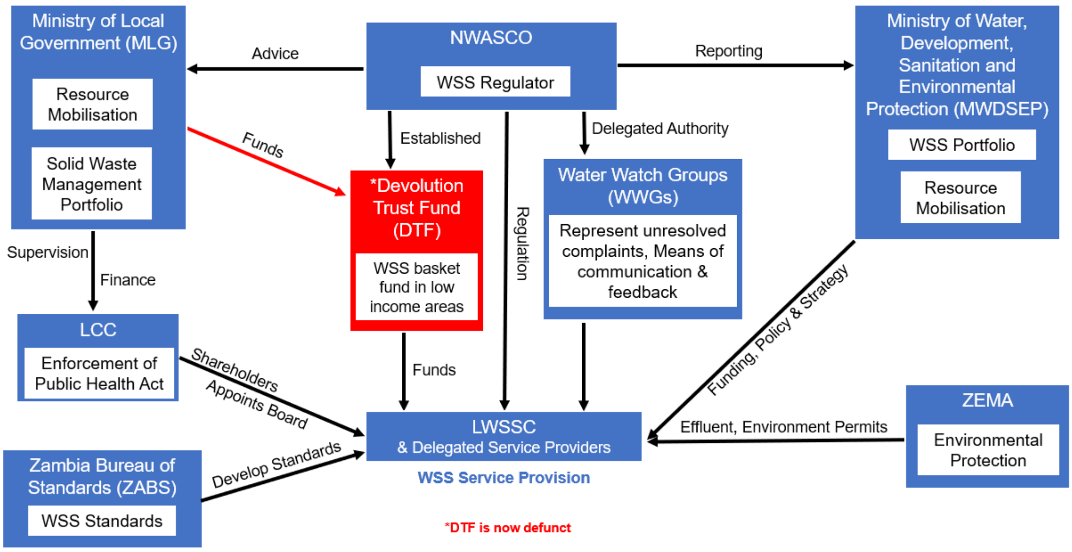

Figure 5-2. Existing institutional and regulatory framework for the urban water supply and sanitation sector (Adapted from MLGH (2015))

The Public Health (Drainage and Latrine) Regulations (1995) Section 75, part 2(9) stipulates that a building within 60.96 metres of a sewer is required to connect. Any owner who fails to comply with regulatory requirements within a time specified shall be guilty of an offence. The WSS Act places the responsibility on landlords to make sewer connections. The Zambia Environmental Management Agency (ZEMA) regulates and issues licenses to sanitation service providers and sets requirements and standards for effluent treatment (*Environmental Management Act No 12*, 2011, p. 135).

Targets

The target is to have 57% of the population in Lusaka using sewerage services by 2035 (MCC, 2011). Current sewerage coverage is estimated to be 14% of the population (LWSSC, 2021). Sewer connections in all urban areas are the highest service level specified in the National Urban Water Supply and Sanitation Program 2011-2030 (NUWSSP) (MLGH, 2011, p. 64). Sewer connections in HILD areas and communal septic tanks in MIMD and LIHD areas define the minimum service level.

NWASCO requires LWSC to meet specified performance criteria for WSS service delivery. However, the number of sewer connections or connection efficiency is not explicit in the eight performance indicators and benchmarks. The benchmarks include; 80% WSS coverage, 25% unaccounted-for water, 100% metering ratio, 18 hours of supply, 98% water quality, eight staff per 1,000 connections, 85% collection efficiency, and 100% cost coverage by collections. LWSC is not accountable to NWASCO when households do not connect. The enforcement function by law is with LCC.

Budget lines

The LWSC strategic plan 2018-2022 has no budget for extending sewer coverage from internally generated funds (LWSC, 2018b, p. 49). The budget lines 2018-2022 to extend sewer services are dependent on financing from International Financing Institutions (IFIs) and the Government of Zambia (GoZ) under the Lusaka Sanitation Program 2016-2021 (LSP). The bulk of the LSP budget is for infrastructure expansion and upgrade (hardware), with some sub-projects allocating funds towards software activities.

Inclusion (planning and budgeting)

The National WSS Policy (2020) recognises water and sanitation as basic needs. However, the policy is silent on equitable access to sanitation but explicitly mentions equitable access to water. “Given that safe water and sanitation is a basic need, equitable access to water, within the context of limited resource availability, will have primary consideration” (MWDSEP, 2020, p. 16).

The NUSS references the sanitation service chain and safely managed services and targets the urban poor (MLGH, 2015). Its basis is providing adequate sanitation on assessing households where facilities are inadequate by setting out the conditions for results-based finance mechanisms. The aim is to incentivise service providers to extend services to low-income areas. In addition, the NUSS aims to “ensure that the needs of women, children and the physically challenged are considered” (MLGH, 2015, p. 47) through the development, promotion and dissemination of sanitation standards that are inclusive and flexible to conditions. The code of practice for sanitation under development includes standard sanitation designs for children and the physically challenged (NWASCO, 2018).

5.2.2 Delivering function

Table 5-2 summarises the findings on capacity and financing mechanisms to develop improved sewered services in Lusaka. Figure 5-3 shows the analysis of the extent to which the mechanisms influence the development of improved sewered services. Appendix D-2 presents the assessment criteria used, and the methodology is described in Section 3.7.4. The questions addressed were:

i. Is there an investment plan for sewerage hardware and software, including all the components necessary to achieve service level targets over the medium term?
ii. Are annual funding allocations for sewerage sufficient to achieve service level targets, and are they used as planned?

iii. Are there effective mechanisms for coordinating sewerage investments between donors; donors and government; and within government?

iv. Is responsibility for delivery of sewerage services mandated to an adequately staffed and structured entity?

v. Does the entity responsible for sewerage have sufficient autonomy to address identified priorities?

vi. Are there active programmes promoting inclusive sewer connections, behaviour change and community engagement?

vii. Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people?

viii. Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people?

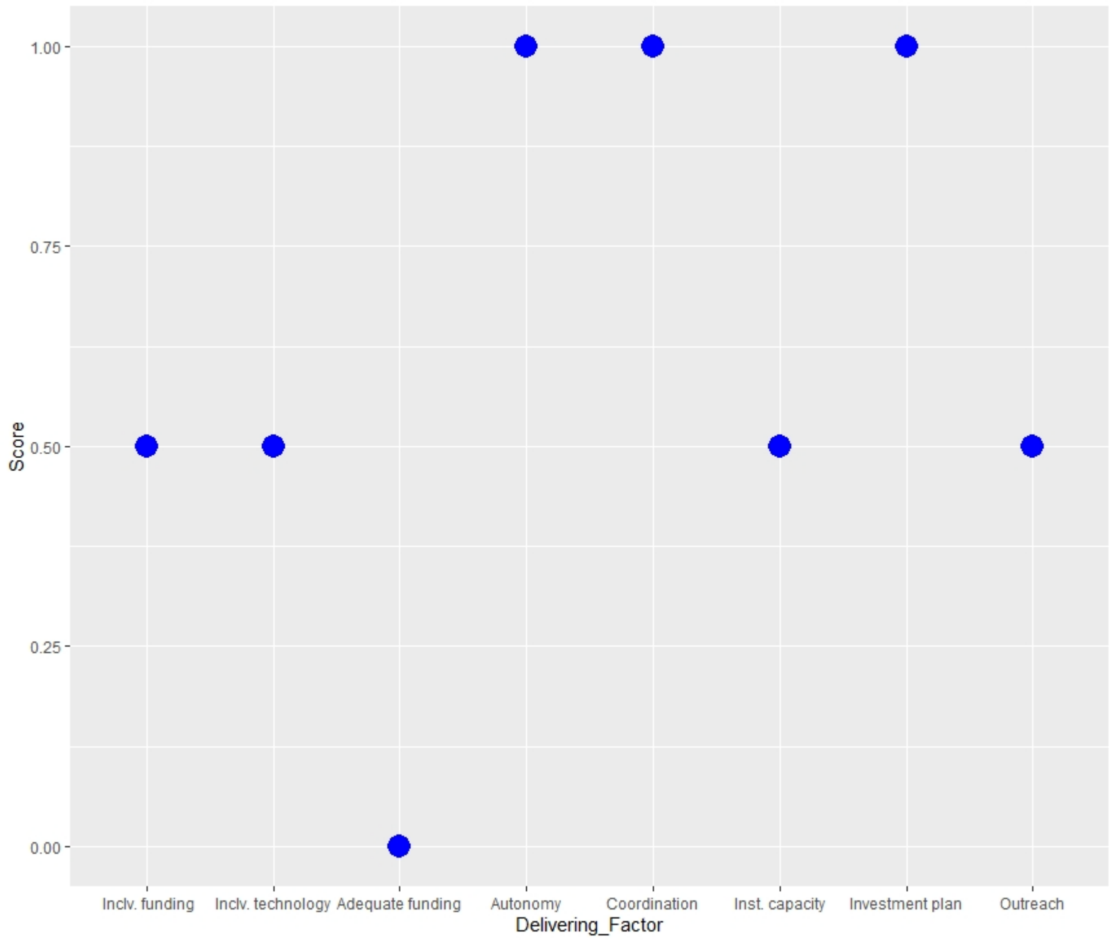

Figure 5-3. Analysis of capacity and financing mechanisms for the development of improved sewered services in Lusaka (Author's own)

Table 5-2. Summary of findings on capacity and financing mechanisms to develop improved sewered services in Lusaka

Delivering function		Evidence for sanitation value chain element		
		WC and house connections	**Sewerage**	**Treatment**
Funding	**Investment plan:** Is there an investment plan for sewerage hardware and software, including all the components necessary to achieve service level targets over the medium term?	- The Lusaka Sanitation Investment Master Plan (LSIMP) is the principal investment framework. - LSIMP identifies 83 collection and 12 treatment system projects to meet 2035 targets. - No software components are costed in the LSIMP		
	Adequate funding: Are annual funding allocations for sewerage sufficient to achieve service level targets, and are they used as planned?	- Current funding is insufficient to meet 2035 targets, with the Lusaka Sanitation Program (LSP) accounting for 20% of the total nominal budget. - Under the LSP, treatment ($140m) has a larger proportion of investment allocation than sewerage collection systems ($115.5m). - There are no funds allocated from internally generated resources within LWSC to extend sewered services.		
	Coordination: Are there effective mechanisms for coordination of sewerage investments between donors; donors and government; and within government?	- Mechanisms between the government and cooperating partners exist that effectively coordinate sanitation sector investments.		
Capacity and outreach	**Institutional capacity:** Is responsibility for delivery of sewerage services mandated to an adequately staffed and structured entity?	- LWSC's institutional capacity to complement and improve sewer services is lacking. - Need staff trained to operate treatment plants coming on board under LSP as technology may be more advanced than LWSC currently operates.		
	Autonomy: Does the entity responsible for sewerage have sufficient autonomy to address identified priorities?	- The Water Supply and Sanitation Act gives LWSC sufficient autonomy to deliver sewered services under the regulation of NWASCO.		
	Outreach: Are there active programmes promoting inclusive sewer connections, behaviour change and community engagement?	- The LSP has components that promote connection to the sewer system. - Within LWSC, information, education, and communication (IEC) outreach campaigns in LIHD areas are minimal and not sustained over time as they usually follow project implementation cycles.		
Inclusion	**Technology**: Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people, according to the agreed definition?	- Some households, especially in LIHD areas, cannot afford connection fees or ongoing service charges.		**N/A**
	Funding: Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people, according to the agreed definition?	- A lack of access to affordable financial services is a key constraint for household investments in improving sewerage service access. - There is limited funding leveraging household-level sanitation facilities (water closets and house connections) investment. - There are initiatives such as the sanitation connection action plan (SCAP) that provided water closets to extremely poor landlords who paid a subsidised connection fee.		**N/A**

Sanitation investment plan

The Lusaka Sanitation Investment Master Plan 2011-2035 (LSIMP) is the principal investment framework based on infrastructure needs and projected growth (MCC, 2011). The LSIMP documents investment needs for LWSC by identifying 83 sewer collection system expansion and upgrade projects to meet targets. Further, it identifies 12 wastewater treatment upgrade and expansion projects - the plan targets at least 50% connectivity rates in areas where sewers are deployed. No software components are costed in the LSIMP. The total estimated cost for the sewer collection and treatment systems is $1.29 billion (US$ 2011). Sewer collection accounts for $654 million, with treatment systems allocated $637 million (MCC, 2011).

The $303.5 million LSP funded by the African Development Bank (AfDB), the European Investment Bank (EIB), the German Development Bank (KfW) and the World Bank (WB) is based on the LSIMP. LSP sub-projects include software components such as hygiene promotion and the institutional strengthening of LWSC, NWASCO and LCC, amongst others.

The sanitation plans are to be reviewed annually and completely updated every five years with LWSC’s strategic plan as an input into updating these longer-term plans (LWSC, 2018b; MCC, 2011). However, no review or update has occurred since their launch in 2011. The macro-economic environment has changed with the local currency (Zambian Kwacha) depreciating 408% against the US Dollar between 2011 and 2020[17].

Adequate funding

Historically, the sanitation sector has been underfunded in capital investments, major maintenance, and operating expenditure (MLGH, 2015). Revenues from tariffs are insufficient to fully recover operation and maintenance costs (Chapter 4), let alone for asset rehabilitation. LWSC has allocated 28.1% of the 2018-

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[17] Bank of Zambia. 2021. *Monetary And Financial Statistics.* [Accessed 9 February 2021]. Available from: https://www.boz.zm/monetary-and-financial-statistics.htm

2022 budget to extending sanitation services to meet its strategic objectives. No funding has been allocated from internally generated resources (tariffs) to extend services. Most of the funding (91%) is from IFIs through loans and grants, with 9% from Central Government (LWSC, 2018b). Under the LSP, the total investment for sewerage collection systems is $115.5m and treatment $140m (World Bank, 2015). Total sewer system investment under the LSP is 20% of the nominal 2035 sanitation targets. Interest payments from loan financing accounted for 5% of LWSC's overall operational budget in 2018 (LWSC, 2019a).

Coordination

Sanitation improvements are funded through several financing agencies (MLGH, 2015). In addition, there is a comprehensive donor coordination framework that operates at the national and sector level. The coordination process is articulated at the national level in the Joint Assistance Strategy for Zambia, which involves a Memorandum of Understanding (MOU) signed by the GoZ and Cooperating Partners (CPs). The MOU provides the platform for developing and harmonising cooperation by CPs and aligning government procedures and processes (AfDB, 2015). On donor financing priorities, personnel from LWSC stated:

> *'… depending on the financier's aims - [..] are more focused on numbers, e.g. how many people are reached; hence, you tend to have most projects in LIHD areas. …. financiers like [..] will look at financial viability – impact – these allow you to go into low density and industrial areas.'*

> *'For LWSC, you would want to sewer the high-income areas …. but then your financier will tell you that your numbers are too low.'*

Institutional capacity

In 2019 LWSC had 801 staff at various levels at post. These include artisans, engineers, and other supporting professional staff. Given the institutional changes and the extension of coverage to new development areas, LWSC's institutional capacity to improve services is lacking. LWSC is constrained due to a lack of capacity to meet service demand. The LSP has components for institutional capacity development to secure LWSC's capacity to deliver sewered services (LWSC, 2016b). The institutional strengthening component re-aligns the Sewerage Services Department (SSD) to improve services and revenue enhancement strategies to ensure cost recovery (World Bank, 2015).

Autonomy

The WSS Act no. 28 of 1997 Part V, Section 24 (3) states, “A utility or service provider and local authority in its service area shall establish procedures for adequate consultation to be carried out for development planning or implementing physical works”. Thus, the Act gives LWSC sufficient autonomy to deliver sewered services under the regulation of NWASCO.

Outreach

There are components under LSP to create public awareness, promote connection to sewers and highlight health and environmental risks associated with inadequate sanitation (AfDB, 2015). However, ongoing information, education and communication (IEC) campaigns by LWSC is limited (LWSC, 2018b) and usually not sustained beyond project implementation.

Technology

The NUSS calls for innovation to balance the need to scale up affordable sanitation services, especially in LIHD areas. It is a policy statement that has not been fully operationalised apart from donor-funded projects. Sewers are considered a high priority in LIHD areas to reduce pit latrine usage (MLGH, 2015). However, some households cannot afford the water closets, connection fees or ongoing service charges (Chapter 6). Personnel from LWSC stated:

> *‘Under LSP, the requirement is to connect as quickly as possible ….in some cases, the connection may be subsidised, then we could also do the network on the customer's side to encourage quick uptake.’*

Funding

Households are responsible for constructing water closets, internal piping and connections to the sewerage network (MLGH, 2015) while funding direct operational costs. However, a lack of access to affordable financial services is a key constraint for household investments in improving sewerage service access. There is limited funding leveraging household-level sanitation facilities (water closets and house connections) investment (MLGH, 2015). LWSC collects a 2.5% sanitation surcharge on water bills from every customer to finance sanitation projects in low-income areas. Improvements are not forthcoming, likely due to the utility having high operational liabilities.

There are initiatives such as the sanitation connection action plan (SCAP) under the Mtendere sewer reticulation project. The project provided water closets to 1,300 extremely poor landlords who paid a subsidised connection fee of ZMW 175 ($17). In addition, some households were offered loans with a 36-month tenure to build water closets. The aim was to have most households have a water closet and connection. An NGO involved in the project stated:

> *'The toilets were built through a revolving fund as loans to households. …. they [households] pay ZMW 200 [$19] as registration fee which counts to the loan repayment, then pay the ZMW 175 [$17] over 36 months.'*

5.2.3 Sustaining function

Table 5-3 summarises the findings on operating and sustaining sewered services in Lusaka. Figure 5-4 shows the analysis of the extent to which the operations of sewered services are sustained. Appendix D-3 shows the assessment criteria used with the methodology fully described in Section 3.7.4. The questions addressed were:

i. Are sewerage system O&M costs known and fully covered by cost recovery through user fees and/or local taxes or transfers?
ii. Are there adequately staffed institutions which monitor performance, health, and environmental standards for sewerage services?
iii. Are failures to meet standards for sewerage system performance systematically monitored and sanctions applied where relevant?
iv. Does the entity responsible for sewerage have sufficient qualified staff to undertake adaptive planning of sewerage rehabilitation and expansion?

v. Does the entity responsible for sewerage have an active and gender-aware staff development programme and incentives to retain workers?

vi. Is the health and safety of sewerage workers adequately protected and monitored?

vii. Are there ongoing programmes and measures to build the capacity of the sewerage service provider?

viii. Are sanitation services keeping pace with population growth?

ix. Is sanitation data routinely collected from women, poor and vulnerable people and used for planning services?

x. Do the city's sanitation systems provide safe sanitation services for all users, including women, poor and vulnerable people?

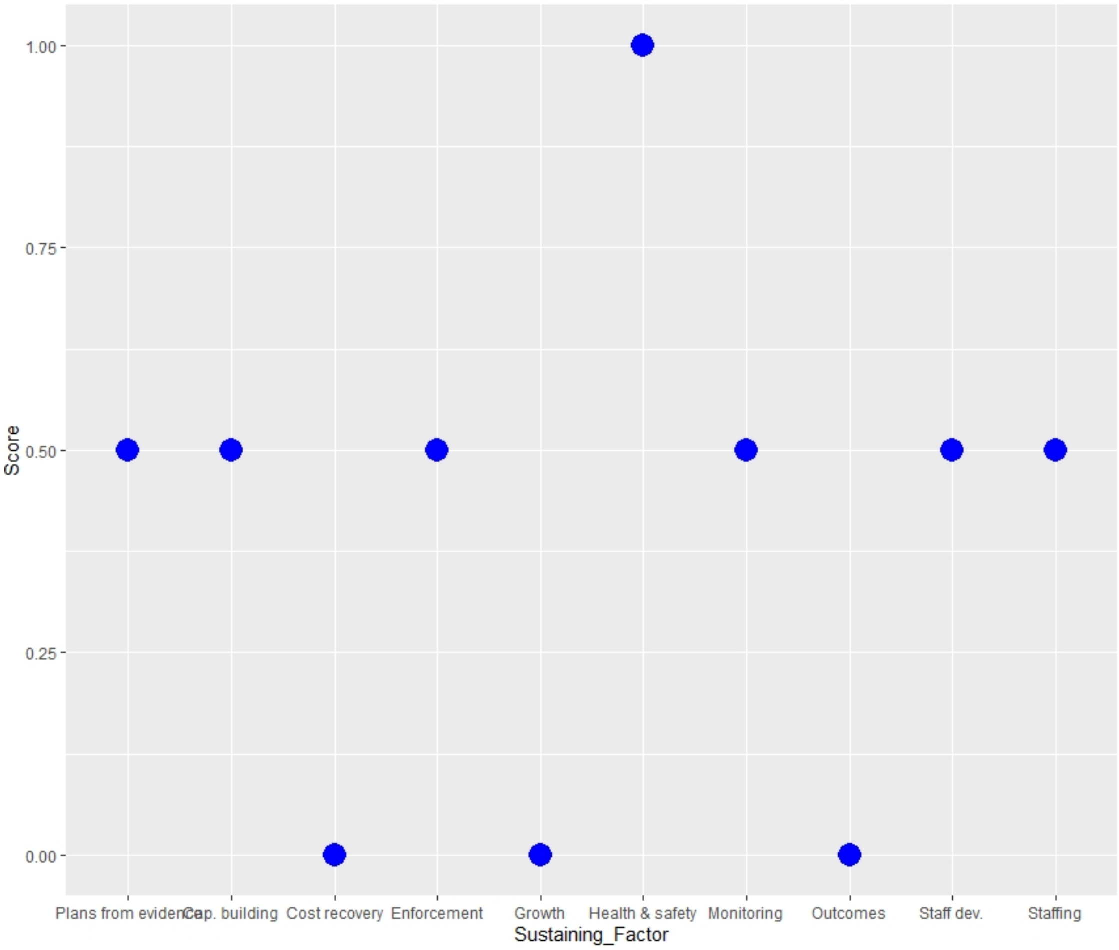


Figure 5-4. Analysis of the extent to which current operations of sewered services are sustained in Lusaka (Author's own)

Table 5-3. Summary of findings on operating and sustaining sewered services in Lusaka

Sustaining function		Evidence for sanitation value chain element		
		WC and house connections	**Sewerage**	**Treatment**
Regulation and cost recovery	**Cost recovery**: Are sewerage system O&M costs known and fully covered by cost recovery through user fees and/or local taxes or transfers?	- LWSC does not know the full costs of delivering sewered services. - Current tariffs are insufficient to sustain the sewered systems.		
	Monitoring: Are there adequately staffed institutions which monitor performance, health and environmental standards for sewerage services?	- NWASCO's performance indicators do not include sewer connection efficiency as part of the licencing agreement. - LCC is not adequately staffed to monitor sewered services as part of its public health enforcement mandate. - ZEMA adequately monitors wastewater discharges into the environment from LWSC WWTPs		
	Enforcement: Are failures to meet standards for sewerage system performance systematically monitored and sanctions applied where relevant?	- Regulations to connect to sewers are not enforced due to capacity-related constraints. - Landlords are not sanctioned for not adhering to public health regulation of connecting		- ZEMA did not sanction LWSC for failure to meet effluent standards in 2019.
Institutions and service providers	**Staffing**: Does the entity responsible for sewerage have sufficient qualified staff to undertake adaptive planning of sewerage rehabilitation and expansion?	- The sewerage services department has suitably qualified engineering staff with an overall staffing level of 76% of staff establishment. - Training staff to operate treatment plants under LSP is needed as technology may be new to LWSC.		
	Staff development: Does the entity responsible for sewerage have an active and gender-aware staff development programme and incentives to retain workers?	- LWSC has a gender responsiveness and social inclusion policy.		
	Health and Safety: Is the health and safety of sewerage workers adequately protected and monitored?	- There is an operational budget for personal protective equipment (PPE). - An occupational health and safety section at LWSC monitors and enforces health and safety.		
	Capacity-building: Are there ongoing programmes and measures to build the capacity of the sewerage service provider?	- There is an annual allocation of funds for staff capacity building through training.		
Inclusion	**Growth:** Are sanitation services keeping pace with population growth?	- Current population growth is outpacing sewer service provision, and the number of people with unsafe sanitation is increasing.		
	Planning from evidence: Is sanitation data routinely collected, including from women, poor and vulnerable people, according to the agreed definition and used for planning services?	- Citywide sanitation data is currently not routinely collected but instead done on an ad-hoc basis.		
	Outcomes: Do the city's sanitation systems actually provide safe sanitation services for all users, including women, poor and vulnerable people, according to the agreed definition?	- Safe sanitation services are not available to many women, poor and vulnerable people. - Only 10% of wastewater from 14% of the population served is safely delivered to treatment, with 4% treated.		

Cost recovery

Business plans at LWSC have primarily focused on sewerage coverage extension. However, current tariffs are insufficient to sustain sanitation services leading sewer assets to deteriorate. Although the collection efficiency of bills has improved, 82% in 2019 (NWASCO, 2020), LWSC does not recover its full operational and maintenance costs (Chapter 4), affecting service delivery. On costs to deliver services, personnel from LWSC stated:

> *'…the proposal we are making to NWASCO [Regulator] is that sanitation is billed separately. …. your water bill is charged on consumption, and the rate is based on operational costs, but you are only paying 30% of your water bill for sanitation. … provision of sewer services must cost more …. we need to have separate tariffs for both water and sanitation.'*

Monitoring

NWASCO monitors sewerage services provision. However, performance indicators do not include sewer connection efficiency. In addition, monitoring adherence to the Public Health Act for connections in sewered areas is not done due to capacity constraints at LCC. Personnel from LWSC stated:

> *'….. coordination between LCC and LWSC is there but weak. .... efforts in the LSP have been to increase the capacity of LCC to enforce – .. usual complaints from LCC are transport, office space – so some vehicles have been procured for LCC, MoH [Ministry of Health], refurbished offices, all intending to improve monitoring and enforcement of regulations.'*

Under the LSP, LWSC has developed a monitoring system for services with end-user training conducted for its staff, LCC and the Ministry of Health (MoH) (AfDB, 2019). ZEMA is responsible for monitoring discharges into the environment. In 2019, effluent from LWSC WWTPs failed to meet regulatory discharge standards (NWASCO, 2020). However, no sanctions were applied.

Enforcement

The LCC, through Environmental Health Officers and Health Inspectors, enforce sanitation regulations related to the Public Health Act. Regulations state that no latrine other than a water closet be constructed within 60.96 meters of a sewer.

Due to capacity-related constraints such as insufficient human resources and logistics, regulations are not enforced. In 2019 LCC only had 45 Public Health Inspectors to cover the whole city. The law states that failure by a landlord to provide sanitary facilities (water closet and house sewer connection) to their tenants may lead to a conviction. However, landlords are currently not sanctioned for flouting the regulations. Personnel from LCC stated:

> *'…. capacity in terms of technical know-how is there …, the challenge is numbers are not enough. For instance, we are 45 public health inspectors, and in my area, we only have two inspectors for the whole constituency…. sometimes we go a week without fuel, and a week is a long time.'*

NWASCO's guidelines on extending sewerage services state that an MOU should be signed between LCC, Ministry of Lands or developer for LWSC to estimate the cost of services and embed them in the cost of plots as a capital contribution. However, LWSC indicates that it does not occur in practice.

Staffing

The engineering department has qualified staff who understand wastewater process operations and plant maintenance principles. However, low ownership of projects necessitates staff capacity building to manage sewerage expansion and rehabilitation projects (LWSC, 2018b). On capacity to roll out sewerage infrastructure, personnel from LWSC stated:

> *'We needed a consultant and contractor to do the works [design and construction of simplified sewers]. ….. the technology was new and a first of its kind to be implemented by LWSC; hence we needed help.'*

The SSD (i.e. sewers, pump stations and WWTPs) has an establishment of 97 personnel and in 2019 had 74 staff at post, translating into a staffing level of 76%. From the total available workforce, around 10% are in supervisory positions. The available workforce translates to about two personnel per 1000 sewer connections. The benchmark set by NWASCO is eight personnel per 1000 connections. Therefore, the SSD is understaffed to deliver services effectively.

In 2019, LWSC plant utilisation for sewer treatment was low (41%). Plant utilisation reflects the operational efficiency of the plant to the design capacity. The low utilisation was attributed to the poor state of sewerage infrastructure and poor maintenance practices (NWASCO, 2020). Personnel from LWSC stated:

> *‘It was designed [main LWSC WWTP] as a trickling filter plant, but the trickling filters are not operational.’*
>
> *‘Right now, we are only able to do about 30% of [sewer] complaint resolution in the [48-hour] time frame stipulated by NWASCO.’*

The capacity to undertake adaptive maintenance of sewerage and treatment infrastructure is lacking.

Staff development and capacity building

LWSC has a gender responsiveness and social inclusion policy that seeks equity in all staff development and management (LWSC, 2018b). In 2018, LWSC spent $114,000 on staff development courses. However, there was no clarity on the portfolio of staff targeted for the training. In 2019, 149 LWSC and LCC staff were trained and supported in the LSP sector investment framework, sanitation, and environmental health.

Health and safety

The health and safety of sewerage workers are adequately protected, with 1% of the SSD operational budget spent on personal protective equipment (PPE). In addition, an occupational health and safety section within LWSC monitors and enforces health and safety.

Growth

There has been inadequate investment in sanitation services while the population and demand have grown exponentially. The city’s sewer system was initially designed for 200,000 people, but the current population is over 2.4 million people. The situation translates to a high proportion of the population not being serviced, with demand outpacing service provision. Only areas with or that will have household water services are considered for sewer services in the sanitation master plan. The situation disadvantages households in LIHD areas where water service levels are low (Chapter 6). On growth versus services provision, personnel from LWSC highlighted:

'…. was originally singles quarters, small-bore sewers but now people have built an extra house for rentals leading to a population boom – the sewers are [over] capacity.'

'The design flow for this plant [main LWSC WWTP] is 35,000m^3/day, but we are currently treating around 65,000m^3/day, way beyond capacity.'

The total number of sewer connections in 2019 was 36,117, up from 32,396 in 2018. The estimated total population of Lusaka in 2019 was 2.4 million, of which the population served with sanitation was 1.89 million, disaggregated as 23% sewerage and 77% septic tanks (NWASCO, 2020). However, NWASCO's sanitation coverage statistic only consists of the population serviced by sewers and septic tanks. The reporting of sanitation data adopted by NWASCO masks the reality prevailing in the city and hinders planning for service improvements.

Planning from evidence

The LSIMP aims for 100% access to improved sanitation, with 57% proposed to be served by sewer reticulation by 2035. The LSIMP was to be updated every five years as an integral component of LWSC's operating budget and to reflect new initiatives and changes in priorities. However, the update is not taking place. The only sewer system data available are those LWSC reports to NWASCO as part of the licencing requirements. Citywide sanitation data is currently not routinely collected but instead done on an ad-hoc basis.

Outcomes

Only 14% of households access sewer services, with 10% of wastewater (from 14%) safely delivered to treatment (Kappauf et al., 2018). Of the waste delivered for treatment, only 4% is treated and safely disposed into the environment. Most treatment facilities are redundant, with some undergoing extension or upgrading under the LSP. The main LWSC WWTP was constructed in 1953 and had major rehabilitation works in the 1960s. The last major rehabilitation was in 1976.

5.3 Enabling environment for non-sewered sanitation

The assessment focused on factors within the enabling environment, enhancing or hindering the use of non-sewered sanitation services in Lusaka.

5.3.1 Enabling function

Table 5-4 summarises the findings on current policies, planning issues and budgetary arrangements for non-sewered services in Lusaka. Figure 5-5 shows the analysis of the extent to which current arrangements enhance or hinder non-sewered services. Appendix C-4 presents the assessment criteria, and the methodology is described in Section 3.7.4. The questions addressed were:

i. Is the use of non-sewered sanitation services enabled by an appropriate, widely-known, acknowledged and available national or local policy?
ii. Is responsibility for non-sewered sanitation service delivery clearly assigned to an institution(s) with well-defined roles, responsibilities and mandates?
iii. Are there national and/or local legislation and regulatory mechanisms for non-sewered sanitation, backed by any necessary complementary codes, specifications, schedules?
iv. Are service levels and targets for non-sewered sanitation specified in current approved plans?
v. Are there annual and medium-term budget lines for non-sewered sanitation, including hardware and software?
vi. Does the policy, planning and budgeting process address inclusive sanitation services?

Table 5-4. Summary of findings on current policies, planning issues and budgetary arrangements for non-sewered sanitation services in Lusaka

Enabling function		**Evidence for sanitation value chain element**		
		Toilet, pit latrine and septic tank	**Emptying and transport**	**Faecal sludge and septage treatment**
Policy and Legislation	**Policy:** Is the use of non-sewered sanitation services enabled by an appropriate, widely-known, acknowledged and available national or local policy?	- The National Water and Sanitation Policy (2020) guides service provision; however, the principles are broad and do not explicitly specify the value chain elements for non-sewered services. - Given that the provision of non-sewered sanitation is unbundled with different service providers supporting the current FSM business model, the WSS policy does not outline measures to meet set objectives. - Households have the responsibility to provide containment facilities		
	Institutional roles: Is responsibility for non-sewered sanitation service delivery clearly assigned to an institution(s) with well-defined roles, responsibilities and mandates?	- LCC has the overall sanitation mandate and enforces the Public Health Act and any by-laws. - LWSC has been delegated the responsibility to provide non-sewered services, which it has further delegated to private sector providers such as vacuum truck operators and Water Trusts in selected low-income areas. - NWASCO monitors the provision of sewered services. - The WSS Act of 1997 is not explicit on providing non-sewered services.		
	Legislation/Regulation: Are there national and/or local legislation and regulatory mechanisms for non-sewered sanitation, backed by any necessary complementary codes, specifications, schedules?	- There is currently no regulation for providing urban on-site sanitation (OSS) and FSM (under development and will follow with revision of the WSS Act of 1997). The current WSS Act is tailored to the regulation of sewered services. - The operating licences for CUs have been amended to allow them to cover both sewered and non-sewered sanitation. - LCC has formulated by-laws applying to the construction, usage and safe management of OSS facilities and the management of faecal sludge generated (yet to be operationalised). - There are currently no standards for non-sewered services (OSS and FSM) for the whole value chain (these are under development).		
Planning and budgeting	**Targets:** Are service levels and targets for non-sewered sanitation specified in current approved plans?	- 43% of the population using FSM services by 2035. - The highest service level is septic tanks with percolation in all urban settings with the minimum level of service of VIP latrines in LIHD areas and septic tanks in MIMD and HILD areas. - There are no service indicators for the provision of non-sewered sanitation to measure the performance of LWSC by NWASCO (regulator).		
	Budget lines: Are there annual and medium-term budget lines for non-sewered sanitation, including hardware and software?	- LWSC budget lines for 2018-2022 to roll out non-sewered services are dependent on IFIs with no funds allocated from internally generated resources. - The bulk of the budget is for hardware (improved household toilets, public toilets and treatment facility expansion and upgrades) with software components such as institution strengthening, private sector capacity building, among others. - Targets under LSP have been scaled down due to escalating program costs.		
Inclusion	**Planning and budgeting:** Does the policy, planning and budgeting process address inclusive sanitation services?	- The NUSS indicates that household facilities should not be directly subsidised but sets out various mechanisms to help less affluent households access adequate sanitation. Some of the measures have been operationalised.		

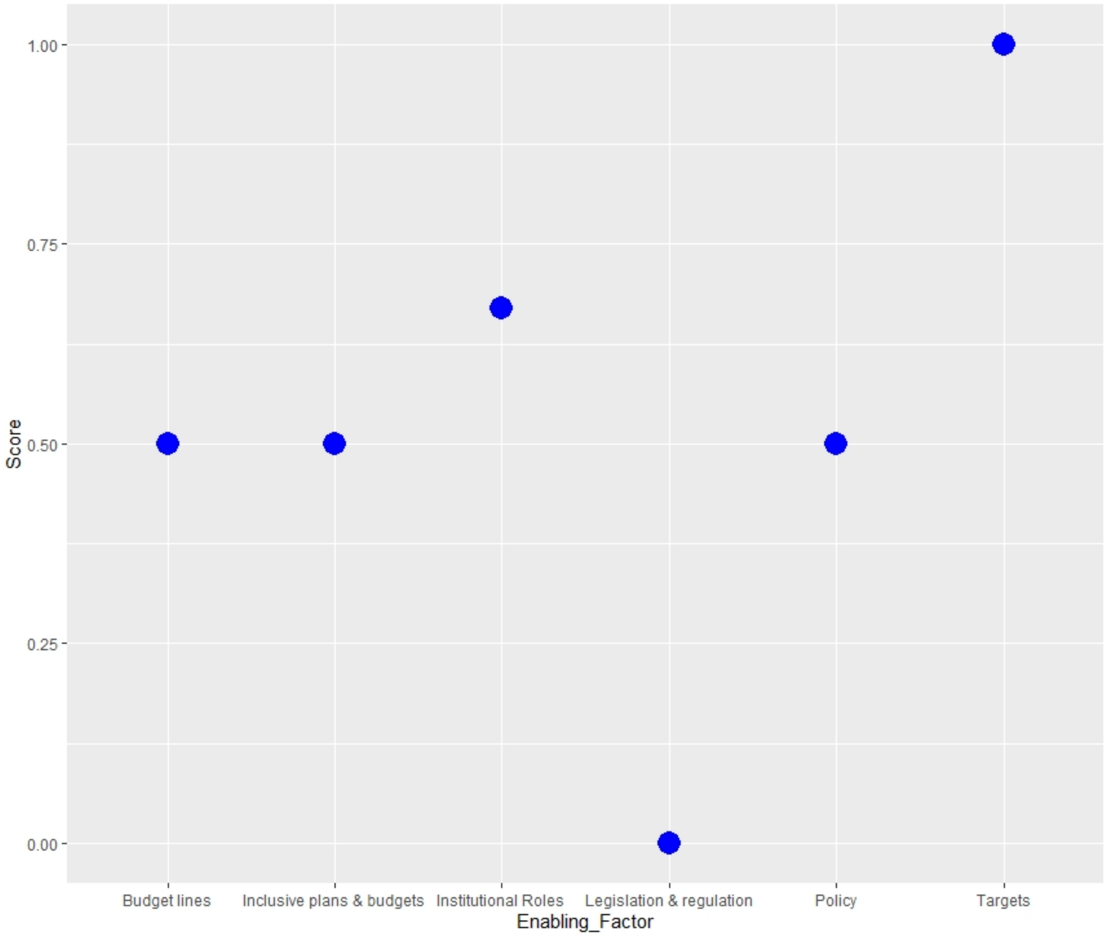


Figure 5-5. Analysis of current policies, planning and budgetary arrangements for non-sewered services in Lusaka (Author's own)

Policy

The WSS policy of 2020 guides overall sanitation services provision. The guiding principles are broad and do not explicitly specify value chain elements for non-sewered services. The NUSS states that utilities have the primary responsibility for sanitation service provision. The strategy encourages utilities to incorporate the private sector in service delivery to bring additional capacity and financing to the sector. Utilities may engage small scale service providers to perform designated tasks such as pit emptying, especially in LIHD areas with no immediate plan for sewerage expansion (MLGH, 2015). Personnel from an international NGO supporting sanitation provision stated:

> *‘There needs to be a policy direction that will create an enabling environment so that entrepreneurs can tap in. Lack of policy is one of the reasons it [non-sewered sanitation] is fragmented.’*

The WSS policy has an objective “To implement strategies for development, maintenance, rehabilitation, modernisation, expansion and operation of infrastructure for WSS with appropriate technology” (MWDSEP, 2020, p. 19). As private service providers support the current FSM business model, the WSS policy does not outline measures to meet the objective. It is not clear whether LWSC or delegated providers are responsible for implementing the strategy.

Institutional roles

The LCC has the overall sanitation mandate, which it has delegated to LWSC. LCC is responsible for enforcing regulations and relevant by-laws (MLGH, 2015). NWASCO regulates sanitation services and defines service levels. NWASCO develops regulatory instruments, tariffs, benchmarks and monitoring schemes for on-site sanitation service providers. The NUSS delegates responsibility to LWSC to deliver non-sewered services (MLGH, 2015). However, for both NWASCO and LWSC, the WSS Act of 1997 is not explicit on providing non-sewered services. The NUSS is a strategy document without legal force.

There are weaknesses in the linkages amongst institutions, which hinders developing an integrated approach towards planning, designing, and delivering sanitation services (MLGH, 2015). Further, the coordination of actors across the value chain is inadequate (NWASCO, 2019). In 2019, LWSC’s mandate was re-aligned by becoming a full-service utility with a dedicated FSM Department established to address weaknesses. Personnel from an international NGO stated:

‘On-site sanitation is regarded as a problem for households; it has been left to them and has created a huge problem that will take time to solve.’

Legislation and Regulation

NWASCO regulates sewered sanitation in urban areas, with non-sewered sanitation not currently covered within the scope of its activities due to capacity constraints (MWDSEP, 2020). There has been insufficient focus on non-sewered services with too much emphasis on reticulated sewerage (MLGH, 2015; NWASCO, 2020). The current WSS Act is tailored to the provision and regulation of sewered services. The ministry responsible for sanitation (MWDSEP) is yet to issue the revised WSS Act. The revised Act is expected to play an enabling role for LWSC and non-sewered services (WSUP, 2019). NWASCO commenced developing the framework for the provision and regulation of urban OSS and FSM (NWASCO, 2018). In 2018 the operating licences for CUs were amended to allow them to cover both sewered and non-sewered sanitation (NWASCO, 2020). LWSC can delegate to private operators or CBOs using a permit system (NWASCO, 2019).

The Public Health Act is tailored to sewerage provision without considering non-sewered sanitation, which most of the population use (>80%). In 2019, LCC formulated by-laws applying to the construction, usage and safe management of OSS facilities and managing the faecal sludge generated (Local Government Act, 2019). Personnel from LCC stated:

> *‘We have been using the Public Health Act, and the challenge has been that there are a lot of grey areas, so we needed to cover those areas with the by-law. For instance, there is nothing [in the Act] on the FSM service chain as it only focuses on sewer.’*

In the by-law, LCC defines the OSS system to be applied within a locality in the city, the number of users and emptying schedules. No person is permitted to construct a new pit latrine or maintain a pit latrine within the city. The by-laws have been submitted to the Minister for Local Government for consideration and approval (NWASCO, 2020). The by-laws are yet to be approved.

The Zambia Bureau of Standards (ZABS) defines the technical standards to enable sanitation systems that provide affordable and quality services (MLGH, 2015). However, non-sewered service standards for the whole value chain are under development and will be published in the second quarter of 2021 (Kalikiti, 2021). The standards are still yet to be published.

Targets

The target for non-sewered sanitation is to have 43% of the population using safely managed non-sewered services by 2035 (MCC, 2011). Most of the city's population uses on-site sanitation, especially in unplanned LIHD areas (LWSSC, 2021). The NUWSSP has set septic tanks with percolation as the highest service level in non-sewered areas (MLGH, 2011, p. 64). VIP latrines in LIHD areas and septic tanks with percolation in MIMD and HILD areas define the minimum service level. There are no service indicators for non-sewered services that measure the performance of LWSC by NWASCO.

Budget lines

The LWSC strategic plan 2018-2022 has no budgetary allocation to provide non-sewered sanitation from internally generated funds (LWSC, 2018b, p. 49). There are budget lines to construct 12,000 improved household sanitation facilities in LIHD areas and four FSTPs from externally funded investments under the LSP. However, the scope has been scaled down due to escalating costs. Personnel under the LSP stated:

> *'… targeting [to build] 2,000 household toilets [in Kanyama] …. We have reduced from the initial 10,000 to 3,500 [in Kanyama and Chawama LIHD areas] because of costs…one is roughly $1,000 [vault latrine] and $1,200 [pour-flush toilet] with households paying 15% ... ZMW 2,400 [$229].'*

The LSP has a budget for software activities such as hygiene promotion (World Bank, 2015; AfDB, 2015).

Inclusion (planning and budgeting)

Households are responsible for investing in their household-level sanitation facilities (MLGH, 2015). The NUSS maintains that household facilities should not be directly subsidised, with various mechanisms to help less affluent households access adequate sanitation. These include low-cost technologies, establishing and developing supply chains for affordable material, local masons training to support households, and financing access via micro-finance institutions (MLGH, 2015). Inclusion mechanisms are considered at the strategy level and partially operationalised, such as training masons to support households under the LSP.

5.3.2 Delivering function

Table 5-5 summarises the findings on capacity and financing mechanisms to develop improved non-sewered services in Lusaka. Figure 5-6 shows the analysis of the extent to which the mechanisms influence the development of improved non-sewered services. Appendix C-5 presents the assessment criteria, and the methodology is described in Section 3.7.4. The questions addressed were:

i. Is there an investment plan for non-sewered sanitation hardware and software, including all the necessary components to achieve service level targets over the medium term?
ii. Are annual funding allocations for non-sewered sanitation sufficient to achieve service level targets, and are they used as planned?
iii. Are there effective mechanisms for coordination of non-sewered sanitation investments between donors; donors and government; and within government?
iv. Is responsibility for delivery of non-sewered sanitation services mandated to fully established and appropriately structured institutions?
v. Do the mandated institutions have adequate levels of qualified staff to carry out their mandates?
vi. Are there active programmes promoting safe non-sewered sanitation, behaviour change and community engagement?
vii. Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people?
viii. Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people?

Table 5-5. Summary of evidence on capacity and financing mechanisms to develop improved non-sewered sanitation services in Lusaka

Delivering function		Evidence for sanitation value chain element		
		Toilet, pit and septic tank	**Emptying and transport**	**Faecal sludge and septage treatment**
Funding	**Investment plan:** Is there an investment plan for non-sewered sanitation hardware and software, including all the necessary components to achieve service level targets over the medium term?	- The LSIMP is the principal investment framework; however, it is not explicit in detailing investment needs for non-sewered sanitation - LSIMP identifies 39 OSS system projects to meet 2035 targets. - The costs of investment needs are not disaggregated across the elements of the sanitation value chain. - No software components are costed in the LSIMP.		
	Adequate funding: Are annual funding allocations for non-sewered sanitation sufficient to achieve service level targets, and are they used as planned?	- Under the LSP, funding for non-sewered sanitation is $25m, representing 8% of the total program budget. - The total non-sewered system investment under the LSP is 3.9% of the nominal 2035 targets. - LWSC is working on a business case by proposing an increase in the sanitation surcharge from the current 2.5% to help fund services beyond the LSP as current funding is insufficient.		
	Coordination: Are there effective mechanisms for coordination of non-sewered sanitation investments between donors; donors and government; and within government?	- Mechanisms exist between government and corporating partners that effectively coordinate sanitation sector investments.		
Capacity and outreach	**Institutional capacity:** Is the responsibility for delivering non-sewered sanitation services mandated to fully established and appropriately structured institutions?	- LWSC have little experience in promoting and limited capacity to implement non-sewered services at scale. - LWSC has established an FSM Department to support the implementation of non-sewered services.		
	Staffing: Do the mandated institutions have adequate levels of qualified staff to carry out their mandates?	- The newly established FSM department has a lean structure with six full-time staff (one head of Unit, three inspectors and two plant operators). - Support required not available within LWSC is sourced through a pool of consultants.		
	Outreach: Are there active programmes promoting safe non-sewered sanitation, behaviour change and community engagement?	- The Peri-Urban Department at LWSC and consultants have spearheaded software activities to promote safe non-sewered sanitation, behaviour change and community engagement. - LCC is a key actor in community engagement and health education activities and partners with LWSC.		
Inclusion	**Technology**: Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people?	- Construction of improved OSS in LIHD areas under the LSP has been prohibitive for households. The program has since subsidised costs to incentivise uptake; hence, it has reduced the number of beneficiaries. - The market is saturated with equipment for emptying septic tanks, with no appropriate or financially attractive equipment for emptying pit latrines.		
	Funding: Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people?	- To support low-income households, the LSP has subsidised the construction of 5,500 improved OSS facilities as part of rolling out LWSC's non-sewered sanitation service model. - LWSC has rolled out a fixed volumetric fee lower than the actual cost of emptying and is designed to be affordable and undercut the informal and unsafe pit emptying market.		

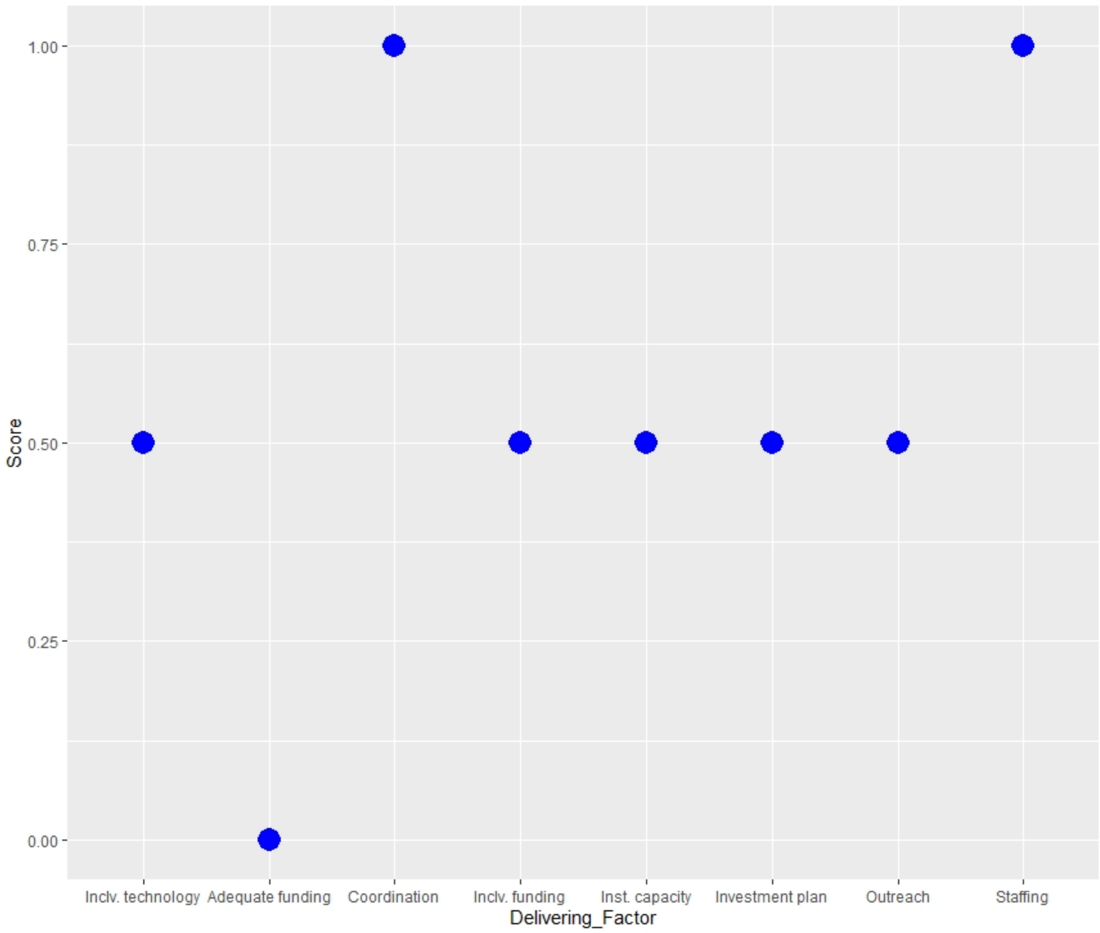


Figure 5-6. Analysis of capacity and financing mechanisms for the development of improved non-sewered services in Lusaka (Author's own)

Investment plan

LSIMP is the principal framework for investing in non-sewered services. Approximately $639 million (US$ 2011) is needed for improved non-sewered sanitation systems (MCC, 2011). The investment plan identifies 39 OSS projects to meet 2035 targets. The LSIMP recommends septic tanks with percolation as the preferred technology. In areas with high groundwater or flooding, elevated Ecosan toilets are the preferred option. The non-sewered component of the LSIMP needs strengthening when considering investments for FSM infrastructure and services and demand creation (WSUP, 2019). The LSIMP is not explicit in guiding investment in non-sewered services, as is the sewered sanitation component. Personnel from LWSC stated:

> *'…the sanitation master plan has not handled on-site sanitation well; it lacks detail, we need a comprehensive master plan for on-site sanitation.'*

The investment costs are not disaggregated across the elements of the sanitation value chain. The plan needs updating with the re-alignment of LWSC's mandate to cover non-sewered services. No software components are costed in the LSIMP, although implementation under LSP has software components.

Adequate funding

LWSC has allocated 28% of its 2018-2022 budget towards extending sanitation services to meet its strategic objectives. Funding is mainly from IFIs (World Bank and AfDB) under the LSP through grants to incentivise the provision of non-sewered services (LWSC, 2018b; World Bank, 2015). Under the LSP, the direct investment for non-sewered sanitation is $25m (World Bank, 2015), representing 8% of the total nominal program budget. The total non-sewer system investment under the LSP is 3.9% of the nominal 2035 targets. LWSC is working on a business case proposing an increase in the sanitation surcharge paid by households to help fund non-sewered sanitation beyond the LSP. Personnel from LWSC stated:

> *'In our business case to NWASCO, we are proposing an increase in the sanitation surcharge ….. we will ring-fence those funds to continue constructing toilets…. We are trying not to rely on donors to scale.'*

Coordination

The existing coordination mechanisms described for sewered sanitation services in Section 5.2.2 are applicable for non-sewered services.

Institutional capacity

LWSC acknowledge a lack of capacity to meet the demand for sanitation services (LWSC, 2018b). They have little experience promoting non-sewered services at scale and limited implementation capacity (World Bank, 2015). However, the LSP is strengthening LWSC's ability to manage sewered and non-sewered sanitation services (WSUP, 2019). Approximately 6% of the total LSP funding is allocated as grants towards institutional strengthening (World Bank, 2015; AfDB, 2015). Personnel from LWSC stated:

'BMGF [Bill and Melinda Gates Foundation] is funding a grant to help LWSC provide non-sewered sanitation …. capacity needs to be built in LWSC to handle on-site services.'

'….. FSM services have not grown to the levels anticipated… we did not institutionalise the whole thing [non-sewered services] because we took them as a project and did not look at the bigger picture.'

LWSC has established an FSM Department to support the implementation of non-sewered services. LWSC has in the past delegated non-sewered services to private service providers and CBOs.

Staffing

The newly established FSM department has a lean structure with six full-time staff (one head of Unit, three inspectors and two plant operators). The department is also reliant on other directorates and departments within LWSC (WSUP, 2019). Support required not available within LWSC or under the LSP is sourced through a pool of consultants (WSUP, 2019).

Outreach

The FSM and Peri-Urban Departments at LWSC are responsible for information, education and communication (IEC), and marketing campaigns. In addition, the Peri-Urban Department and consultants have spearheaded software activities such as behaviour change and community engagement. LCC is a key actor in community engagement and health education activities and partners with LWSC. LCC personnel stated:

'Stakeholder engagement is lacking ….in George [LIHD area], only 450 [households] have signed up, and only 130 have paid the minimum contribution fee for the toilet to be built. The issue is that it is mainly a top-down approach with little community participation.'

Technology

The NUSS calls for affordable sanitation services, especially in LIHD areas. Construction of improved OSS in LIHD areas under the LSP has been prohibitive for households with some toilets costing $1,000-$1,200 (US$ 2018);

hence, there has been low uptake. The LSP has subsidised the OSS costs and reduced the number of beneficiaries to incentivise uptake, with households paying $229 over six months. Personnel from an NGO stated:

‘Their [LSP] model is a toilet costing ZMW 12,600 [$1,200] in a PUA [Peri-Urban Area]….. They are asking people to pay ZMW 2,400 [$229] upfront …. They began in George [LIHD] and took 8 months to mobilise 50 beneficiaries…. With time they [LWSC] restructured the payment terms.’

Furthermore, the market is saturated with equipment for emptying septic tanks, with no appropriate or financially attractive equipment for emptying pit latrines (WSUP, 2019). There are no local importers, distributors or manufacturers of pit emptying equipment (LWSC, 2019b). Personnel from an international NGO stated:

‘Access to sanitation hardware and knowledge on the existence of these [FSM] services is very low. The reason could be the supply chain is fragmented, not well organised and not fully developed.’

Funding

To support low-income households, the LSP has subsidised the construction of 5,500 improved OSS facilities as part of rolling out LWSC’s non-sewered sanitation service model. Personnel under the LSP stated:

‘We are subsidising 85% of the cost [building 5,500 toilets], and they [households] are paying 15%, which they pay in 6 months.’

LWSC has rolled out a fixed volumetric fee of $12 per m^3 for private-sector-led safe pit emptying services using performance-based contracts. The fee, which is lower than the actual cost of emptying, is designed to be affordable to undercut the informal and unsafe pit emptying market (WSUP, 2018a). In addition, formalised pit emptiers will get access to a ‘top up’ intended to cover the full cost of emptying and transporting waste to treatment (WSUP, 2019). Personnel under the LSP stated:

‘…..$800,000 is set aside as a performance subsidy to top-up what households will be paying for the service. The ZMW 125/m^3 [$12/$m^3$] is not cost-reflective… the subsidy tops-up this tender price [$12/$m^3$]…’

5.3.3 Sustaining function

Table 5-6 summarises the findings on operating and sustaining non-sewered services in Lusaka. Figure 5-7 shows the analysis of the extent to which non-sewered service operations are sustained. Appendix C-6 shows the assessment criteria used with the methodology fully described in Section 3.7.4. The questions addressed were:

i. Can non-sewered sanitation service providers cover their full operating costs and make reasonable profits from user fees and/or local revenue or transfers?
ii. Are there adequately staffed institutions which monitor performance, health and environmental standards for non-sewered sanitation?
iii. Are failures to meet non-sewered sanitation performance standards systematically monitored and sanctions applied where relevant?
iv. Do the institutions responsible for non-sewered sanitation have sufficient qualified staff to undertake adaptive planning and implementation for service expansion?
v. Do the institutions responsible for non-sewered sanitation have active and gender-aware staff development programmes and incentives to retain workers?
vi. Is the health and safety of non-sewered sanitation workers adequately protected and monitored?
vii. Are there ongoing programmes and measures to build the capacity of private sector service providers to deliver non-sewered sanitation services?
viii. Are sanitation services keeping pace with population growth?
ix. Is sanitation data routinely collected, including from women, poor and vulnerable people, and used for planning services?
x. Do the city's sanitation systems actually provide safe sanitation services for all users, including women, poor and vulnerable people?

Table 5-6. Summary of evidence on operating and sustaining non-sewered sanitation services in Lusaka

Sustaining function		**Evidence for sanitation value chain element**		
		Toilet, pit and septic tank	**Emptying and transport**	**Faecal sludge and septage treatment**
Regulation and cost recovery	**Cost recovery**: Can non-sewered sanitation service providers cover their full operating costs and make reasonable profits from user fees or transfers?	- Service providers for non-sewered sanitation do not recover their full operational and maintenance costs. - LWSC septage and faecal sludge dumping fees are not ring-fenced for treatment. - Water Trusts cross-subsidise by as much as 30% of costs with revenue from water sales to operate FSM services.		
	Monitoring: Are there adequately staffed institutions that monitor performance, health and environmental standards for non-sewered sanitation?	- NWASCO was set to introduce OSS and FSM key performance indicators (KPIs) and service level indicators in 2019 but has not done so as SLGs have not been revised. - ZEMA does not have specific service indicators for VTOs to monitor transport services effectively. - Due to LCC capacity constraints, monitoring adherence to the Public Health Act for non-sewered services is inadequate.		
	Enforcement: Are failures to meet non-sewered sanitation performance standards systematically monitored and sanctions applied where relevant?	- LCC is responsible for regulating the siting and building of OSS facilities. However, this is not being done as LCC approve housing construction drawings, but there is no follow up on the actual construction. - Under the Public Health Act, on-site sanitation regulation is not explicitly addressed; hence, enforcement is challenging. - The standards for VTOs are inadequate as there are no service indicators to measure performance.		
Institutions and service providers	**Staffing**: Do the institutions responsible for non-sewered sanitation have sufficient qualified staff to undertake adaptive planning and service expansion?	- Due to informal arrangements, the number of workers offering non-sewered services is unclear. - There is an oversupply of vacuum trucks on the market (59 vacuum trucks, 38 companies), with less than 20% utilisation rates. - The Water Trusts in Chazanga and Kanyama have limited technical and financial capacity to maintain existing FSTPs.		
	Staff development: Do the institutions responsible for non-sewered sanitation have active and gender-aware staff development programmes and incentives to retain workers?	- LWSC has a gender responsiveness and social inclusion policy for staff development. - The skillset required is hands-on training for service delivery and occupational health and safety, absent until 2018.		
	Health and Safety: Is the health and safety of non-sewered sanitation workers adequately protected and monitored?	- Most FS collection and transport service providers do not practice basic health and safety protection practices. - Due to budget constraints, employers often do not prioritise PPE and training for sanitation workers. - Zambia does not have health and safety regulations tailored for FSM. OHS guidelines have been developed for the emptying and transport of FS.		
	Private sector capacity-building: Are there ongoing programmes and measures to build the capacity of private sector service providers to deliver non-sewered sanitation services?	- The vocational training authority has approved a practical training program on FSM service provision. - The LSP is investing in equipment for 18 emptying teams for OSS facilities in LIHD areas and has trained men and women to build improved OSS facilities as a full-time business.		
Inclusion	**Growth:** Are sanitation services keeping pace with population growth?	- Current population growth is outpacing non-sewered service provision, and the number of people with unsafe sanitation is increasing.		
	Planning from evidence: Is sanitation data routinely collected, including from women, poor and vulnerable people, and used for planning services?	- Citywide sanitation data is currently not routinely collected but instead done on an ad-hoc basis. - NWASCO plans to develop a sanitation database necessary for comprehensive sanitation reporting.		
	Outcomes: Do the city's sanitation systems actually provide safe sanitation services for all users, including women, poor and vulnerable people?	- Safe sanitation services are not available to many women, poor and vulnerable people. - Only 13% of the waste generated is safely managed; 12% of FS is contained and not emptied, 10% FS is emptied, and only 1% is safely treated.		

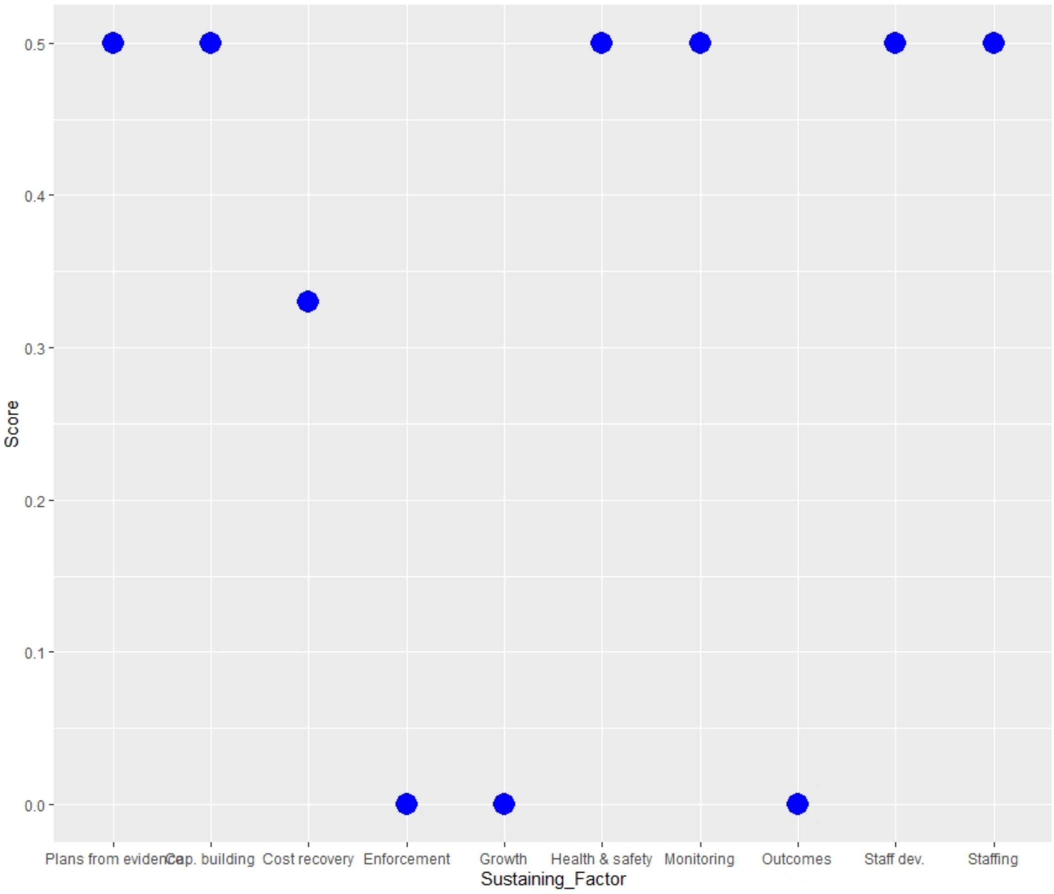


Figure 5-7. Analysis of the extent to which current operations of non-sewered services are sustained in Lusaka (Author's own)

Cost recovery

Service providers for non-sewered sanitation do not recover their full operational and maintenance costs (Chapter 4). However, VTOs are closest to recovering costs as services extend to commercial and industrial clients where fees are higher than those paid by households. For example, a vacuum truck operator stated:

> *'We have contracts with entities like shopping malls … their septic tanks fill up quickly. …. We usually use the biggest truck [15m^3] for commercial clients as they pay more… the other vehicles we wait for customers to come – mainly for households.'*

LWSC septage and faecal sludge dumping fees are not ring-fenced for treatment (LWSC, 2019b). Limited ability to pay for formalised safe pit emptying services by lower-income customers considerably affects cost recovery (WSUP, 2019). Water Trusts cross-subsidise by as much as 30%, with revenue from water sales to operate FSM services. Water Trust personnel stated:

> *'……. the water component subsidised the sanitation service as operation costs were very high due to low demand …….'*
>
> *'The costs of operation are very high, and we subsidise the FSM service as it does not make any profit, and without the water component, the FSM service would be non-existent. The service requires a lot of support.'*

Monitoring

NWASCO's mandate for monitoring non-sewered services has not been fully implemented because the primary focus has been on sewer services (MLGH, 2015). NWASCO was set to introduce OSS and FSM key performance indicators (KPIs) and service level indicators in 2019 (NWASCO, 2019). This has not materialised as service level guarantees have not been revised. ZEMA does not have specific service indicators for VTOs (WSUP, 2019), making the monitoring of transport services challenging. Due to LCC capacity constraints, monitoring adherence to the Public Health Act for non-sewered services across the whole value chain is inadequate, especially in LIHD areas (see the section on institutional capacity). Under LSP, LWSC, LCC and the Ministry of Health (MoH) are building capacity for monitoring the effectiveness of sanitation and hygiene investments in Lusaka.

Enforcement

LCC is responsible for regulating the siting and building of onsite sanitation facilities. However, this is not being done as LCC approve construction drawings, but there is no follow up on the actual construction (NWASCO, 2019). Standards for non-sewered sanitation are yet to be published. Under the Public Health Act, on-site sanitation regulation is not explicitly addressed; hence, enforcement is challenging (NWASCO, 2020). The autonomous nature with which VTOs and informal pit emptiers conduct their operations is steered by a lack of regulation, standards and/or enforcement of the existing regulation (WSUP, 2019). Although some standards exist in the case of ZEMA with VTOs obtaining licences, the standards are inadequate as there are no service indicators to measure performance. In 2018, ZEMA only had a list of 8 valid VTO licences out of the 38 companies transporting waste (WSUP, 2018a).

Staffing

The number of workers offering non-sewered services is unclear due to informal working arrangements (Kapulu, 2020). There is an over-supply of vacuum trucks on the market (59 vacuum trucks, 38 companies), with utilisation rates of less than 20% (WSUP, 2019). Nearly the entire fleet of vacuum trucks is second-hand imported vehicles that regularly break down, with limited spare parts and expertise to ensure limited downtimes (WSUP, 2019). The Water Trusts in Chazanga and Kanyama have limited technical and financial capacity to maintain existing FSTPs (WSUP, 2019).

Staff development

Overall, LWSC has a gender responsiveness and social inclusion policy for staff development (LWSC, 2018b). The sector is male-dominated, with no evidence of women working in the space (Kapulu, 2020). The skillset required is hands-on training for service delivery and occupational health and safety, which has been absent until 2018 (Gerlach et al., 2020).

Health and safety

There is no standard when building on-site sanitation facilities in Lusaka (NWASCO, 2018), compromising infrastructure quality. Most FS collection and transport service providers do not practice basic health and safety protection practices (WSUP, 2019). For example, during data collection in Kanyama (a LIHD area), a septic tank collapsed during emptying with two emptiers falling into the tank. The emptying team did not have adequate PPE. PPE and training for sanitation workers are often not prioritised by private sector employers due to budget constraints (Kapulu, 2020). Zambia does not have health and safety regulations tailored for FSM. However, formal OHS guidelines to empty and transport faecal sludge have been developed (WSUP, 2019).

Private sector capacity building

The limited business capacity of many VTOs and CBOs to keep financial records and conduct marketing prevents their growth (WSUP, 2019). In 2018 the Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA) approved a practical training program on FSM service provision. TEVETA has trained 69 sanitation professionals on inspection, enforcement, manual pit emptying, vacuum truck operation and maintenance (Gerlach et al., 2020). The training costs range between ZMW 2500-3500 ($ 238-333), a high financial investment for small-scale providers (Kapulu, 2020).

The LSP is investing in equipment for 18 emptying teams for OSS facilities in LIHD areas and providing a subsidy to cover the difference between fees paid and the cost of services (WSUP, 2019). In addition, the program has trained men and women from George (a LIHD area) to build improved OSS facilities as a full-time business: An international NGO supporting sanitation stated:

> *'In George, they [LSP] are using local masons who have been trained on how to build the toilets …….*
>
> *The contracts [with the private sector] are performance-based for providing the service [emptying and transport] …. funded by the World Bank, and the equipment required is funded by AfDB.'*

Growth

A high proportion of the population (>80%) depends on on-site sanitation. There has been inadequate investment to manage the waste generated with population growth and demand outpacing service provision. Non-sewered sanitation has mainly been self-supplied by households, with LWSC taking a leading role only recently. Efforts under LSP for non-sewered service provision are estimated to benefit 450,000 to 900,000 people in LIHD areas (LWSSC, 2021; WSUP, 2019). The estimated population in Lusaka without safely managed FS services is 71% (Kappauf et al., 2018) or 1.7 million people.

Planning from evidence

Currently, the only sanitation data readily available is regarding sewerage systems (NWASCO, 2019). NWASCO plans to develop a sanitation database necessary for comprehensive sanitation reporting. Information will be collected through surveys on the type of sanitation facilities, size, their condition, and usage (NWASCO, 2019). Projections in the LSIMP for non-sewered services are not explicit, and the plans have not been reviewed or updated since 2011.

Outcomes

About 82% of the city population use on-site sanitation (Kappauf et al., 2018). Only 13% of waste generated is safely managed, with 12% of FS contained and not emptied. Around 10% FS is emptied, and only 1% is safely treated.

5.4 Summary of key findings and their interpretation

The assessment of the enabling environment highlighted the factors responsible for the status quo in developing and sustaining sewered and non-sewered services. Results showed that the existing enabling environment for sewered services is slightly more developed than for non-sewered services (Figure 5-8).

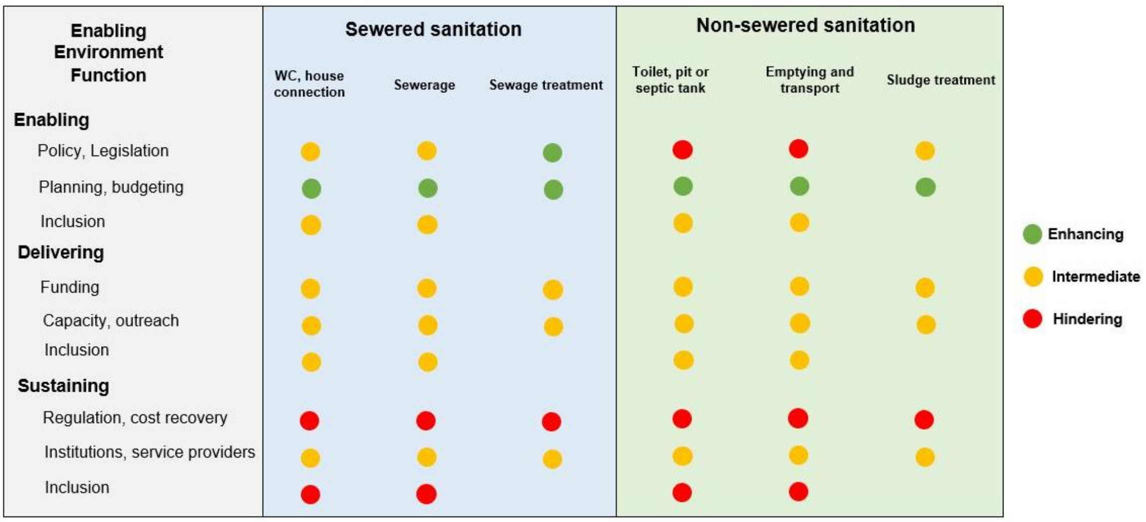


Figure 5-8. State of the enabling, delivering, and sustaining functions of the enabling environment for sanitation services in Lusaka

5.4.1 Sewered services

Available policies prioritise the construction of sewer and treatment infrastructure. However, the operation and maintenance of sewered systems are not fully supported with clear and deliberate actions other than aspirational strategies. The analysis showed that weaknesses in policy implementation and regulation enforcement undermined effective service delivery, aligning with findings by Cairncross et al. (2010). For example, connection to sewers by households is silent in policy but highlighted in regulations and strategies, but not enforced. Regulation enforcement is lacking due to constrained capacity at the local authority level. The capacity needed includes human resources to monitor adherence to regulations and operational capacity in logistics to facilitate monitoring.

Available policy and regulatory instruments, when implemented and enforced, will lead to enhanced service delivery. The local authority has the mandate to enforce; however, they are constrained, while the utility provides the service but cannot enforce connections. City authorities could consider increasing capacity at the local authority to effectively carry out their mandate or amend the law to allow the service provider (utility) to enforce connections, as this is their direct line of business.

Furthermore, the licencing framework for utilities does not consider sewer connection efficiency as a performance benchmark. Institutional roles among stakeholders are clear, but the discharge of these roles is not well coordinated. In addition, there are currently no standards for the design, construction, operation and maintenance of sewered systems across the value chain, thus impacting the accountability of service providers.

Current funding and financing levels are insufficient to meet the 2035 sanitation coverage targets set out in the investment master plan. The plans have not been updated to reflect the changing social and economic environment. Also, Infrastructure related activities take priority over software activities which are critical in ensuring the hardware aspect functions, corroborating findings by

Trémolet and Binder (2013). The capacity to effectively deliver sewered services to meet demand is lacking. Further, access to affordable financial services is a constraint for household investment in service access, which is in line with Trémolet et al. (2015). However, some donor-funded projects have mechanisms to help fund pro-poor sanitation.

Current tariffs are insufficient to sustain sewered operations resulting in poor service delivery outcomes, corroborating findings by Sohail (2004). The capacity and numbers to undertake adaptive planning of sewerage rehabilitation and expansion are inadequate within the utility. A high proportion of the population is not serviced, with demand outpacing service provision. Planning for services is not entirely driven by evidence, as sanitation data is collected on an ad-hoc basis.

5.4.2 Non-sewered services

Available policies and regulations permit utilities to incorporate the private sector to bring additional capacity in service delivery. However, weak linkages and coordination among institutions hinder an integrated approach to delivering non-sewered services. LWSC’s mandate has been re-aligned to become a full-service utility to address challenges of non-provision of non-sewered services. The WSS Act is under revision to allow utilities to play an enabling role for non-sewered services. The utility needs to play a central role in service delivery by building its human resource and technical capacity to scale services as the emphasis has been on reticulated sewerage. There are no service indicators for non-sewered services to measure the performance of utilities. Household facilities are not directly subsidised, with various mechanisms to help low-income households access safe sanitation.

Current funding is inadequate to meet service targets. Sanitation funding is donor-dependent, with proposals to place households at the centre of financing non-sewered services. However, the public sector (utility and government) needs to take responsibility from households for services. A detailed master plan guiding investment in non-sewered services is lacking as the current plan is not explicit with the service chain components not disaggregated. LWSC has limited capacity to implement non-sewered services at scale and has been strengthened by establishing an FSM Department. Outreach activities promoting non-sewered sanitation services are limited, with the local market not well organised with appropriate equipment to support the emptying of latrines.

Costs for the provision of non-sewered sanitation are not fully recovered. Financial constraints in providing training by private sector businesses may prevent them from performing non-sewered sanitation effectively. However, there are mechanisms under the LSP to build the capacity of the private sector. Demand is outpacing the provision of services with planning from evidence not fully realised as sanitation data is not routinely collected.

Overall for both sewered and non-sewered services, the financial incapacity of service providers and public sector underfunding has negatively affected service delivery. Sector budgetary allocations are low and primarily donor-dependent, highlighting the low levels of prioritisation by the public sector. Consequently, inadequate public funding has led to under-investment in maintenance with poor outcomes in operations. The poor outcomes increase public health risks and environmental degradation, as noted by Evans et al. (2009). Therefore, sector funding needs to be an integral part of public sector spending with realistic allocations for the continuous development and repair of excreta management systems.

Broadly the enabling environment is relatively conducive to both sewerage and FSM. There is no systemic reason or justification for why one should be preferred over the other, i.e., sewerage vs FSM. However, the overall environment in which sewered and non-sewered services are delivered could usefully be strengthened for all types of sanitation systems. In addition, the challenges highlighted for both sewered and non-sewered sanitation need overcoming to deliver inclusive services effectively (Chapter 7 and 8).

Chapter 6: Exploration of factors influencing household sewer connectivity and access to safely managed faecal sludge management services

6.1 Introduction

This chapter presents findings based on the Lusaka Sanitation Assessment Survey and secondary data. The third of the three results chapters follow the methodology described in Section 3.7.5. The results provide insight into the factors influencing household-level access to sanitation services in Lusaka. The aim was to understand whether specific socio-economic, demographic, and service characteristics influence the likelihood that households will or will not have access to sewered or non-sewered sanitation. Specifically, the hypotheses listed below were tested. These hypotheses are based on findings from the literature and preliminary fieldwork in Lusaka. The hypotheses are:

1. In areas where sewers are available, low-income renting households with large[18] families residing in a compound where water supply is unreliable were less likely to connect to the sewer network.
2. In areas where sewers were unavailable, high-income owner-occupied households with small families using improved facilities and not living in a compound were more likely to access safely managed faecal sludge services.

Sewered areas had some households not connecting to the network. In non-sewered areas, FSM service provision is by the private sector, either informal or formal. Informal providers offered unsafely managed services.

The results offer insights into household sanitation experiences and highlight drivers influencing sewered and non-sewered service access. Understanding the factors influencing sanitation service access will help inform plans for scaling up citywide sanitation services in Lusaka.

[18] Family size: households with five or less members were considered small while those with six or more members were considered large families (see Methodology section 3.7.5).

6.2 Household socio-economic and demographic characteristics

Table 6-1 presents the socio-economic and demographic characteristics of household respondents from 33 Wards of Lusaka. The data was collected under the sanitation mapping assessment. Section 3.5.6 and 3.7.5 of the Methodology describe the research data. The total number of households surveyed was 1,495, and sewered and non-sewered area descriptors disaggregate the data. In addition, general population statistics were synthesised from 1,530 households reported in the 2015 Living Conditions Monitoring Survey (CSO, 2015).

The percentage of respondents in sewered and non-sewered areas was evenly distributed by age, gender, and household size. Over 66% of respondents were below 40 years, with 76% female and 93% having a household size of at least six members. At least 67% of respondents had a secondary or higher level of education. More than half of the respondents (58%) were house-owners. At least 84% of households had occupied the house for more than a year.

In sewered areas, a large proportion of survey respondents (41%) were from MIMD households. Only 34% of respondents lived in a compound, mainly from LIHD areas. Income levels for 53% of households were below the 2015 monthly city average of ZMW 2,893 ($276). In non-sewered areas, 98% of respondents were from LIHD households, with over 63% of these households living in compounds. Income levels for 72% of households were below the city average. More than 58% of the national population earn incomes below the international poverty line of $1.90 per day (or $57 monthly), with 75% living in rural areas[19].

[19] The World Bank (2020): Zambia country overview. Available at: https://www.worldbank.org/en/country/zambia/overview#2 [Accessed 29 January 2021].

Table 6-1. Household respondent socio-economic and demographic characteristics disaggregated by the availability of sanitation services, compared to general population statistics of Lusaka

Characteristic	Sewered[a] % (n = 557)	Non-sewered[a] % (n = 938)	Lusaka Overall[b] % (n = 1,530)
Age			
18 - 29	34 (341)	39 (369)	40 (612)
30 - 39	33 (183)	27 (252)	31 (474)
40 - 49	15 (82)	164 (17.5)	16 (245)
≥ 50	17 (104)	16 (152)	13 (199)
Gender of respondent			
Female	76 (422)	76 (713)	
Male	24 (135)	24 (225)	
Gender of household head			
Female			22 (337)
Male			78 (1193)
Household size			
≤ 5	7 (37)	5 (44)	
≥ 6	93 (520)	95 (894)	
Living arrangements			
Owned	62 (347)	58 (546)	34 (520)
Rented	38 (209)	42 (391)	66 (1010)
Length of stay			
≤12 months	11 (60)	16 (154)	
>12 months	89 (496)	84 (783)	
Level of education			
Up to primary	20 (108)	33 (304)	35 (536)
Secondary and above	80 (439)	67 (618)	65 (994)
Level of monthly income			
≤ ZMW 2,893 ($276)	53 (297)	73 (685)	59 (903)
> ZMW 2,893 ($276)	47 (260)	27 (252)	41 (627)
Urban setting			
LIHD	34 (189)	99 (843)	78 (1193)
MIMD	41 (231)		13 (199)
HILD	25 (137)	1 (11)	9 (138)
Living in a compound			
Yes	34 (192)	63 (584)	
No	66 (365)	37 (336)	

Sources: [a]Sewered and non-sewered area statistics synthesised from the Lusaka Sanitation Mapping Assessment Survey; and
[b]Population statistics synthesised from the 2015 Living Conditions Monitoring Survey

6.3 Access to water supply and sanitation services in sewered and non-sewered areas

Table 6-2 summarises access to water supply and sanitation services amongst respondent households in selected sewered and non-sewered areas. Section

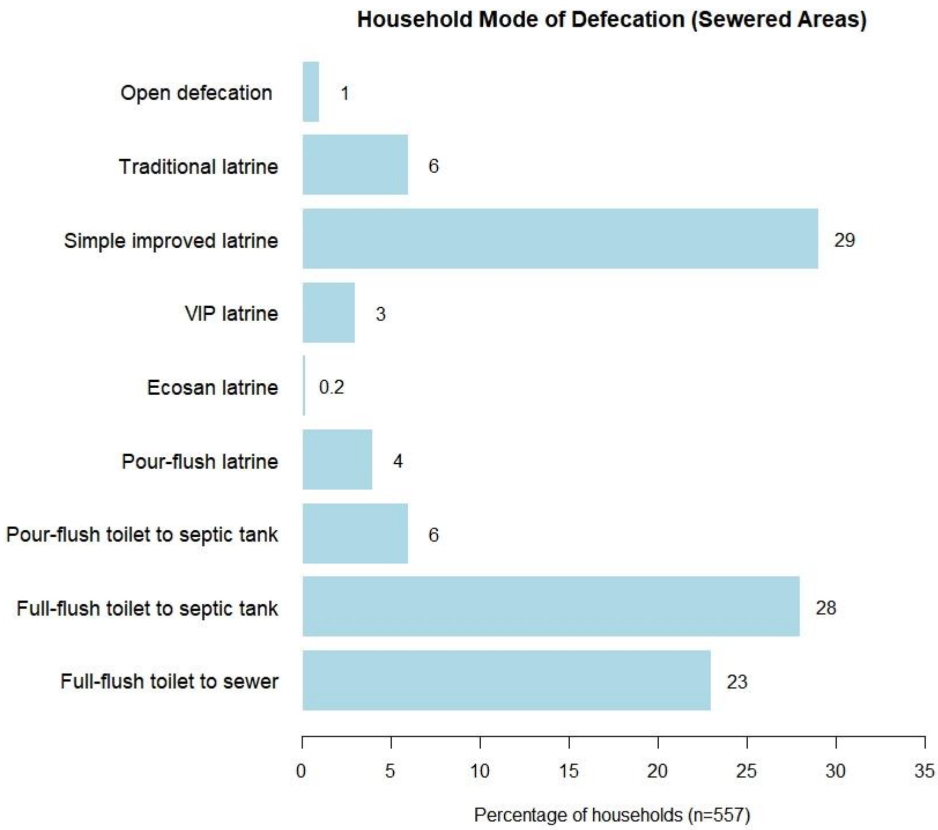
3.7.5 of the Methodology defines the WaSH characteristics in the context of this research. Over 70% of the city population reside in LIHD areas, with sewerage serving around 14% of the total population, while over 80% use on-site sanitation (LWSC, 2018a; LWSSC, 2021). Most households surveyed in non-sewered areas were from LIHD settings. In sewered areas, the urban settings were spread across the different area types, i.e., LIHD, MIMD, and HILD.

Table 6-2. Household WaSH characteristics in surveyed sewered and non-sewered areas compared to general population statistics of Lusaka

Characteristic	Sewered[a] % (n = 557)	Non-sewered[a] % (n = 938)	Lusaka Overall[b] % (n= 10,700)
Sanitation facility			
Unimproved	7 (37)	11 (102)	19 (2,033)
Improved	93 (518)	89 (833)	80 (8,560)
Water source			
Unimproved	1 (4)	4 (40)	2 (214)
Improved	99 (552)	96 (897)	98 (10,486)
Water availability			
Yes	44 (246)	15 (148)	40 (4,280)
No	56 (309)	84 (790)	60 (6,420)
Facility access			
Private	64 (350)	36 (336)	34 (3,638)
Shared	36 (200)	64 (584)	46 (4,922)

Sources: [a]Sewered and non-sewered area statistics synthesised from the Lusaka Sanitation Mapping Assessment Survey; and
[b]General population statistics synthesised from the 2018 Zambia Demographic and Health Survey (ZDHS)

A higher proportion of water and sanitation services in sewered areas were improved compared to non-sewered areas. Overall, the use of improved sanitation facilities was high (89%), with 11% of households using unimproved facilities (traditional latrines) or open defecation (Table 6-2). Figure 6-1 presents the disaggregated data for where household members usually defecated. In sewered communities, only 24% were connected to the network, with 75% using various on-site systems (Figure 6-1). The sewer connections in LIHD areas were 9%, MIMD 27%, and HILD 39%. Thus, many households do not have a connection to sewers.



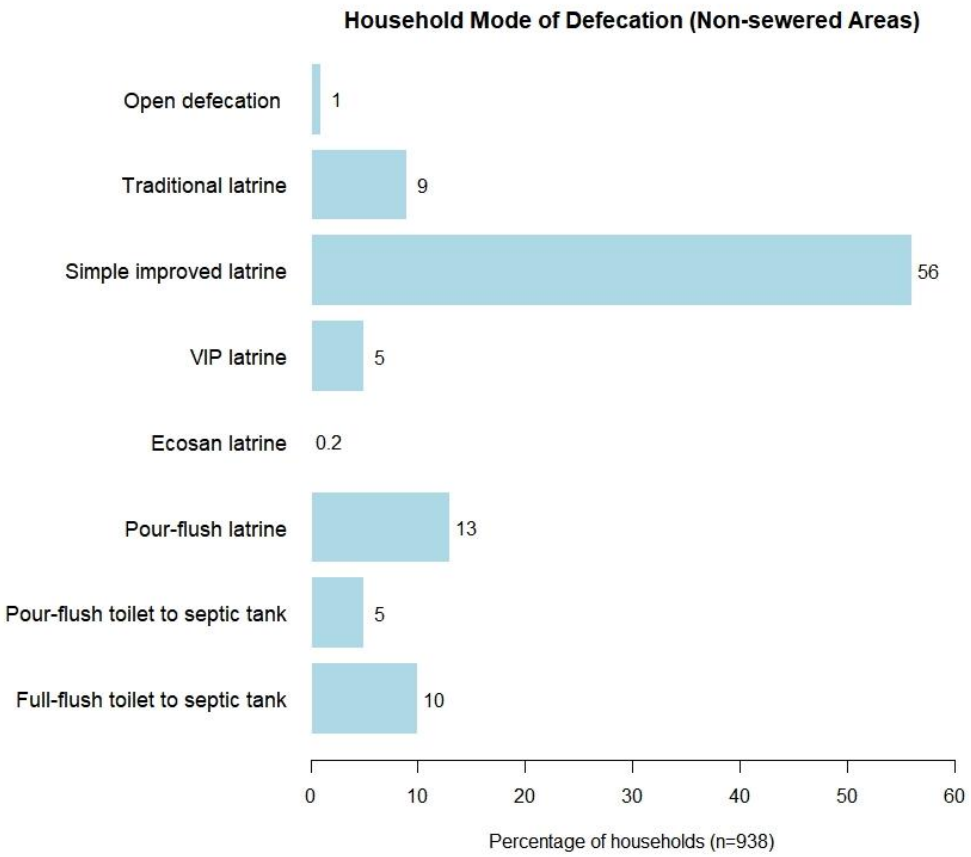


Figure 6-1. Where household members usually defecated across different urban settings (Top) Sewered and (Bottom) Non-sewered areas

Access to water supply was explored to help understand household sewer connectivity. The use of improved water sources was very high (>95%) in both sewered and non-sewered areas (Table 6-2). These were piped household (in-house and yard) connections, private boreholes, a neighbour's tap, and/or a public stand tap. However, disaggregating the data across urban settings showed considerable differences (Table 6-3). Overall, 39.6% of the population has household connections in Lusaka, while 60.4% use water kiosks and stand taps (NWASCO, 2020).

Table 6-3. Household water supply levels of service disaggregated by urban setting and sanitation system

Level of service	**LIHD**		**MIMD**	**HILD**	
	Sewered % (n=188)	Non-sewered % (n=927)	Sewered % (n=231)	Sewered % (n=137)	Non-sewered % (n=11)
Household connection	38 (71)	25 (232)	75 (174)	83 (113)	64 (7)
Private borehole	2 (3)	2 (19)	0.4 (1)	17 (24)	36 (4)
Neighbours tap	16 (30)	25 (233)	16 (38)		
Public stand tap	42 (80)	44 (403)	8 (18)		
Well	2 (4)	4 (40)			

Source: Lusaka Sanitation Mapping Assessment Survey

In sewered areas, piped household water connections provided by the utility or privately through boreholes were highest in HILD areas (100%), MIMD (75%), and lowest in LIHD areas (40%). Most households in LIHD areas are reliant on lower levels of service - a neighbours tap (16%), public stand tap (42%), or well (2%) (Table 6-3).

In non-sewered areas, simple improved latrines were the predominant sanitation technology (56%) (Figure 6-1). Latrines were associated with LIHD areas, while all the households in HILD areas used septic tank systems. In terms of water supply, 100% of HILD households had individual water connections or private boreholes compared to only 27% of LIHD households.

Most LIHD households accessed water from a public stand tap (44%) or a neighbour (25%) (Table 6-3).

Individual household toilets were more common in sewered areas (64%) than non-sewered areas (36%). Bivariate logistic regression with a crude odds ratio (COR) (see Methodology section 3.7.5) helped show associations. The type of sanitation access (i.e., private or compound shared) was significantly correlated ($p < 0.0001$) with the urban setting. LIHD households were more likely to share their sanitation facility than MIMD and HILD households (Appendix E-2 and E-6). In sewered areas, shared toilets were mostly used by six or more household members (93%). The highest number of households reported using a shared toilet was 14 (Median = 3). The highest number of people using a shared toilet was 42 (Median = 13). In non-sewered areas, most shared toilets were used by six or more member households (95%). The highest number of households using a single toilet was 15 (Median = 3). The highest number of people using a toilet was 47 (Median = 15). Tenants were more likely to use a shared sanitation facility than landlords ($p < 0.0001$). In sewered areas, COR = 2.15, 95% confidence interval [CI]: 1.51 - 3.08 (Appendix E-2). In non-sewered areas, COR = 2.03, 95% CI: 1.62 - 2.55 (Appendix E-6).

6.4 Factors influencing connectivity to the sewerage network

Higher sewer connectivity rates facilitate higher self-cleansing flows within the network and reduce the TACC and TACH for the system (Chapter 4). Therefore, why do some households living in areas with sewerage not connect to the network? Further, does it tend to be households on high income who connect?

Only 24% of households in sewered areas were connected (Figure 6-1). Over half of the households (53%) reported a monthly income below the 2015 Lusaka average (ZMW 2,893 (US$ 276)), signifying that majority were low-income. The urban settings in this research are defined as having income levels above or below the city average. The 2015 average national monthly income reported was ZMW 1,801 ($ 171), with the extremely poor having a mean monthly income of ZMW 746 ($ 71) (CSO, 2015). Bivariate logistic regression with COR was used to test significance. Income level had a significant association ($p<.0.0001$) with the urban setting where a household resides (Appendix E-2). The odds of having an income lower than the city average and residing in a LIHD area were higher (COR = 3.30, 95% CI: 2.27 - 4.84). In LIHD areas, 72% of households had incomes lower than the city average. For households connected to sewers, 39% and 27% were residents in HILD and MIMD areas compared to only 9% in LIHD areas.

A multivariate logistic regression model was fitted to select predictors with the most influence on sewer connectivity (Methodology section 3.7.5). Table 6-4 presents the adjusted odds ratio (AOR[20]) of the factors significantly associated with household sewer connectivity in sewered communities of Lusaka.

Table 6-4. Factors associated with household sewer connectivity in sewered urban communities of Lusaka

Explanatory variable	Not connected % (n)	AOR (95% CI)
Availability of water supply		
Yes	52 (129)	1
No	75 (232)	1.98 (1.30 – 3.05) **
Urban setting		
MIMD/HILD	51 (190)	1
LIHD	91 (171)	8.24 (4.75 – 15.16) ***

**p < 0.001: ***p < 0.0001
Source: Lusaka Sanitation Mapping Assessment Survey

The odds of not connecting to the network were higher for households living in LIHD settings (AOR = 8.24, 95% CI: 4.75 - 15.16). Further, households without an available and reliable water supply also had increased odds of not connecting (AOR = 1.98, 95% CI: 1.30 - 3.05). Appendices E-1 and E-2 show the bivariate analysis. The stepwise selection of predictors and the final regression model are presented in Appendices E-3 and E-4. Household income

[20] Adjusted Odds Ratio (AOR) controlled for other predictor variables in the regression model. It explained variability between the predictors and controlled for confounding bias.

levels, level of education, living in a compound, the type of sanitation access, i.e., private or compound shared, and the household size were confounders.

At the city level, the characteristics of an area where a household lives appeared to have influenced the likelihood of having a sewer connection. The characteristic of the area influenced services provision. From the 18 sewered Wards analysed, five were LIHD areas compared to HILD (6) and seven MIMD areas. LIHD settings have the least sewer network reach compared to MIMD and HILD settings yet with the most population. MIMD and HILD areas are planned compared to LIHD areas that are unplanned regularised settlements. A household's socio-economic and demographic characteristics further influenced the connection to sewers. The highest proportion of unconnected households (91%) were residents in LIHD areas compared to MIMD (73%) and HILD (61%) areas. Higher sewer connectivity was more likely to be supported by households on higher incomes in MIMD and HILD areas than LIHD areas.

The area characteristic, i.e., LIHD, MIMD or HILD, influenced water supply provision and sewerage services. Higher levels of service (piped supply from the utility or private boreholes) were more prevalent in the planned MIMD (75%) and HILD (100%) areas than LIHD areas (40%) (Table 6-3). The availability and reliability of water supply were significantly associated with a households urban setting. There were increased odds of living in a LIHD setting and not having a readily available water supply (COR = 5.33, 95% CI: 3.55 - 8.16). LWSC or delegated providers such as Water Trusts provide water supply services to LIHD areas. Some households self-supply using boreholes. However, only 38% of households in LIHD areas had piped utility in-house or yard connections compared to 75% and 83% in MIMD and HILD areas. Lower service levels (public taps or drawing from neighbours) characterise LIHD areas, with supply often erratic for most households (58%). A reliable water supply is essential for the enhanced quality of life and the optimal functioning of sewerage. The low availability and unreliability of the water supply, especially in LIHD areas, was a significant factor influencing sewer connections. Simple improved latrines (dry sanitation) were the dominant sanitation option in LIHD settings (Figure 6-1).

Figure 6-2 summarises why households in sewered areas did not connect to the network. Connection costs were a constraint for 17% of households, while 13% used latrines inappropriate to connect in their current state. Households in the two categories had monthly incomes lower than the city average ($ 276). A sewer connection cost ranges from $276 to $480 (Chapter 4), equivalent to 12-14% of Lusaka's average annual household income. Further, the connection costs are equivalent to 23-40% of the 2018 annual Zambian minimum wage.[21]

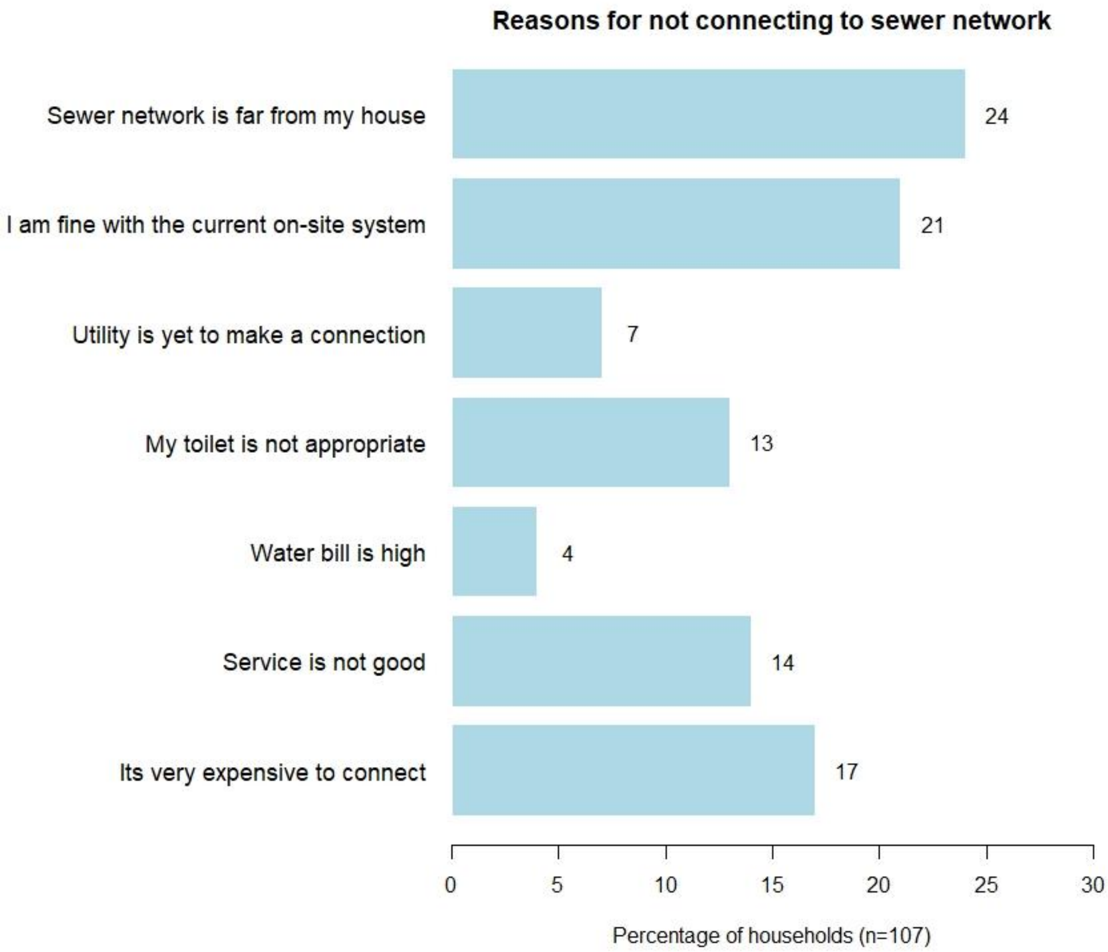


Figure 6-2. Household reported reasons for not connecting to the sewer network (Source: Lusaka Sanitation Mapping Assessment Survey)

Community-scale secondary sewer networks were not extensive; 24% of households were too far from the network to connect at an affordable cost.

[21] Statutory Instrument No.71 of 2018, set the minimum monthly wage at ZMW 1,050 (equivalent to $100) (The Minimum Wages and Conditions of Employment Act, 2018)

Connection costs are borne by households and are a function of the distance to the nearest point on the network. These households opted to continue using on-site systems to avert connection costs. The majority (57%) had sanitation facilities deemed appropriate to connect to the sewer network. At least 21% of households expressed satisfaction with their current on-site system; hence did not connect. Most households (90%) expressing satisfaction used water closets connected to septic tanks, with 86% having higher than the average city income. The constraint for these households was likely due to a non-extensive network, preventing the connection. A further 7% were awaiting LWSC to connect them, while 14% perceived the sewerage service by LWSC as not good. It highlights utility capacity limitations and overall challenges in enforcing connectivity regulations[22] in sewered areas (Chapter 5).

6.5 Factors influencing access to safely managed faecal sludge services

For households using on-site facilities, do most of them use a safely managed FSM service or not? Do they predominantly have a better socio-economic status? Only 12% of the sanitation facilities were reported to have ever filled up, with 41% emptying their system at least once, whether full or not. For households that emptied their facility, 59% reported using an unsafely managed service (informal provider and household member) (Figure 6-3). In non-sewered areas, only 27% reported a monthly income above the 2015 Lusaka average ($ 276), signifying that majority were low-income. Income had a significant association ($p<.0.0001$) with a household's use of an emptying service and the urban setting (Appendix E-6).

[22] Section 75, part 2(9) of the Public Health Act (1995) stipulates that a household using a cesspool or septic tank must connect when within 60.96 meters of the sewer network.

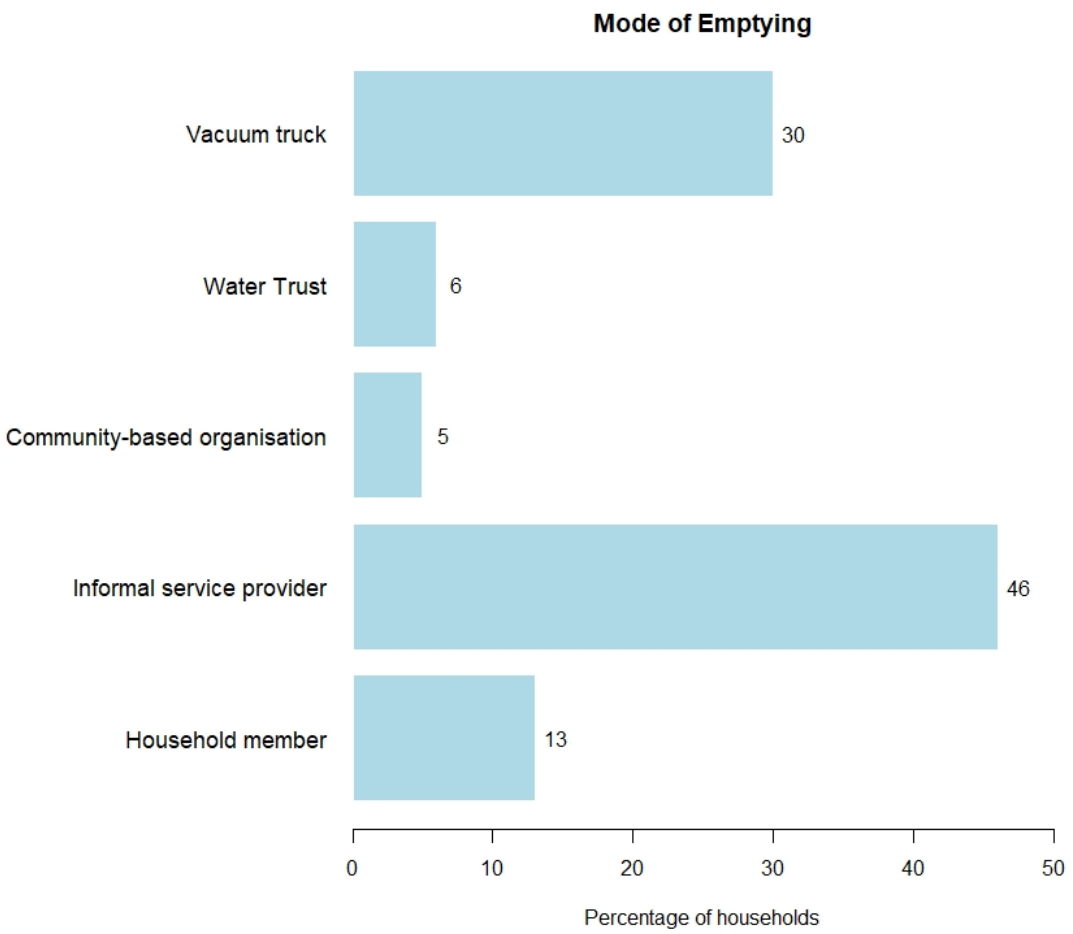


Figure 6-3. Household reported service used to empty containment (Source: Lusaka Sanitation Mapping Assessment Survey)

Table 6-5 presents multivariate logistic regression results for factors associated with households accessing a safely managed emptying service in Lusaka. Predictors associated with increased odds of accessing a safely managed emptying service were higher household income, being a landlord, and access to a reliable water supply. Other predictors include not living in a compound, not residing in a LIHD setting, and using an improved sanitation facility. Appendices E-5 and E-6 show the bivariate analysis. The stepwise selection of predictors and the final regression model are shown in Appendices E-7 and E-8. Level of education, household length of stay, the type of sanitation access, i.e., private or shared, and the household size were confounding factors.

Table 6-5. Factors associated with households using a safely managed emptying service in urban areas of Lusaka

Explanatory Variable	Access to a safely managed emptying service % (n)	AOR (95% CI)
Income-level		
≤ ZMW 2,893 ($ 276)	40 (358)	1
> ZMW 2,893 ($ 276)	61 (257)	1.42 (1.08 – 1.88) *
Living arrangement		
Rented	28 (152)	1
Owned	59 (462)	3.77 (2.89 – 4.95) ***
Availability of water supply		
No	39 (405)	1
Yes	71 (210)	2.52 (1.82 – 3.52) ***
Not living in a compound		
No	43 (286)	1
Yes	49 (329)	1.29 (1.01 – 1.66) *
Urban setting		
LIHD	43 (460)	1
MIMD/HILD	60 (155)	1.50 (1.06 – 2.11) *
Type of sanitation facility		
Unimproved	6 (7)	1
Improved	51 (615)	16.00 (7.45 – 41.74) ***

*p < 0.05: ***p < 0.0001
Source: Lusaka Sanitation Mapping Assessment

High-income earning households were more likely to access a safely managed emptying service (AOR = 1.42, 95% CI: 1.08 - 1.88). Most households (61%) in MIMD and HILD areas had incomes above the $276 city average. These households were more likely to procure safely managed services than most LIHD households (68%) on lower incomes. Informal FSM service providers in LIHD settings were hired by 46% of households. Informal providers use unsafe emptying methods, dump the waste in the open environment or bury it in a pit within the yard or compound. Informal providers offer cheaper services than the formalised providers who safely empty, transport, and/or treat waste. Fees charged by informal emptiers range from $14 to $48 per emptying event. The average fees are 2% of the median annual income ($2,052) for LIHD households. On average, containments are emptied every 2-3 years (Chapter 4). Fees charged by formalised providers range from $57 (Water Trusts) to $171 (VTOs) per emptying event and are equivalent to 3-8% of the annual median LIHD household income. Water Trusts offering FSM services are only available in two LIHD areas.

Being a landlord increased the likelihood of accessing a safely managed emptying service (AOR = 3.77, 95% CI: 2.89 - 4.95). The sampled population had a larger proportion of landlords (58%) than tenants (42%). When containments were full, 75% of landlords expressed willingness to empty their facilities compared to only 24% of tenant households. Most tenants (55%) informed their landlord when their containment was full, and these were predominantly from LIHD areas. House ownership was an essential element in procuring services, with landlords in most instances having more autonomy than tenants in decision making.

Not living in a compound increased the odds of using a safely managed emptying service (AOR = 1.29, 95% CI: 1.01 - 1.66). A household could be living in a compound and yet use a private toilet facility. The use of private facilities gave autonomy to the household in the choice of sanitation service to procure. Not living in a compound increased the likelihood of private toilet use or ownership (COR = 1.61, 95% CI: 1.30 - 2.01). Living in a compound primarily signifies sharing toilet facilities and was more common in LIHD areas where 64% of households shared facilities. There was a significant association ($p < 0.0001$) between the type of access, i.e., private or shared, and the use of a safely managed emptying service. Privately used facilities were more likely to be safely emptied than shared facilities (COR = 1.66, 95% CI: 1.34 - 2.07).

The use of an improved sanitation facility increased the odds of accessing a safely managed emptying service (AOR = 16.00, 95% CI: 7.45 - 41.74). There were variations in the types and quality of construction of facilities, mainly in LIHD areas. Observations of latrines in LIHD settings showed that they are not built to be emptied as there was no provision for faecal sludge removal. When emptying, a part of the structure is broken off to access the faecal sludge. In MIMD and HILD settings, septic tanks were the predominant technology in use.

Accessing a safely managed emptying service was significantly correlated with having a reliable water supply (AOR = 2.52, 95% CI: 1.82 - 3.52). For 28% of households using water-borne on-site sanitation systems, a reliable water supply was essential in making the system functional.

6.6 Summary of key findings and their interpretation

Several factors influence household sewer connectivity and access to safely managed faecal sludge services in Lusaka's urban settings. The key social and service-orientated factors are summarised. These challenges are addressed in more detail in Chapter 8.

6.6.1 Drivers of household sewer connectivity

The most influential factors on sewer connectivity were the urban setting a household lived in, specifically income levels (a proxy for wealth), demographics, water supply availability and reliability.

Sewerage services are prevalent in the more planned areas than those primarily unplanned, with a considerable proportion of households relying on on-site sanitation systems. Sewer connectivity rates were higher in MIMD and HILD areas than LIHD areas. Sewer connection costs were 12-14% of Lusaka's average annual household income and constrained 17% of households in sewered communities. Sanitation facilities were not appropriate to connect for 13% of households, with the cost to build a water closet a likely constraint. Investment in sanitation services was more likely to be supported by higher-income households, aligning with findings by Mills et al. (2020) and Bolaane and Ikgopoleng (2011), thus facilitating the higher sewer connectivity rates in MIMD and HILD areas compared to LIHD areas. The network's reach (coverage) was a constraint for 24% of households in sewered communities. The non-extensive network was a reason for a larger proportion of households not connecting.

For the optimal functioning of sewerage, a reliable water supply was essential. However, water service levels were disproportionately lower in LIHD areas than in MIMD and HILD areas, corroborating Meehan et al. (2020). Most residents in LIHD areas (58%) were dependent on neighbours and public stand taps for water supply. Improved water accessibility would encourage investment in water closets and increase the likelihood of household sewer service uptake. Sanitation services need to be delivered with complementary services such as water supply to facilitate operations and good hygiene. For all population segments, every household member needs at least 70 litres day^{-1} (including water for sanitation needs)[23] for a good quality of life. As community demand pushes towards sewerage, the reliability and predictability of services are needed, with adequate water supply a key driver of this delivery. Therefore, this water needs to be managed with the sanitation system part of its management.

6.6.2 Drivers of household access to safely managed faecal sludge services

The factors influencing households in accessing a safely managed faecal sludge service were being a landlord, having a high income, and having a reliable water supply. Other factors were not living in a compound, not residing in a LIHD setting, and using an improved sanitation facility.

Access to safely managed services was more likely for households on higher incomes and those living in MIMD and HILD settings. Fees for safely managed emptying services were up to 8% of the median annual income of LIHD households. Informal emptying services cost 2% of the median annual LIHD household income, with households opting for these cheaper services. The choice of emptying service was linked to a household's socio-economic and demographic status when procuring a faecal sludge service. In LIHD areas, the current low demand for safely managed services affects the operational viability of services, aligning with Peletz et al. (2020) and has implications on service delivery outcomes.

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[23] WHO (2011). Technical notes on drinking-water, sanitation and hygiene in emergencies. https://www.who.int/water_sanitation_health/publications/2011/tn9_how_much_water_en.pdf

House ownership was a significant factor in accessing safely managed emptying services. The analysis showed that tenants were transient and less likely to invest in sanitation, corroborating findings by Scott et al. (2013) and Ssemugabo et al. (2020). Only 24% of tenants emptied their containments when full, with the majority (55%) informing their landlords. Landlords have more autonomy in decision-making than tenants; hence could be compelled to ensure the use of safely managed emptying services. The effect of cost and tenure status as drivers constraining access to improved sanitation is consistent with Foggitt et al. (2019), Schütz (2019) and Günther et al. (2011). Sharing facilities, renting, and living in a compound significantly reduce the likelihood of using a safely managed emptying service. Hence, landlords have an essential role in the use of services. Policies on housing and their enforcement should mandate house owners to provide improved facilities. The proposed sanitation by-law (Local Government Act, 2019) is a step in realising this; however, it should be backed up with enforcement.

Overall for sewered and non-sewered services, affordability can be analysed as a correlation between costs and household disposable income (e.g. Potter et al., 2011; Smets, 2012). The analysis showed that containment costs dominate, placing a higher burden on households. For example, sewer connection costs averaged 13% of the city's average annual household income, considered unaffordable when benchmarked against the 4-5% affordability threshold applied by institutions such as the World Bank, OECD and AfDB (Hutton, Guy 2012). As a result, unaffordability limits households accessing improved services. Therefore, well-structured and targeted subsidies would help ensure household access to safely managed services. Consequently, subsidising excreta management is justified due to the public health benefits beyond individual private benefits, as Jenkins and Sugden (2006) noted.

It is essential to understand and consider household socio-economic and demographic characteristics when providing sanitation services across different urban settings. Arising from the drivers highlighted in accessing sewered and non-sewered sanitation solutions must be adapted to deliver inclusive services effectively (Chapter 8).

Chapter 7: Approach to city-level safely managed sanitation optioneering

7.1 Introduction

This chapter presents the approach for generating strategic options to scale citywide sanitation access and services in Lusaka. Also, the chapter briefly puts into context the research within the urban sanitation planning literature. The development of sanitation approaches has led to various system choices influencing decision support methodologies and assessments (Agudelo et al., 2007). In developing urban areas, identifying the appropriate sanitation systems may be challenging when conventional solutions do not fit the local context (Spuhler et al., 2018). Also, the systematic generation of decision options is a substantial weakness facing planning and decision-making in these developing settings (Hajkowicz and Collins, 2007; Spuhler et al., 2018). Further, the diversity of available technologies, the multiple sustainability dimensions, and corresponding criteria are often not sufficiently considered (Spuhler et al., 2018). The scenario highlights the multi-dimensional aspect of sanitation systems planning and the importance of trade-offs (Zurbrügg et al., 2009).

Strategic decision making is premised on long term planning (Ishizaka and Nemery, 2013). However, the challenge decision-makers face is linking local needs with system characteristics, implying different solutions may fit any given context (Agudelo et al., 2007). The importance of urban sanitation is evident in the evolution of approaches that put human dignity, the quality of life and environmental protection at the centre of planning (Schertenleib et al., 2021). Several planning approaches have been proposed for developing urban areas. They include the Strategic Sanitation Approach (SSA) (Wright, 1997; Tayler et al., 2003), the Household-Centred Environmental Sanitation (HCES) (EAWAG and WSSCC, 2005), Community-Led Urban Environmental Sanitation (CLUES) (Lüthi et al., 2011). Others are the Open Planning of Sanitation Systems (OPSS) (Kvarnström and Petersens, 2004), City Sanitation Planning (CSP) and Sanitation 21 (Parkinson et al., 2014), among others.

The SSA responds to demand, demonstrated by community participation in planning, management, and willingness to pay for services (Kennedy-Walker, Ruth et al., 2014). The outcome is the unbundling of different sanitation service solutions in different parts of the city across the entire value chain. The HCES combines bottom-up and top-down planning approaches with the city allocated into spatial zones, emphasising reuse and focusing on the enabling environment (EAWAG and WSSCC, 2005). CLUES is a multi-actor approach that focuses on area-based and demand-responsive planning with community-level participation while highlighting the importance of the enabling environment (Schertenleib et al., 2021). OPSS uses a cross-cutting stakeholder approach to provide sanitation by evaluating the different system option consequences (Kvarnström and Petersens, 2004). CSP prioritises investments and selects the most viable options for citywide sanitation planning. The Sanitation 21 framework guides stakeholders to develop appropriate and cost-effective solutions while considering user demands and institutional constraints.

Despite these various well-established sanitation frameworks, all of which highlight the likelihood that adequate sanitation will rely on various systems or technology types being deployed. In reality, planning still often follows a 'one-size-fits-all approach' (Spuhler and Lüthi, 2020) and uptake at scale still lags (Schertenleib et al., 2021). The challenge most urban sanitation planning approaches face is the effective representation of highly heterogeneous communities with economic and social disparities in urban services provision (Schertenleib et al., 2021). Stakeholders within the sector have since formulated the Manila Citywide Inclusive Sanitation (CWIS) Principles (Gambrill et al., 2020; Schrecongost et al., 2020) to highlight further the need to provide both sewered and non-sewered services encompassing all city areas. CWIS does not introduce new principles but picks on lessons learned from past approaches by framing them to specifically address the current sanitation challenges within a city (Schertenleib et al., 2021).

The environment enabling the development of strategic plans needs to answer the questions: 'Where are we now?', 'Where do we want to be?' and 'How do we get there?' (Schertenleib et al., 2021, p. 13). A conducive enabling environment is essential for planning to succeed in practice (EAWAG and WSSCC, 2005). It helps deal with incentives and demand-based focus (Colin et al., 2009; Peal, AJ et al., 2010). The enabling environment is critical in emphasising empowerment, equity, trust, and learning for planning to be successful (Reed, 2008; Kennedy-Walker, Ruth et al., 2014). Further, it promotes the "scaling-up concept" and "the whole system approach" (Schertenleib et al., 2021).

Most research has focused on understanding the context or selecting a preferred option, assuming appropriate sanitation options are already available (Spuhler and Lüthi, 2020). However, selecting appropriate sanitation options involves using multi-criteria decision-making that combines diverse technologies and stakeholder preferences (Kvarnström and Petersens, 2004; Zurbrügg et al., 2009). For example, selection criteria may include health, environmental protection, technical and institutional fit, financial viability, and socio-cultural acceptance (Spuhler and Lüthi, 2020). Therefore, to be inclusive and achieve citywide services, sanitation solutions need to respond to the different urban realities within a given context.

7.2 Overview and selection of decision-making methodologies

7.2.1 Decision-making methodologies

Decisions are made among alternatives to maximise benefits. Roy (1981) identifies four types of problems in decision-making. They include the choice problem, which aims to select the best option; the sorting problem sorts options into organised categories and regrouped into options with comparable characteristics for predictive reasons. The ranking problem orders options through scores or pairwise comparisons, while the description problem describes options and their consequences.

In practice, several methodologies are used in decision-making. The cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis are discussed. Figure 7-1 presents the decision tree of possible methodologies within the decision-making domain.

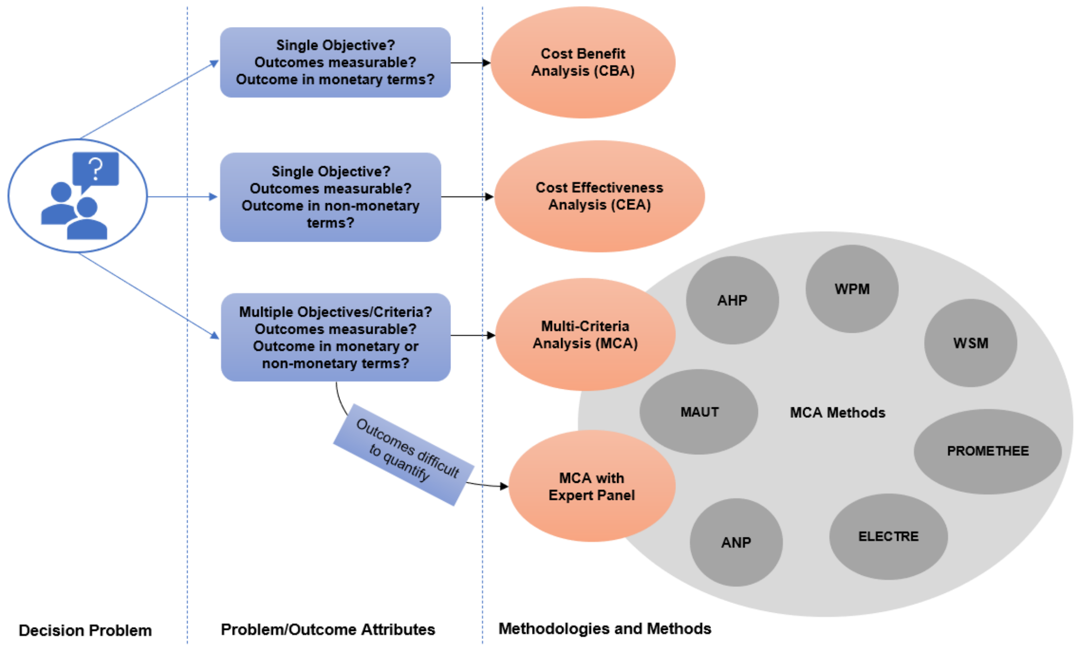


Figure 7-1. Decision tree of possible approaches used within decision-making domains (Adapted from UNFCCC, 2011; Boyd and Hunt, 2004). Analytical hierarchy process (AHP), analytical network process (ANP), weighted product method (WPM), weighted sum method (WSM), Preference Ranking Organisation METhod for Enrichment Evaluations (PROMETHEE) and Multi-attribute utility theory (MAUT).

Cost-benefit analysis (CBA) emerged from economic theory applications and can be categorised as financial, economic, or social. In practice, economic and social CBA are economic analyses (Irvin, 1986). CBA examines policy options by evaluating the costs and benefits to identify the most efficient (Haque, 2016) and is mainly used without value judgments. Value judgement in CBA raises a degree of subjectivity. Therefore, the criteria and value judgements in CBA should be made explicit for transparency (Snell, 1997). The use of CBA implies having costs and benefits in a 'common' unit of measure. However, decision-making based on costs and benefits can be complicated and challenging to execute when considering multi-dimensional problems as the costs and benefits may not be accurately quantifiable (Stevens and Michalski, 1993; Snell, 1997). Therefore, only quantifiable factors can be included in CBA.

Cost-effectiveness analysis (CEA) has wide application in health policy and economics. The method helps choose the outcomes with the least cost (Levin and McEwan, 2000). CEA is primarily applied when it is difficult to express all the benefits in monetary terms or value economically, but costs can be quantified (Snell, 1997). The approach is limited as it does not consider other dimensions such as co-benefits, equity and feasibility (Haque, 2016). CEA has an advantage over CBA because benefits may not need to be explicitly valued in some cases (Boyd and Hunt, 2004). CEA and CBA inform resource allocation decisions (McEwan, 2012). However, the financial or economic value may not be the only consideration for decision-making.

Multi-criteria analysis (MCA) emerged from the psychology, engineering, and management science disciplines and was developed explicitly as a decision-making tool. MCA is an approach for structuring multi-dimensional decision problems and alternatives to generate and aggregate preferences (Myšiak, 2006). MCA integrates multiple objectives in a quantitative analysis without assigning monetary values to all factors (Boyd and Hunt, 2004). MCA reflects judgements (Watson, 1981) and improves the transparency and analytic rigour of decision-making processes (Dunning et al., 2000).

Table 7-1 presents the strengths and weaknesses of each decision-making methodology. A distinction between methodologies is whether the analysis is a quasi-objective representation of reality or simply an aid for decision-makers (Watson, 1981). CBA and CEA are similar in approach but differ in quantifying the benefits. CBA gives an objective model of the context, while MCA represents the decision-makers subjective preferences. MCA helps overcome selective and biased tendencies (Myšiak, 2006) and provides a more satisfactory approach to handling uncertainty. In contrast, CBA applications disregard uncertainty or explore it by sensitivity analysis (Watson, 1981).

Table 7-1. Strengths and weaknesses of decision-making methodologies

Methodology	Strengths	Weaknesses
Cost-benefit analysis	- Simplifies complex quantifiable decisions - It gives clarity to unpredictable decision problems - It is easy to compare outcomes - It helps overcome biases	- Only quantifiable factors can be analysed; hence does not account for all variables - Potential inaccuracies in identifying and quantifying costs and benefits - It monetises non-market goods and does not account for equity
Cost-effectiveness analysis	- It does not require the economic valuation of benefits - It aids decision-making based on efficient resource allocation - Allows for comparison of interventions achieving the same outcome	- It does not explicitly deal with uncertainties - It relies on a single metric when comparing options - May exclude other potential benefits or outcomes
Multi-criteria analysis	- It integrates qualitative and quantitative multiple objective criteria in analysis - It shows the relative importance of each attribute - Ideal for handling uncertainty - It provides a structured framework for combining expert judgement and stakeholder preferences	- It has no analytical technique to compare impacts - It is weak when making inter-temporal comparisons - Analysis of uncertainty will usually remain subjective and qualitative

CBA ignores distributional effects by masking inequities between those bearing the costs and those receiving the benefits. In contrast, MCA considers equity by explicitly showing the relative importance of attributes. CBA associates a value (usually monetary) with each different kind of benefit, with benefits added together in problems with conflicting objectives. The limitation of CBA is the use of only one criterion or objective with the assessment expressed in monetary terms (Haque, 2016). The approach is a drawback when dealing with a multi-dimensional problem as it assumes the utilities are linear and additive. MCA considers both quantitative and qualitative criteria compared to CEA and CBA (Haque, 2016). MCA scores or ranks the performance of alternative decision options against multiple criteria in different units (Sadiq and Tesfamariam, 2009).

In summary, multiple criteria assessments in the decision-making process are needed to make sustainable and inclusive strategic decisions. Service delivery decisions go beyond economic or financial valuation, measured in monetary terms. Other decision objectives expressed through quantitative non-monetary or qualitative indicators are equally essential. Therefore, a combination of several criteria is needed to overcome decision challenges in each local context. Because decision-making involving several criteria can be complicated (Ishizaka and Nemery, 2013), MCA helps analyse different alternatives with conflicting criteria and makes trade-offs (Zanghelini et al., 2018). Therefore, MCA is useful for multi-dimensional decision-making that may involve technical, social, institutional, economic, and environmental indicators.

7.2.2 Application of multi-criteria analysis

MCA has been applied in sanitation studies. The studies include; technological innovation and user acceptance in East Africa (Hendriksen et al., 2011), WaSH planning in rural Kenya (Ezbakhe and Perez-Foguet, 2018), technology selection in South Africa (Salisbury et al., 2018), choice of sanitation technology and urban water quality in Burkina Faso (Yiougo et al., 2012), sanitation systems planning (Maurer et al., 2012). In most cases, the analysis is tailored to sanitation facilities than overall sanitation systems. This research explores the use of MCA for strategic sanitation planning to prioritise the scaling-up of citywide services. The assessment is conducted within the MCA methodological framework, allowing normative judgment using a ‘simplified planning approach’ to make strategic decisions reasonably quickly.

7.2.3 Multi-criteria analysis methods

MCA provides an approach to decision-making by ordering alternatives based on various criteria. The methodology is widely applicable through participatory processes (Chowdhury and Rahman, 2008) by integrating information and stakeholder values (Kabir et al., 2014). It provides a framework for collecting, storing, and processing relevant information from various sources (Hendriksen et al., 2011). MCA quantifies non-monetary factors to compare alternative courses of action (Huang et al., 2011) and is easily adaptable to local contexts (Fall et al., 2009).

Table 7-2 highlights the various methods used when conducting MCA. There are different ways of choosing appropriate MCA methods to solve specific problems. One way is by looking at the required input information (data and parameters), the modelling effort (which defines the richness of output), outcomes and their level of detail (Ishizaka and Nemery, 2013). According to Myšiak (2006), MCA methods differ based on the following:

- Underlying theory, e.g. value or utility versus outranking methods.
- Approach pursued i.e. generation of trade-offs versus elicitation of value judgments, priori methods versus progressive or interactive methods.
- Assumed form of multi-criteria preference function, e.g. non-additive versus additive versus non-linear; and
- Elicitation of value judgments, i.e. direct assessment versus trade-offs.

Table 7-2. Selected MCA methods and their characteristics

Method	**Characteristics**
Weighted sum model (WSM)[1] Weighted product model (WPM)[1]	- A common approach for single-dimensional problems - Not suited for problems with different criteria or variables - All criteria variables have the same dimensions - Normalisation is required when solving multi-dimensional problems, which is considered a weakness.
Analytic hierarchy process (AHP)[2]	- Suited when the importance of preferences or weights of the criteria and alternatives is required - The decision problem is structured with pairwise comparisons made - The criteria and alternatives are considered independent - Applicable for either single or multiple problems as it incorporates both qualitative and quantitative criteria - Suffers information loss due to compensation on criteria

Method	Characteristics
Analytic network process (ANP)[3]	- Similar to AHP; however, the difference is that there are interdependencies among the criteria
ELECTRE[4]	- Preferred for decision problems based on the definition of outranking relations between alternatives that use pairwise comparisons - Applicable with missing information and when there are incomparable alternatives and incorporates uncertainties - Applicable to quantitative and qualitative attributes
PROMETHEE[5]	- Uses a finite set of alternative actions, ranked, and selected among conflicting criteria - No normalisation is required and applicable with missing information.
Multi-attribute utility theory (MAUT)[6]	- Evaluates value (what people want) and expert judgments needed for public policy decisions. - Construction of the utility function requires much effort

[1]Evangelos (2000); Fishburn (1967); Kabir et al. (2014); Miller (1963); [2]Saaty, T. (1980); Kabir et al. (2014): [3]Ishizaka and Nemery (2013): [4]Kabir et al. (2014); Ishizaka and Nemery (2013): [5]Brans and Vincke (1985); Kabir et al. (2014): [6]Dunning et al. (2000); Ishizaka and Nemery (2013).

The description above shows two main MCA methods: firstly, value-oriented methods, which transform options into perceived value or utility, such as AHP, ANP and MAUT; and secondly, outranking methods that incorporate incomplete and inconsistent preferences such as ELECTRE and PROMETHEE. The utility function measures the desirability or the preference of options (alternatives). An advantage to defining utility functions is that it permits having a global score in which options are compared by ranking them from best to worst (Ishizaka and Nemery, 2013). A good score in value-oriented approaches can compensate for a poor score on one criterion, allowing full aggregation or complete ranking.

For outranking methods, the options are compared two-by-two using a preference degree. The preference degree reflects the suitability of one option over another. However, some options may be incomparable as they may have different profiles (Ishizaka and Nemery, 2013). The incomparability, a consequence of the non-compensatory aspect of the methods, may mean complete ranking is not always possible - leading to a partial ranking.

If the ‘utility function’ of an independent criterion is known, MAUT is recommended. However, the construction of the utility function requires a lot of effort (Ishizaka and Nemery, 2013). An alternative approach is pairwise comparisons between independent criteria and options, which the AHP method supports. ANP uses pairwise comparisons of criteria that have interdependencies. The difference is that the evaluation of comparisons is on a ratio scale for AHP and ANP. MAUT uses a utility score which shows the degree of well-being the options provide to the decision-maker (Ishizaka and Nemery, 2013). For selecting citywide high-level sanitation service options, the approach would be structured by rank ordering of options with pairwise comparison to ascertain performance against set criteria that are independent.

7.3 How AHP works - illustrated by a worked example

AHP is advantageous when the decision-maker cannot construct a utility function. AHP mainly uses a three-step process to obtain the ranking of alternatives. These include:

1. Structuring the problem
2. Evaluating scores or priorities based on pairwise comparisons
3. A consistency check.

Step (3) is optional but recommended to confirm the robustness of the results. It is common in methods using pairwise comparisons (Ishizaka and Nemery, 2013). For the rest of this section, a car selection problem (case study) is considered to illustrate the different steps of the AHP.

7.3.1 Problem structuring

The decision problem is structured according to a hierarchy and priorities through pairwise comparisons. The principal element of the hierarchy is the goal of the decision, with the second level representing the criteria. If included, the third level may represent sub-criteria while the lowest level represents the alternatives. The decision problem for the case study is ‘which car to buy’ based on three criteria: quality, safety, and design. There are four alternative cars to choose from: A, B, C and D (Figure 7-2).

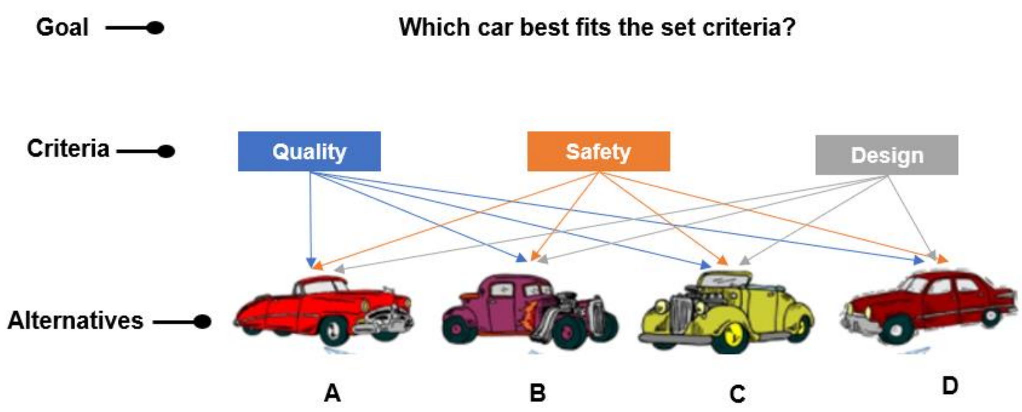


Figure 7-2. Structuring of a decision problem in AHP (Adapted from 123ahp.com)

Figure 7-2 represents the hierarchy required to solve a problem with AHP. Prioritisation depends on the context and the decision-maker.

7.3.2 Priority calculation

A priority or score ranks the importance of the alternative or criterion in the decision. Three types of priorities are calculated:

- **Criteria priorities**. Criterion importance with respect to the goal
- **Local alternative priorities**. Importance of an alternative with respect to one specific criterion; and
- **Global alternative priorities**. Criteria and local alternative priorities are intermediate results used to calculate global alternative priorities. The global alternative priorities rank alternatives with respect to all criteria and the overall goal.

The criteria and local alternative priorities are calculated using the same technique. Pairwise comparisons are generally evaluated on a 1–9 scale. Table 7-3 presents the conversion from a verbal to a numerical scale. Ishizaka and Nemery (2013) argue that a smaller scale, say 1–5, would not give the same level of detail in a data set and that the decision-maker would be lost using a larger scale. For example, scaling 1–100, it is difficult for the decision-maker to distinguish between a score of 62 and 63 (Ishizaka and Nemery, 2013). In practice, there is no fixed rule, with other scales proposed.

Table 7-3. The 1-9 rating scale used to make judgements on criteria and alternatives

Numerical rating	Verbal judgements
1	- Equally preferred more important or preferred
2	- Equally to moderately more important or preferred
3	- Moderately preferred more important or preferred
4	- Moderately to strongly more important or preferred
5	- Strongly preferred more important or preferred
6	- Strongly to very strongly more important or preferred
7	- Very strongly preferred more important or preferred
8	- Very strongly to extremely more important or preferred
9	- Extremely more important or preferred
Reciprocals of above	- If activity ***i*** has one of the above non-zero numbers assigned to it when compared with activity ***j***, then ***j*** has the reciprocal value when compared with ***i***

The numerical ratings and verbal judgements adapted from Saaty, T.L. (2008)

Table 7-4 shows the case study pairwise comparison matrix between the criteria using the rating scale in Table 7-3 above. Comparisons on the main diagonal are **1** because a criterion compares with itself. The matrix is reciprocal because the upper triangle is the reverse of the lower triangle. For example, Design is **1/4** as important as Quality and Quality is **4** times as important as Design. To derive the overall local priorities requires weighting the comparison matrix. This is done by adding the values in each criterion (or alternative) column to obtain a sum. Then each pairwise comparison is divided by the sum to obtain a weighted matrix. For example, in the quality criterion column (Table 7-4), the sum is **1.58,** which when divided by the design vs quality value (**1/4)**, the weighted design vs quality value is **0.16**. From the weighted matrix, the overall local priorities are obtained by averaging the value of each row. For example, the local priority for the quality criteria is the average of 0.63, 0.67 and 0.57, which is **0.62**.

Table 7-4. Pairwise comparison and weighted matrix to obtain criteria local priorities

	Quality	Safety	Design	
Quality	**1**	3	4	
Safety	1/3	**1**	2	
Design	1/4	1/2	**1**	
Sum	**1.58**	**4.50**	**7.00**	
Weighted Matrix				**Local Priorities**
Quality	0.63	0.67	0.57	**0.62**
Safety	0.21	0.22	0.28	**0.24**
Design	0.16	0.11	0.14	**0.14**

A similar approach for obtaining criteria priorities is taken to derive local priorities for the cars to choose from, i.e., cars A, B, C and D (alternatives). Each car has its quality and safety rating and design specifications. Table 7-5 shows the pairwise comparison and weighted matrix to obtain local priorities for alternatives with respect to the criteria. In AHP, comparisons involving quantitative criteria such as cost, higher costs are less preferred and desirable. Therefore, quantitative criteria are inverted by taking the reciprocal of each alternative, then dividing each cell by the sum of that criterion to derive the local priorities.

Table 7-5. Pairwise comparison and weighted matrix to obtain alternatives local priorities with respect to the criteria

	Quality				Safety				Design			
	A	B	C	D	A	B	C	D	A	B	C	D
A	**1**	4	2	3	**1**	1/5	1/4	1/2	**1**	1/4	1/7	1/8
B	1/4	**1**	1/2	3	5	**1**	2	3	4	**1**	1/4	1/5
C	1/2	2	**1**	1	4	1/2	**1**	2	7	4	**1**	1
D	1/3	1/3	1	**1**	2	1/3	1/2	**1**	8	5	1	**1**
Sum	**2.08**	**7.33**	**4.50**	**8.0**	**12.0**	**2.03**	**3.75**	**6.50**	**20.0**	**10.25**	**2.39**	**2.32**
Weighted Matrix												
A	0.48	0.54	0.44	0.37	0.08	0.10	0.07	0.08	0.05	0.02	0.06	0.05
B	0.12	0.14	0.12	0.37	0.42	0.49	0.53	0.46	0.20	0.10	0.10	0.09
C	0.24	0.27	0.22	0.13	0.33	0.25	0.27	0.31	0.35	0.39	0.42	0.43
D	0.16	0.04	0.22	0.13	0.17	0.16	0.13	0.15	0.40	0.49	0.42	0.43
Local Priorities												
A	**0.46**				**0.08**				**0.04**			
B	**0.19**				**0.47**				**0.12**			
C	**0.21**				**0.29**				**0.40**			
D	**0.14**				**0.15**				**0.43**			

Calculation of the overall priority uses the local priority of each alternative, which is multiplied by its criterion weight. The resulting weights for each alternative are added to synthesise the overall priority. For example, Car A the overall priority is (0.62 x 0.46) + (0.24 x 0.08) + (0.14 x 0.04) = **0.31** (Table 7-6).

Table 7-6. Global and local weights, priorities, and overall priorities for the criteria and alternatives

Criteria	Quality (0.62)	Safety (0.24)	Design (0.14)	Overall Priority
Car A	0.46	0.08	0.04	**0.31**
Car B	0.19	0.47	0.12	**0.25**
Car C	0.21	0.29	0.40	**0.26**
Car D	0.14	0.15	0.43	**0.18**

The overall priorities for the alternatives (which sum to 1) help select the most preferred alternative or determine the relative value of the alternatives. Table 7-6 shows the model synthesis for each alternative following the convention of showing the local priorities of alternatives (cells) and the weights for each criterion (at the top of each column) (Mu and Pereyra-Rojas, 2017).

7.3.3 Consistency check

A consistency check may be performed to detect possible contradictions in the entries when the matrix is complete. For example, when several successive pairwise comparisons are presented, they may contradict each other. The reasons for these contradictions could be vaguely defined problems, a lack of sufficient information or uncertain information (Ishizaka and Nemery, 2013). AHP allows up to 10% inconsistency.

Since AHP requires collating several weightings and more than one set of data, it is common practice to use proprietary software. In this case, Microsoft Excel (Version 2016, Redmond, Washington: Microsoft Corporation) was used to compute the comparison and weighted matrices. Super Decisions (Version 3.2, Creative Decisions Foundation, 2021) was used to check the consistency.

7.4 Option selection for city-level sanitation planning

A combination of social, institutional, financial, and technical decision-making criteria is needed to overcome sanitation provision challenges (Hendriksen et al., 2011). Criteria can be structured through a decision hierarchy that explicitly identifies, specifies and ranks the various criteria (Hummel et al., 2014).

The goal is to establish a simplified approach for comparing strategic sanitation service options at the city level. In this study, a pragmatic decision was taken to limit the criteria to three; cost, fit with the enabling environment, and the community responsiveness or acceptability of each option. Different decision-makers - the sanitation utility, local and central government, the community, financing institutions, project promoters and consultants - might have differing views of the relative importance of each of these three criteria.

A multi-criteria strategic planning approach was developed to manage the range of priorities of the different stakeholders. Since stakeholders may have differing priorities for the selection criteria and the decision-making process is likely to be extremely complex, all possible options are considered. For this reason, it is helpful to select a set of ‘boundary cases’ or interventions which represent the most extreme solutions to the problem. Figure 7-3 shows the construction of these cases. The use of extreme solutions in AHP simplifies a complex multi-criteria decision problem among extremes on a continuum (Pérez, 1995) by structuring the problem with the hierarchy created, helping the decision-maker identify the optimal solution (McQuail, 1993).

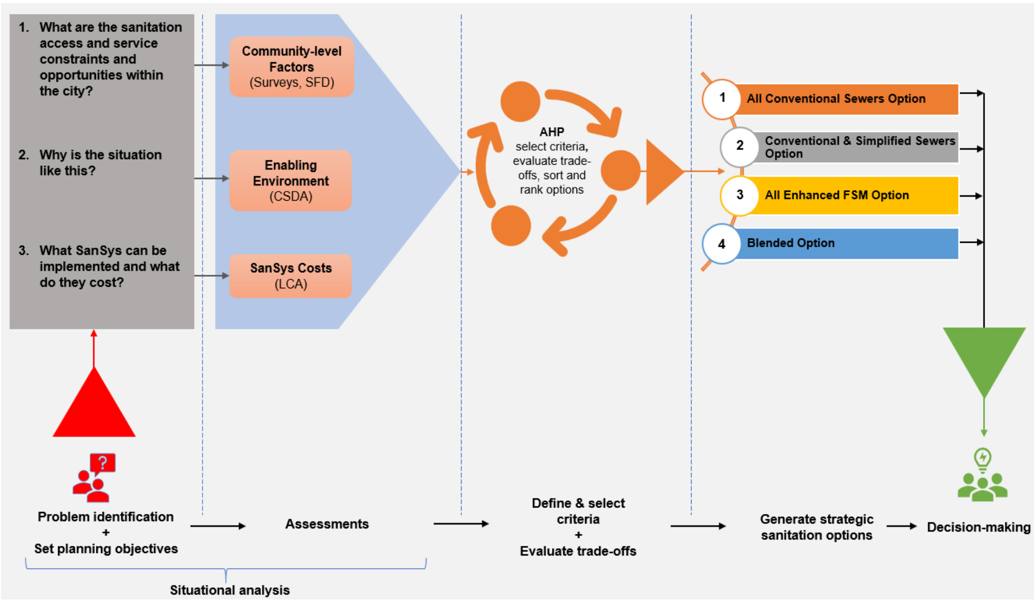


Figure 7-3. Overview of the approach to generate strategic sanitation options (Author’s own). Faecal waste flow diagram (SFD), city service delivery assessment (CSDA) and life-cycle costing assessment (LCA).

Analysis of the boundary cases illustrates a path towards a rational, balanced solution that in reality may comprise elements of each extreme case. The boundary cases are represented by:

1. Moving all households to conventional sewerage.
2. Moving all households to a combination of simplified and conventional sewerage.
3. Moving all households to enhanced (well managed) FSM.

Case 1 would require even households using effective FSM services to move to conventional sewerage. Similarly, each of the other cases represents populations moving from one ‘working’ solution to another. In reality, parts of the population could most efficiently retain their current type of service, even when improved services are rolled out in other parts of the city. Once a clear analysis of the performance of each boundary case has been completed, it should be possible to construct an optimum blended solution that works close to optimally in all parts of the city (Case 4).

7.5 Selection of the AHP criteria in the case of Lusaka

For the AHP analysis, the value judgements used to ascertain the performance of the sanitation options are based on cost analysis (Chapter 4), the enabling environment (Chapter 5), and community-level responsiveness (Chapter 6). The AHP method supports the approach where structured alternative solutions are sorted and compared against set criteria. As an outcome, the research presents the decision-maker(s) with optimal solutions that can be selected for implementation based on what they prioritise. Table 7-7 presents the criteria and sub-criteria used to ascertain the performance of the sanitation options.

Table 7-7. Criteria used to generate city-level strategic sanitation options

Goal	**To generate city-level strategic sanitation options**	
Criteria	Sub-criteria	Description of Sub-criteria
1. Cost	- Annualised investment costs (CapEx) - Annualised recurrent costs (O&M)	- Total capital, operational and maintenance system costs system per year ($2018)
2. Enabling Environment	- Policy and legislation - Institutional roles and capacity - Monitoring and enforcement - Institutions and service providers - Cost recovery	- Assessment of the influence of policy and legislation; institutional roles and capacity; monitoring and enforcement; and institutions and service providers on sanitation option performance. - Proportional of capital and recurrent costs recovered from tariffs/fees.
3. Community-level factors	- Population density - Willingness and ability to pay - Water supply access	- Assessment of the influence of population density on sanitation system. - Willingness and ability to pay within the urban setting; and - The extent to which a sanitation system is tolerable to variability in water supply access

Costs are an essential consideration for sanitation planning, particularly in urban settings. However, urban sanitation costs along the value chain have not been fully understood or documented to support service delivery. Therefore, an approach was taken to characterise annualised capital and recurrent cost as a performance criterion. The criterion was chosen to help establish what sanitation systems can be delivered and sustained given the city context.

Understanding the sanitation status quo by exploring factors within the environment enhancing or hindering services is essential to make the needed improvements. The factors within the enabling environment considered are the extent to which current policy and legislation, institutional roles and capacity, monitoring and enforcement, institutions and service providers, and current cost recovery policies influence sanitation services delivery in the city.

Threading together costs and the institutional drivers specific to the enabling environment are factors dealing with community-level responsiveness or acceptability. These factors include the influence of population density on the different sanitation systems and the levels households are willing and able to pay the costs for delivering and sustaining the sanitation services. Further, the responsiveness of the various sanitation systems to complementary water supply services that aid the optimal operations of sanitation.

Each criterion was weighted three different ways (highest-medium-lowest priority) to ascertain the extent to which the criteria influence overall priorities in selecting the optimal solution. The comparison matrices evaluated are:

i. The first criterion has the highest priority, with the two other criteria having equal priority.
ii. The first criterion has the highest priority, with the second criterion having a higher priority than the third criterion.
iii. The first criterion has the highest priority, with the third criterion having a higher priority than the second criterion.

The results of this analysis are presented in detail in Chapter 8.

Chapter 8: Generating strategic options for citywide sanitation access and services

8.1 Introduction

This chapter presents the analysis for generating options to scale citywide safely managed sanitation access and services in Lusaka. A strategic planning approach has been used that uses an explicit decision-making frame, revealing the effects of moving different categories of people between sanitation service categories. The chapter first assesses the baseline conditions and then establishes planning units for the city. After which, the three boundary cases as presented in Chapter 7 are analysed and discussed. This is followed by analysing the trade-offs for the three boundary cases and the overall AHP analysis. An essential step is to reveal the policy priorities to facilitate informed 'negotiation' between different stakeholders. On this basis, the optimum options for each planning unit will be established, thus enabling the setting out of blended options that are workable and likely to result in good outcomes.

8.2 Baseline status - Collation of cost, enabling environment and community-level information to generate sanitation options

Before assessing the impacts of changes, the current status (baseline situation) can be summarised from data presented in Chapters 4, 5 and 6. Table 8-1 and 8-2 present the current status of the population with respect to sanitation services – indicating the populations served with sewered and non-sewered services. The resultant baseline status of the sanitation system, with respect to the costs of delivery, alignment with the enabling environment, and alignment with acceptability and other community-level factors, can thus be established. This baseline can be compared with the modelled outcomes of the proposed boundary cases to estimate the net impact of moving the population to a new state of sanitation service provision. The baseline is presented using the urban setting descriptors - LIHD, MIMD and HILD as described in Chapter 3.

Table 8-1. Collated cost, enabling environment and community-level information for generating safely managed sewered service options in Lusaka

<table>
<tr><th rowspan="2">Urban Setting</th><th rowspan="2">Sanitation Technology</th><th colspan="3">Sanitation System Costs [1]
(US$ 2018 capita^{-1} year^{-1})</th><th rowspan="2">Community-level Trade-offs[2]</th><th rowspan="2">Enabling Environment Trade-offs[3]</th></tr>
<tr><th>CapEx Range</th><th>OpEx Range</th><th>CapEx and OpEx Range</th></tr>
<tr><td rowspan="2">LIHD</td><td>Conventional sewerage</td><td>55 - 66</td><td>23 - 24</td><td>78 - 90</td><td rowspan="2">• For some households, toilet construction and sewer connection costs are a constraint due to lower incomes.
• Households are less likely to have an available and reliable yard or in-house water connection.
• Households are more likely to share their sanitation facility.
• More likely to have households renting than those that are owner-occupied.
• Some households would connect to sewers when the network is close to the house or compound boundary, as connection costs are lower with proximity to the network.
• The population density is high, with most areas unplanned.</td><td rowspan="5">• There is currently no policy explicitly addressing sewer connectivity.
• There are currently no standards for the design, construction, operation, and maintenance of sanitation facilities.
• There are no performance indicators and benchmarks for sewer connections or connection efficiency in the performance monitoring framework set by the regulator; (no accountability when households do not connect)
• Regulations to connect to sewers are not enforced due to capacity-related constraints at the local authority.
• The law places the responsibility on landlords to make sewer connections. Currently, they are not sanctioned for not adhering to the regulation.
• Institutional capacity to complement and improve sewer service delivery by the utility is lacking.
• A lack of access to affordable financial services for low-income households is a constraint for household investments in improving sewerage service access.
• Revenues from tariffs are insufficient to fully recover operation and maintenance costs (tariffs are not cost-reflective).
- In LIHD areas, cost recovery averages 23%.
- In MIMD areas, cost recovery averages 47%.
- In HILD areas, cost recovery is 100%.</td></tr>
<tr><td>Simplified sewerage</td><td>64 - 65</td><td>22 - 23</td><td>86 - 88</td></tr>
<tr><td rowspan="2">MIMD</td><td>Conventional sewerage</td><td>54 - 62</td><td>6 - 20</td><td>60 - 82</td><td rowspan="3">• Households are more likely to connect to sewers due to having higher incomes, and if the sewer network is nearby, as connection costs would be lower.
• Households are more likely to have an available and reliable in-house water connection.
• Individual household toilets are more likely compared to shared facilities.
• More likely to have owner-occupied households than renting households.
• The population density is low to moderate with areas planned.</td></tr>
<tr><td>Simplified sewerage</td><td>69</td><td>22</td><td>91</td></tr>
<tr><td>HILD</td><td>Conventional sewerage</td><td>75 - 78</td><td>9 - 23</td><td>84 - 99</td></tr>
</table>

LIHD – Low-Income High Density; MIMD – Medium-Income Medium Density; HILD; High-Income Low Density
Notes: /1 – see Chapter 4 pages 64 to 65
/2 – see Chapter 6 pages 134 to 138
/3 – see Chapter 5 pages 87 to 106

Table 8-2. Collated cost, enabling environment and community-level information for generating safely managed non-sewered service options in Lusaka

Urban Setting	Sanitation Technology	Sanitation System Costs[1] (US$ 2018 capita^{-1} year^{-1})			Community-level Trade-offs[2]	Enabling Environment Trade-offs[3]
		CapEx Range	OpEx Range	CapEx and OpEx Range		
LIHD	Improved Pit Latrines	18 - 35	13 - 22	31 - 57	• Households are less likely to have an available and reliable yard or in-house water connection. • Due to lower incomes, households are less likely to use a safely managed emptying service. • Households are more likely to share sanitation facilities, with sharing households less likely to use safely managed emptying services. • Households using an improved sanitation facility are more likely to use a safely managed emptying service. • More likely to have renting households than owner-occupied households. • Tenants are less likely to use a safely managed emptying service	• Provision of non-sewered sanitation is unbundled with different service providers supporting service delivery. • There is no regulatory framework for providing on-site sanitation (OSS) and FSM (under development). • By-laws applying to the construction, usage and safe management of OSS facilities and the FS generated have been formulated but yet to be operationalised. • There are currently no standards for non-sewered services (OSS and FSM) across the whole value chain. • Coordination of actors across the value chain is inadequate. • The utility has limited capacity and experience to implement non-sewered services at scale. • Construction costs of improved OSS in LIHD areas are a constraint for households. • The market is saturated with equipment for emptying septic tanks leading to low utilisation rates, with no appropriate or financially attractive equipment for emptying pit latrines. • There are no local importers, distributors or manufacturers of pit emptying equipment. • Service providers do not recover their full operational and maintenance (O&M) costs. However, VTOs are closest to recovering costs from households (73%). They make profits by extending services to commercial and industrial clients where fees are higher than those paid by households. Water Trusts only recover around 24% of their O&M costs. • Dumping fees from VTOs are not ring-fenced for treatment. • Monitoring adherence to the Public Health Act for non-sewered services is inadequate due to capacity constraints, and the Act is tailored towards sewer service provision. • Under the Public Health Act, on-site sanitation regulation is not explicitly addressed; hence, enforcement is challenging. • There are currently no health and safety regulations tailored for FSM; however, formal OHS guidelines have been developed for emptying and transporting FS.
	Sealed Tanks	27 - 44	13 - 17	40 - 61		
MIMD	Sealed Tanks	60 - 61	12 - 14	72 - 75	• Households are more likely to use safely managed emptying services due to earning higher incomes; use improved facilities which are not shared and have an available and reliable in-house water connection. • More likely to have owner-occupied households than renting households.	
HILD	Sealed Tanks	84 - 85	12 - 14	96 - 99		

Notes: /1 – see Chapter 4 pages 76 to 77
/2 – see Chapter 6 pages 138 to 142
/3 – see Chapter 5 pages 106 to 124

Table 8-3 shows the distribution of the population by sanitation services (sewered, non-sewered, and no service) across the different urban settings.

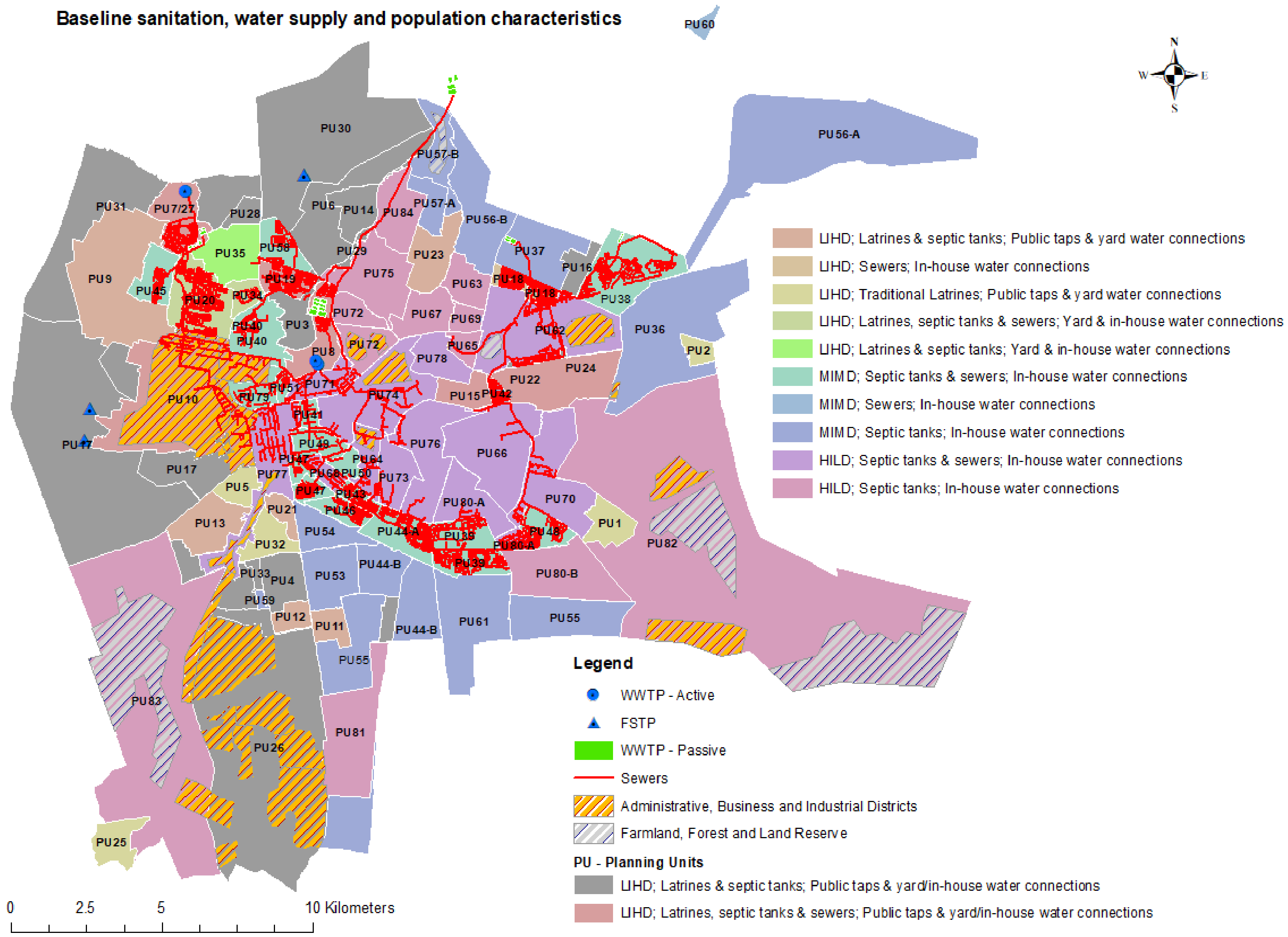
Table 8-3. Distribution of the population with and without access to sanitation across the different urban settings in Lusaka

Category	Urban Setting	Sanitation Technology	Estimated 2020 Population	Percentage of City Population
Sewered	LIHD	Simplified sewerage	1,029	0.04
	LIHD	Conventional sewerage	131,126	5
	MIMD		102,964	4
	HILD		100,096	4
Non-sewered	LIHD	Latrines[2]	1,361,187	56
	LIHD	Septic tanks	85,884	4
	MIMD		330,416	14
	HILD		213,445	9
Unserved[1]	LIHD		93,086	4
	Total Estimated City Population		2,420,234	100%

[1]4% of the population have no access to a sanitation facility Kappauf et al. (2018)
[2]An estimated 90% of households in non-sewered LIHD areas use latrines (LWSSC, 2021)

Using GIS-based shapefiles[24] for Wards in Lusaka delineated by the Zambia Statistical Agency and water supply districts from LWSC as the base map, a baseline representation of the city, summarising the data in Table 8-3 is shown as Figure 8-1. The city map shows the current sanitation and water supply status, with areas disaggregated as residential, business or industrial districts. The city was divided into planning units (PU) to simplify the modelling of proposed changes in sanitation services. Planning units represent contiguous areas with similar housing density, wealth, and current sanitation and water supply situation (Figure 8-1 and Table 8-4). Each planning unit has a unique number. Appendix F-1 to F-3 shows the water supply and sanitation status, spatial organisation, and estimated population of each planning unit.

[24] A shapefile is a non-topological format for storing the geometric location and attribute information of geographic features. https://desktop.arcgis.com/en/arcmap/10.3/manage-data/shapefiles.htm



Location of planning units and their population across the different urban settings at baseline

LIHD Areas			MIMD Areas			HILD Areas		
PU	**Location**	**Population**	**PU**	**Location**	**Population**	**PU**	**Location**	**Population**
1	East	32,000	**36**	East	40,740	**62**	East	19,284
2	East	27,000	**37**	Northeast	17,735	**63**	Northeast	5,623
3	Central	27,170	**38**	Northeast	48,398	**64**	Central	4,504
4	South	89,502	**39**	South	24,056	**65**	Central	2,120
5	Central	39,000	**40**	West	31,649	**66**	Central	13,363
6	North	46,158	**41**	Central	1,806	**67**	Central	9,700
7	Northwest	4,006	**42**	East	10,463	**68**	Central	14,174
8	Central	87,891	**43**	Central	4,264	**69**	Central	2,535
9	Northwest	158,252	**44**	South	34,096	**70**	East	3,264
10	West	151,382	**45**	West	6,381	**71**	Central	8,308
11	South	16,124	**46**	Central	12,018	**72**	Central	10,040
12	South	61,333	**47**	Central	9,586	**73**	Central	5,519
13	Central	100,000	**48**	Southeast	5,182	**74**	Central	31,802
14	North	29,000	**49**	Central	5,207	**75**	Central	22,587
15	Central	11,435	**50**	Central	2,538	**76**	Central	14,738
16	Northeast	4,759	**51**	Central	1,452	**77**	Central	73,779
17	West	50,940	**52**	East	21,222	**78**	Central	13,831
18	Northeast	4,574	**53**	South	20,545	**79**	Central	11,520
19	North	53,501	**54**	Central	18,106	**80**	Southeast	12,766
20	West	32,525	**55**	South	55,526	**81**	South	6,900
21	Central	25,959	**56**	Northeast	27,000	**82**	Southwest	5,400
22	East	104,454	**57**	North	4,800	**83**	Southwest	18,564
23	North	52,918	**58**	North	2,706	**84**	North	3,220
24	East	26,000	**59**	South	3,642			
25	Southwest	23,000	**60**	Northeast	3,396			
26	South	13,000	**61**	South	23,866			
27	Northwest	17,000						
28	Northwest	15,000						
29	North	18,000						
30	North	73,285						
31	Northwest	80,862						
32	Central	24,041						
33	South	40,405						
34	West	22,405						
35	Northwest	17,346						

Figure 8-1. Baseline sanitation and water supply coverage disaggregated by technology and population characteristics in Lusaka

Table 8-4. Baseline sanitation and water supply status in planning units across Lusaka

Urban Setting	Baseline Sanitation and Water Supply Status in Planning Units						
	Latrines and septic tanks: Public taps, in-house and yard connections	Latrines, septic tanks and sewers: Public taps and yard connections	Latrines and septic tanks: Public taps and yard connections	Latrines: Public taps and yard connections	Latrines, septic tanks and sewers: Yard and in-house water connections	Septic tanks and sewers: In-house water connections	Sewers: In-house water connections	Septic tanks: In-house water connections
LIHD	PU3-4, PU6, PU14, PU16-17, PU24, PU26, PU28-31, PU33	PU7-8, PU10, PU15, PU19, PU22, PU27	PU9, PU11-13, PU21, PU23	PU1-2, PU5, PU25, PU32	PU20, PU34-35		PU18	
MIMD						PU38-41, PU43-51, PU58	PU42, PU51, PU60	PU36-37, PU44-B, PU53-57, PU59, PU61
HILD						PU62, PU64, PU66, PU68, PU70-71, PU73-74, PU 76-80A		PU63, PU 65, PU67, PU69, PU72, PU75, PU80B-84

The current treatment capacity for both sewered and non-sewered services is around 655,601 people (about 27% of the 2020 city population). The situational analysis shows that only 1% of faecal sludge is safely treated, with 12% of faecal sludge contained and not emptied (Kappauf et al., 2018). Treatment occurs in pit latrine and septic tank/soakaway systems. However, it is challenging to ascertain if groundwater contamination does not occur, as the hydro-geological conditions within the city differ. The low treatment capacity necessitates an increase in the number and/or expansion of existing treatment facilities to manage the waste generated safely. The wastewater and faecal sludge treatment facilities are in the Western, Central, Northern and Eastern parts of the city. As the South-West and South-East (21% of the population) are predominantly non-sewered, faecal sludge and septage transport may not be as efficient due to the location of treatment plants.

8.3 Boundary case options for scaling up citywide safely managed sanitation

The overall goal is establishing a simplified approach for comparing strategic sanitation service options at the city level for the different decision-makers who might have differing views of the relative importance of each of the criteria used. Analysis of the boundary cases illustrates a pathway to a solution that may comprise elements of each extreme case in making the needed sanitation improvements at the city level (Chapter 7). The summarised information presented in Tables 8-1 and 8-2 helped allocate the performance of different sanitation systems in the different urban settings against cost, enabling environment, and community level criteria. The boundary case options considered are

- all-conventional sewers (BC-1),
- conventional and simplified sewers (BC-2), and
- all-enhanced FSM option (BC-3).

The boundary cases are theoretical options, showing the extremes in planning. The cases highlight how fully sewered, and non-sewered sanitation systems perform against the three criteria. For BC-1, all areas are allocated conventional sewers except in the LIHD area, with simplified sewers currently deployed. For BC-2, conventional sewers are allocated in HILD and MIMD areas with simplified sewers in all the LIHD areas without the conventional sewers. The literature shows that with increased population density, there is a considerable reduction in the cost of simplified sewers (Manga et al., 2020). Therefore, simplified sewers are preferable in densely populated areas from a cost perspective. For BC-3, areas with a mixed spatial organisation (i.e., haphazard and organised), with sewers currently deployed signifying access to some reliable water supply, septic tanks are allocated. Simple and traditional latrines used by 65% of the LIHD population (Chapter 6) are upgraded and/or replaced with improved latrines, complemented by safely managed faecal sludge services.

Table 8-5 presents the city-level costing for the boundary cases across urban settings for the estimated population in Lusaka. As cost data are presented as ranges, the upper limit of the ranges for each sanitation option was used in the analysis. The costing is based on 100% connection efficiency for sewers and full operator capacity for FSM services. Capital expenditure for all boundary cases only covers the new population served. Operational liabilities cover both the existing and new services.

Table 8-5. City-level costing for the boundary case safely managed sanitation system options for Lusaka

Sanitation Options	Urban Setting	Baseline Population Served	% of Pop.	New Population Served	% of Pop.	Sanitation System Costs (US$ 2018 $year^{-1}$)			
						CapEx ($capita^{-1}$)	OpEx ($capita^{-1}$)	Population Total - CapEx	Population Total - OpEx
All conventional sewers (BC-1)	$LIHD_{CS}$	131,126	5	1,541,157	64	55-66	23-24	84,763,635 - 101,716,362	38,462,509 - 40,134,792
	$LIHD_{SS}$	1,029	0.04				22-23		22,638 - 23,667
	$MIMD_{CS}$	102,964	4	330,416	14	54-62	6-20	17,842,464 - 20,485,792	2,600,280 - 8,667,600
	$HILD_{CS}$	100,096	4	213,445	9	78-78	9-21	16,008,375 - 16,648,710	2,821,869 - 6,584,361
	$LIHD_{IPL}$	1,361,187	56						
	$LIHD_{ST}$	86,884	4						
	$MIMD_{ST}$	330,416	14						
	$HILD_{ST}$	213,445	9						
	Unserved	93,086	4						
						Total cost liabilities (BC-1)		**118,614,474 - 138,850,864**	**43,907,296 - 55,410,420**
Conventional and simplified sewers (BC-2)	$LIHD_{SS}$	1,029	0.04	1,514,717	64	64-65	22-23	98,634,048 - 100,175,205	33,928,092 - 35,470,278
	$LIHD_{CS}$	131,126	5				23-24		3,015,898 - 6,294,048
	$MIMD_{CS}$	102,964	4	330,416	14	54-62	6-20	17,842,464 - 20,485,792	2,600,280 - 8,667,600
	$HILD_{CS}$	100,096	4	213,445	9	75-78	9-21	16,008,375 - 16,648,710	2,821,869 - 6,584,361
	$LIHD_{IPL}$	1,361,187	56						
	$LIHD_{ST}$	86,884	4						
	$MIMD_{ST}$	330,416	14						
	$HILD_{ST}$	213,445	9						
	Unserved	93,086	4						
						Total cost liabilities (BC-2)		**132,484,887 - 137,309,707**	**42,366,139 - 57,016,287**
All enhanced FSM (BC-3)	$LIHD_{IPL}$	1,361,187	56	953,655	39	18-35	13-22	17,165,790 - 33,377,925	12,397,515 - 20,980,410
	$LIHD_{ST}$	86,884	4	632,774	26	27-44	13-17	17,084,898 - 27,842,056	9,355,554 - 12,234,186
	$MIMD_{ST}$	330,416	14	102,964	4	60-61	12-14	6,177,840 - 6,280,804	5,200,560 - 6,067,320
	$HILD_{ST}$	213,445	9	100,096	4	84-85	12-14	8,408,064 - 8,508,160	3,762,492 - 4,389,574
	$LIHD_{SS}$	1,029	0.04						
	$LIHD_{CS}$	131,126	5						
	$MIMD_{CS}$	102,964	4						
	$HILD_{CS}$	100,096	4						
	Unserved	93,086	4						
						Total cost liabilities (BC-3)		**48,836,592 - 76,008,945**	**30,716,121 - 43,671,490**

CS - Conventional Sewerage; SS – Simplified Sewerage; ST - Septic Tanks; IPL – Improved Pit Latrines

8.3.1 All-conventional sewers option (BC-1)

The option shifts the population across all the urban settings to conventional sewers. Simplified sewers in the LIHD area where these are currently deployed are maintained. In LIHD areas, the population shift to conventional sewers is from 5% to 69%. In MIMD areas, the shift is from 4% to 18% and 4% to 13% in HILD areas (Table 8-6).

Figure 8-2 shows the distribution of sewer service coverage across the different urban settings in the city. Most LIHD PUs serviced mainly by traditional latrines, and some septic tanks require investment in reliable water supply services. This supports 44% of the city population in non-sewered LIHD areas shifting to sewerage (Table 8-6). Households in these areas mostly use public taps, and some have a yard or in-house water connection. LIHD PU 7-8, 10, 15, 20, 22, 27, 31 and 34 are partly sewered with households using public taps, yard, and in-house water connections. Around 15% of the city population in this category moves to sewerage, with investment in water supply needed to facilitate operations and improve quality of life outcomes. PU 18 is fully sewered with households using in-house water connections. Around 6% of the city population in PU 1-2, 5, 25 and 32 shifts from traditional latrines to sewerage. In MIMD areas, around 77% of the population shift from septic tanks to sewerage, while the shift in HILD areas is 68%. In these settings, water services are likely to be available and reliable.

The current location of wastewater treatment facilities is in the West, North, slightly Central and East of the city. In switching everybody to sewerage, there is a need to expand the treatment capacity to cover 87% of the population shifting to sewers. In addition, conventional sewerage is actualised over a longer time horizon as the systems are extensive, and with city demographics changing, there is a need to over-invest by designing treatment for some future capacity.

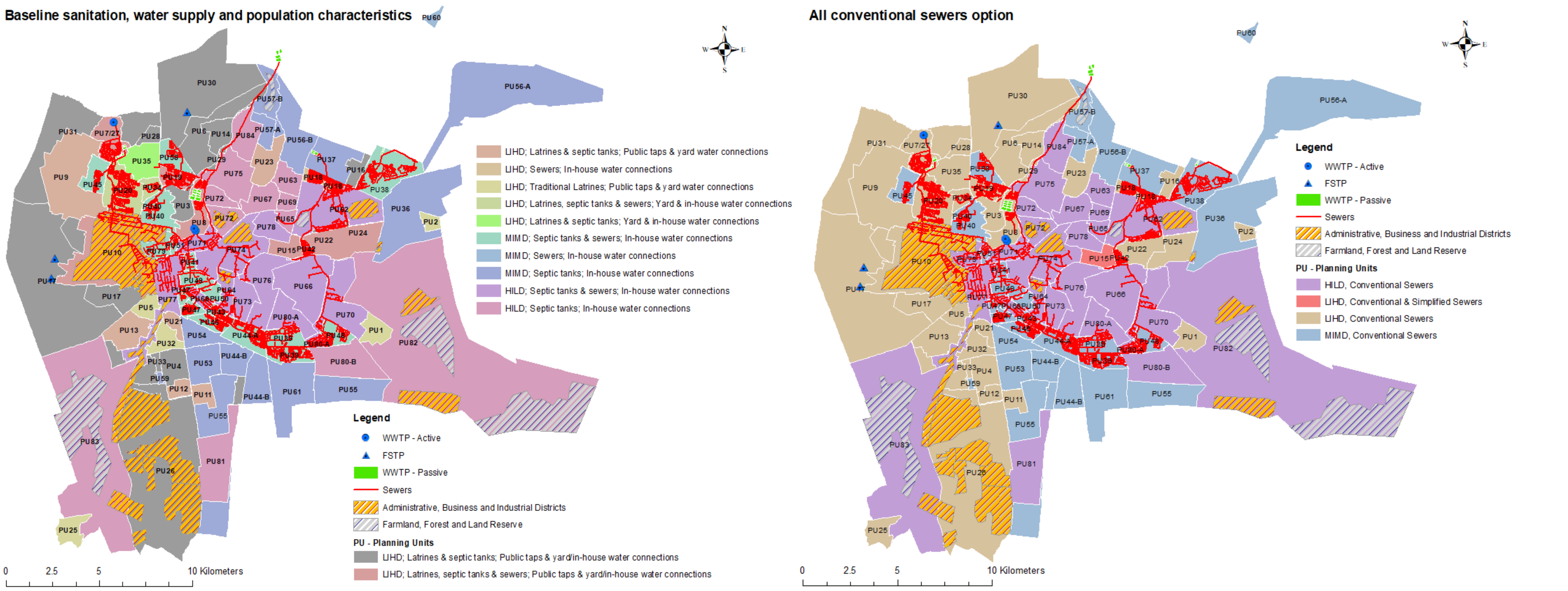


Figure 8-2. Population shift from baseline scenario to all conventional sewers across urban settings in Lusaka (Left) Baseline; (Right) All conventional sewers

Table 8-6. Cost liability data, total population moving from baseline scenario to all conventional sewers, and change occurring from the shift in categories

Urban Setting	Sanitation System	Baseline		All Conventional Sewers (BC-1)[1]			Change from Baseline Scenario
		Population	% Pop.	Costs (US$ 2018 $year^{-1}$)[1]	Population	% Pop.	
LIHD	Conventional Sewerage	131,126	5	123,226,144 - 141,851,154	1,672,284	69	- In non-sewered areas, 918,652 people (55% of the LIHD or 38% of the city pop.) mainly on traditional latrines and septic tanks shift to sewerage.
	Simplified Sewerage	1,029	0.04	22,638 - 23,667	1,029	0.04	- In areas partly sewered, 367,379 people (23% of the LIHD or 15% of the city pop.) shift to sewerage.
	Latrines	1,361,187	56				- In non-sewered areas with traditional latrine use, 145,041 people (9% of LIHD or 6% of the city pop.) shift to sewerage.
	Septic tanks	86,884	4				- 93,086 people (4% of the unserved population) also shift to sewers.
Unserved		93,086	4				
MIMD	Conventional Sewerage	102,964	4	20,442,744 – 29,153,392	433,380	18	- 330,416 people (77% of the MIMD or 14% of city pop.) shift to sewerage.
	Septic tanks	330,416	14				
HILD	Conventional Sewerage	100,096	4	18,830,244 – 23, 233,071	313,541	13	-213,445 people (68% of the HILD or 9% of the city pop.) shift to sewerage.
	Septic tanks	213,445	9				

[1]Cost and population data are obtained from Table 8-5

Plans are underway to construct a new wastewater treatment plant (WWTP) in the North with a 2025 (year) capacity of 524,613 people and a 2040 expansion to cater for 1,449,105 people (LWSC, 2016b). However, even with the new treatment plant, the capacity falls short to cater for the population shifting to sewers. The 2025 and 2040 treatment expansion capacity only cover 22% and 60% of the 2020 estimated population. Therefore, highlighting the challenges in actualising the option for citywide services. Furthermore, the Southeast and Southwest of the city are sparsely populated with a very low population density that would render sewerage services in these areas very costly to deliver and sustain.

8.3.2 Conventional and simplified sewers option (BC-2)

The option shifts the population across the MIMD and HILD areas to conventional sewers. In LIHD areas, the population shifts to simplified sewers. The LIHD area population shift to simplified sewers is from 0.04% to 64%, while 5% of the population using conventional sewerage from the baseline is maintained. In MIMD areas, the shift is from 4% to 18% and 4% to 13% in HILD areas (Table 8-7).

Figure 8-3 shows the distribution of sewer coverage across all urban settings in the city for the option considered. Overall, the population shift highlighted in Section 8.3.1 applies to the system option, though with simplified sewer use in the LIHD areas without conventional sewers. In LIHD areas, investment in reliable water services is needed to operationalise sewerage services. In MIMD and HILD areas, water supply services are likely to be reliable.

The treatment challenges and considerations outlined for the all-conventional sewers option directly apply to the combined conventional and simplified sewers option.

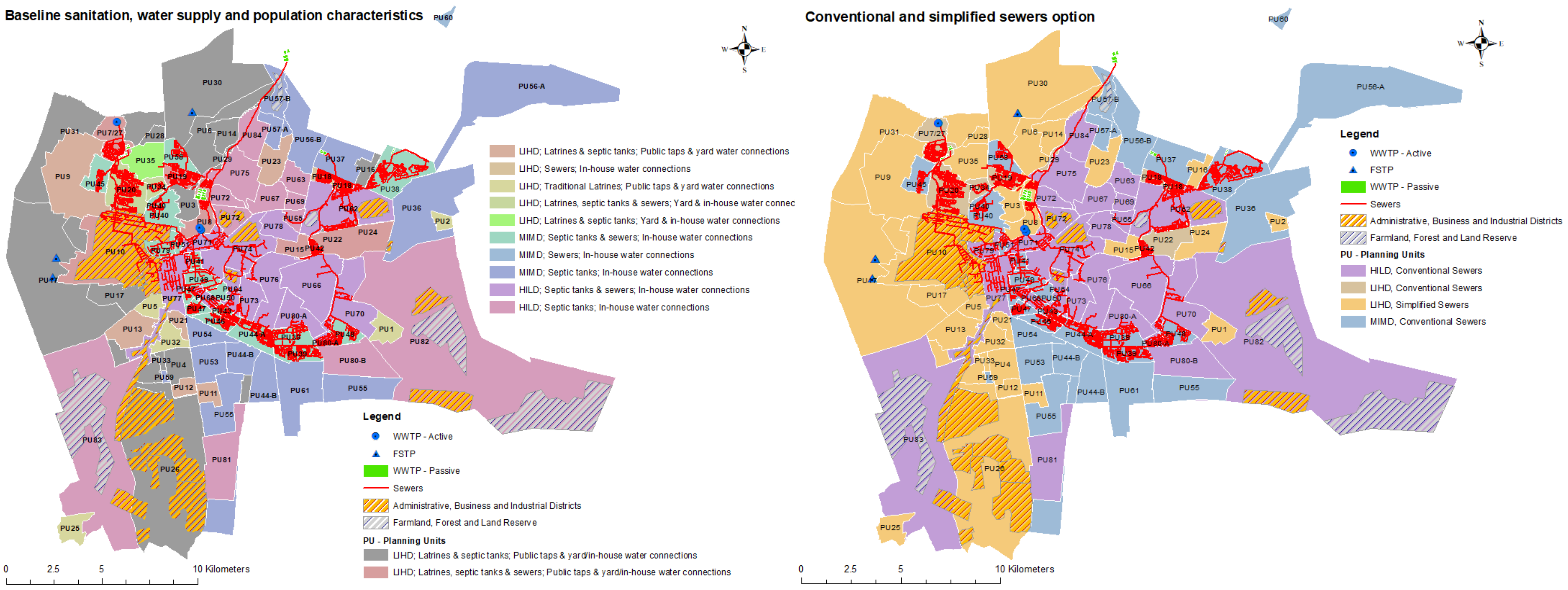


Figure 8-3. Population shift from baseline scenario to conventional and simplified sewerage across urban settings in Lusaka (Left) Baseline; (Right) Conventional and simplified sewers

Table 8-7. Cost liability data, total population moving from baseline scenario to conventional and simplified sewers, and change occurring from the shift in categories

Urban Setting	Sanitation System	Baseline		Conventional and Simplified Sewers (BC-2)[1]			Change from Baseline Scenario
		Population	% Pop.	Costs (US$ 2018 year^{-1})	Population	% Pop.	
LIHD	Conventional Sewerage	131,126	5	3,015,898 - 6,294,048	131,126	5	- In non-sewered areas, 918,652 people (55% of the LIHD or 38% of the city pop.) mainly on traditional latrines and septic tanks shift to sewerage. - In areas partly sewered, 367,379 people (23% of LIHD or 15% of city pop.) shift to sewerage. - In non-sewered areas with traditional latrine use, 145,041 people (9% of the LIHD or 6% of the city pop.) shift to sewerage. - 93,086 people (4% of the unserved population) also shift to sewers.
	Simplified Sewerage	1,029	0.04	132,562,140 – 135,645,483	1,542,187	64	
	Latrines	1,361,187	56				
	Septic tanks	86,884	4				
Unserved		93,086	4				
MIMD	Conventional Sewerage	102,964	4	20,442,744 – 29,153,392	433,380	18	- 330,416 people (77% of the MIMD or 14% of city pop.) shift to sewerage.
	Septic tanks	330,416	14				
HILD	Conventional Sewerage	100,096	4	18,830,244 – 23, 233,071	313,541	13	-213,445 people (68% of the HILD or 9% of the city pop.) shift to sewerage.
	Septic tanks	213,445	9				

[1]Cost and population data are obtained from Table 8-5

8.3.3 All-enhanced FSM option (BC-3)

The option shifts the whole population to on-site FSM-based systems. In LIHD areas, the population shift within the IPL category is from 56% to 39%, with a 4% to 30% shift in septic tank use. In MIMD areas, septic tank use increases from 14% to 18% and 9% to 13% in HILD areas (Table 8-8).

Figure 8-4 shows non-sewered services across the different urban settings. In LIHD PU 1-35 except PU 18, the population primarily using traditional latrines shift to improved latrines. Improved pit latrines are 'tolerable' to a limited water supply. However, investment in water supply services is needed for hygiene purposes as most households depend on public taps. PU 18 is serviced with in-house water connections and shifts to septic tanks. Households with a yard or in-house water connections shift to septic tanks. Investment in reliable water supply services is essential for the operation of the sanitation systems for the population serviced by septic tanks (30%) (Table 8-8).

MIMD PU 42, 51 and 60 shift from full sewer coverage to septic tanks. The partly sewered PU 38-41, 43-51 and 58 shift to full septic tank use. HILD areas, partly sewered PU 62, 64, 66, 68, 70-71, 73-74, and 76-80A shift to full septic tank use. In MIMD and HILD areas, water services are more likely to be reliable to facilitate the operations of the sanitation systems.

The current treatment capacity for non-sewered sanitation (faecal sludge and septage) is inadequate. The treatment capacity is around 5% of the non-sewered population. The use of enhanced FSM services necessitates increased collection, transport, and treatment capacity to safely manage faecal sludge and septage. Faecal sludge and septage treatment facilities are in the western, central and northern parts of the city. For this option, there is a need to consider having treatment facilities in the southern, central, and eastern parts of the city to make the collection and transport service efficient by reducing travel time and distance to treatment.

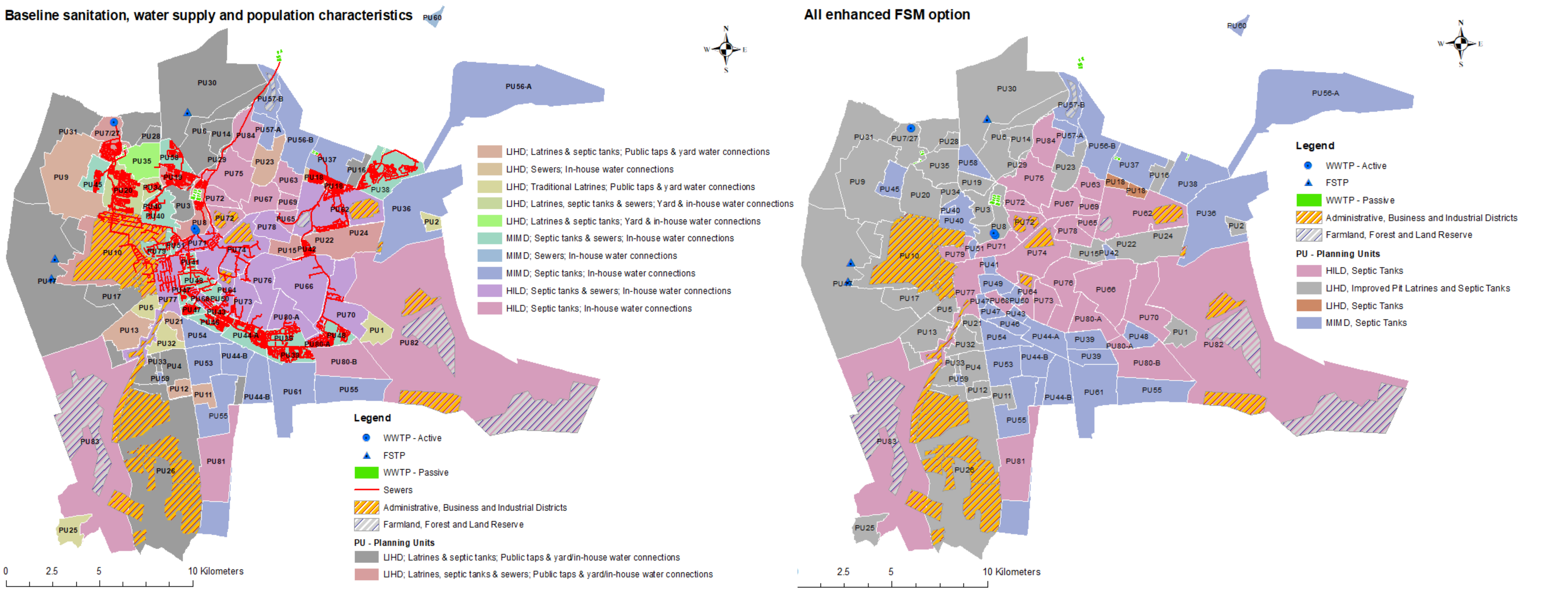


Figure 8-4. Population shift from baseline scenario to all enhanced FSM across urban settings in Lusaka (Left) Baseline; (Right) All-enhanced FSM option

Table 8-8. Cost liability data, total population moving from baseline scenario to all enhanced FSM, and change occurring from the shift in categories

Urban Setting	Sanitation System	Baseline		All Enhanced FSM (BC-3)[1]			Change from Baseline Scenario
		Population	% Pop.	Costs (US$ 2018 year^{-1})	Population	% Pop.	
LIHD	Conventional Sewerage	131,126	5				- The population shift within the latrine category is 56% to 39%.
	Simplified Sewerage	1,029	0.04				- The unserved population (4%) shifts to improved pit latrines.
	Latrines	1,361,187	56	29,563,305 – 54,358,335	953,655	39	- The population shift within the septic tank category is 4% to 30%.
	Septic tanks	86,884	4	26,440,452 – 40,076,242	719,539	30	
Unserved		93,086	4				
MIMD	Conventional Sewerage	102,964	4				- The population on sewers (4%) shifts to septic tanks, with a cumulative total of 18%.
	Septic tanks	330,416	14	11,378,400 – 12,348,124	433,380	18	
HILD	Conventional Sewerage	100,096	4				-The population on sewers (4%) shifts to septic tanks, with a cumulative total of 13%.
	Septic tanks	213,445	9	12,170,556 – 12,879,734	313,541	13	

[1]Cost and population data are obtained from Table 8-5

8.4 Trade-off analysis for the boundary cases

This section outlines the characteristics of each boundary case for cost, enabling environment and community-level criteria. Further, the proportion of the population moving to sub-optimal services for all three criteria are analysed.

8.4.1 All-conventional sewers option (BC-1)

Option BC-1 ranks as the least cost-effective solution for capital costs and second for operational liabilities (Table 8-5). Policies and legislation promoting sewerage services within the existing enabling environment are explicit. However, policies addressing sewer connectivity are ineffective. Enforcement of regulations related to sewer connections is constrained due to a lack of capacity. Further, monitoring sewer connectivity is inadequate; hence, rates of connections may be low, especially in LIHD areas. The utility may not be incentivised to push for higher connection rates as the performance framework set by the regulator does not monitor connectivity rates. Institutional roles are clear, with capacity available to an extent. However, the capacity to scale sewerage to the entire city is lacking within the utility.

Sewerage systems are responsive to population density, with higher densities and connection efficiencies facilitating lower system costs overall. In LIHD areas, most households (69%) are less likely to have a reliable water supply to facilitate the optimal operation of sewers. For some, costs to construct water closets and connect to sewers may be a constraint. The risk is the sub-optimal performance of the overall sewerage system due to low connection efficiency leading to escalation of system costs. However, the convenience offered by a sewer system, when reliable with service charges linked to the water bill, spread monthly, may be a driver to connect. For 31% of the population in MIMD and HILD areas, there is a higher likelihood of having a reliable water supply and a sewer connection when the service is available due to higher incomes.

8.4.2 Conventional and simplified sewers option (BC-2)

The option ranks second for capital costs and least cost-effective for operational liabilities (Table 8-5). The manner in which simplified sewers are delivered influences costs. For example, simplified sewers are delivered with communal septic tanks, which discharge into conventional trunk sewers. The mode of delivery with communal septic tanks considerably adds to the capital and operational costs. For the enabling environment, policy, enforcement and monitoring related to sewer connectivity are inadequate. In addition, institutional capacity to scale simplified sewers to all LIHD areas is lacking due to limited utility experience. As a result, delivery of simplified sewer services in LIHD areas has been challenging for the utility, resulting in sub-optimal performance.

The unplanned nature of some LIHD areas may suit the roll-out of simplified sewerage. The technology is adaptable to highly dense and spatially disorganised settlements from an implementation perspective. In HILD and MIMD areas with lower population densities, the cost performance may not be optimal compared to FSM systems. However, population density has little effect if households do not connect to sewers. Therefore, connectivity rates are essential for optimal cost and operational performance of sewerage systems.

8.4.3 All-enhanced FSM option (BC-3)

The option ranks as the most cost-effective for capital and operational costs as most of the infrastructure needed is in place (Table 8-5). This is because most of the population use FSM-based systems. Within the existing enabling environment, regulations for the construction, usage, and safe management of on-site facilities and the faecal sludge generated have not been operationalised. There is currently no regulations or legislation directly dealing with non-sewered sanitation. However, this is an endogenous factor, and stakeholders in the city are putting together a regulatory framework for non-sewered services. The Public Health Act is tailored towards sewered sanitation; hence is inadequate for monitoring and enforcing regulations for non-sewered services. Monitoring and enforcing institutions are constrained due to a lack of capacity. Full-scale citywide FSM services might be challenging as the utility has limited capacity and experience in implementing non-sewered services. The services are currently unbundled among different providers, with coordination of actors inadequate. The risk is inefficient service delivery when scaled.

Population density may have a minimal influence on the costs of non-sewered systems. However, the spatial organisation in the LIHD areas may influence the efficiency of motorised collection and transport services. The situational analysis showed that the market is currently saturated with equipment for emptying septic tanks leading to low utilisation rates. With the increased demand for FSM services, providers are likely to operate at full capacity, improving cost efficiency for collection and transport services. However, collection and transport services may need to expand to meet increased demand.

Lack of affordable financial services limits many low-income households in constructing sanitation facilities and procuring FSM services due to cost constraints. Most households in LIHD are less likely to have an available and reliable water connection to facilitate the optimal operation of water-borne septic tanks systems. For 30% of the LIHD population using septic tanks, sub-optimal performance is likely due to the unreliability of the water supply in these areas. MIMD and HILD households are more likely to have a reliable water connection and procure an FSM service due to higher household incomes.

8.5 Results of AHP analysis for the boundary cases: cost, enabling environment and community-level prioritisation

The size of the population shifting between sanitation services is summarised in Section 8.3. The trade-offs and implications for each boundary case giving the decision-maker the implementation practicality given the city context, are set out in Section 8.4 above. This section presents the analysis of the prioritisation of costs, the enabling environment, and community-level criteria. Because the effect of moving populations between sanitation systems are complex, it is difficult to see the net effect across the entire city. However, AHP provides a framework that summarises these effects. The complete AHP analysis is shown in Appendix F Tables 4 to 7. An example for one pairwise comparison and weighted matrix of sub-criteria is shown below in Table 8-9. The summary analysis for the overall priorities is shown in Table 8-10.

Table 8-9. Pairwise comparison and weighted matrix of sub-criteria when costs have the highest priority with the enabling environment and community-level factors having equal priorities

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP[1]	Water supply access	
CapEx	1	1	9	9	9	9	9	9	9	9	
OpEx	1	1	9	9	9	9	9	9	9	9	
Policy & legislation	1/9	1/9	1	1	1	1	1	1	1	1	
Institutional roles & capacity	1/9	1/9	1	1	1	1	1	1	1	1	
Monitoring & enforcement	1/9	1/9	1	1	1	1	1	1	1	1	
Institutions & service providers	1/9	1/9	1	1	1	1	1	1	1	1	
Cost recovery	1/9	1/9	1	1	1	1	1	1	1	1	
Population density	1/9	1/9	1	1	1	1	1	1	1	1	
WAP[1]	1/9	1/9	1	1	1	1	1	1	1	1	
Water supply access	1/9	1/9	1	1	1	1	1	1	1	1	
Sum	**2.89**	**2.89**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	
Weighted Matrix											**Priority**
CapEx	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	**0.34**
OpEx	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	**0.34**
Policy & legislation	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Institutional roles & capacity	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Monitoring & enforcement	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Institutions & service providers	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Cost recovery	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Population density	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
WAP[1]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**
Water supply access	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	**0.04**

[1]WAP: Willingness and Ability to Pay
Notes: See Section 7.3 explaining the procedure for making the pairwise comparisons

Table 8-10. Overall priorities for cost, enabling environment and community-level criteria analysed

Sanitation Options	**Overall Priorities**		
Cost Priority	Costs have a higher priority with the enabling environment and community-level factors having equal priorities	Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	Costs have a higher priority, with community-level factors having a higher priority than the enabling environment
All Conventional Sewers (BC-1)	**0.33**	**0.34**	**0.33**
Conventional and Simplified Sewers (BC-2)	**0.29**	**0.28**	**0.29**
All Enhanced FSM (BC-3)	**0.38**	**0.38**	**0.37**
Enabling Environment Priority	Enabling environment has a higher priority with costs and community-level factors having equal priorities	Enabling environment has a higher priority with costs having a higher priority than community-level factors	Enabling environment has a higher priority, with community-level factors having a higher priority than costs
All Conventional Sewers (BC-1)	**0.43**	**0.42**	**0.43**
Conventional and Simplified Sewers (BC-2)	**0.24**	**0.24**	**0.25**
All Enhanced FSM (BC-3)	**0.33**	**0.33**	**0.33**
Community-level Priority	Community-level factors have a higher priority with costs and the enabling environment having equal priorities	Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	Community-level factors have a higher priority, with the enabling environment having a higher priority than costs
All Conventional Sewers (BC-1)	**0.36**	**0.35**	**0.36**
Conventional and Simplified Sewers (BC-2)	**0.33**	**0.33**	**0.32**
All Enhanced FSM (BC-3)	**0.31**	**0.32**	**0.31**

Note: The sanitation option scoring highest in each case is highlighted

8.5.1 Overall performance of the boundary case options

Table 8-10 presents the overall priorities when costs, the enabling environment, and community-level criteria are prioritised. The table shows the performance of each boundary case option with respect to the different criteria priorities.

Appendix F, Table 6 shows the local priorities for the boundary cases with respect to the three criteria used. When capital costs are prioritised, the all-enhanced FSM option (47%) gives a better performance than the sewer-based options. When operational costs are the priority, the enhanced FSM option (39%) still performs better than the sewer options. Given current policy and legislation, sewerage has the best fit (47 and 43%) compared to FSM services (10%). The all-conventional sewer option (73%) performs better when considering institutional roles and capacity than the conventional and simplified sewer system option (16%). The all-conventional sewers option (62%) shows better performance when considering institutions and service providers. The enhanced FSM system (78%) has better performance for cost recovery than the sewer-based options based on current policies.

When population density is considered, the sewer-based systems (47%) out-perform the all-enhanced FSM option (6%). Population density has a considerable effect on the performance of sewers in comparison to FSM systems. The sewer-based systems (44%) perform better than the all-enhanced FSM option (12%) when willingness and ability to pay is considered. Available and reliable water supply access is essential to the operation of sewer-based and water-borne FSM systems. The FSM-based system (72%) performs better as it is more tolerable to limited water supply than the sewer-based system (14%) when all other performance factors are held constant.

Figure 8-5 presents the overall performance of the boundary cases against the three criteria priorities when planning for improved sanitation services across the city. Overall, when the cost criterion is prioritised, the optimal sanitation option is the all-enhanced FSM option. When criteria within the enabling environment are prioritised, the optimal sanitation option is the all-conventional sewers option. Finally, when community-level criteria are prioritised, the all-conventional sewers option is the optimal sanitation solution for the city.

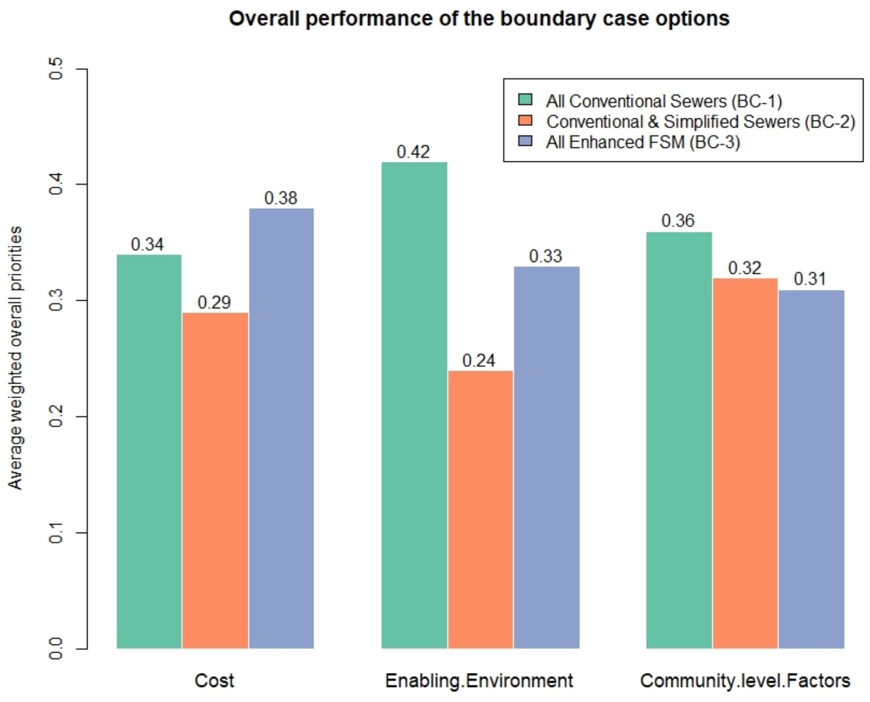


Figure 8-5. Weighted output of the AHP analysis when cost, the enabling environment and community-level criteria are prioritised

The results show that in Lusaka, current policies within the existing enabling environment support cost recovery better for FSM services than sewer-based services. FSM services are delivered by the private sector, which is profit-driven, while the public sector delivers sewer services.

8.5.2 A case for the citywide optimised blended service approach

In summary, a fully sewered system adoption responds well to community needs but does not perform well on cost. While it performs well on community needs, it fits with the enabling environment but would be costly and time-consuming to implement. A safely managed FSM system would also respond to community needs, but communities have never experienced a fully operational FSM system. The existing service is associated with poor performance and high one-off payments. However, it would be possible for FSM to be delivered as part of a full sanitation service, paid for through the water bill in the same way as sewerage, and offering the same level of service to the household. A fully

FSM system does not fit well with the enabling environment. On costs, it fits well as most of the population use on-site sanitation. However, the infrastructure needs upgrading and rehabilitating in some places. From the analysis, a probable direction for the city is to use the existing sewerage infrastructure with improved service delivery. Further, considerations to extend the sewerage infrastructure as the first step while upgrading and/or rehabilitating non-sewered infrastructure and services is needed. Thus, eliminating the unsafe traditional latrines and open defecation.

Based on the trade-off analysis in Section 8.4, it is possible to develop several pathways towards sanitation improvement, which would create complete, safely managed citywide services. The pathways - hybrid solutions - achieve close to optimal outcomes for individual planning units, building up to the entire sanitation system. The hybrid solutions - a blend of services - consider the need to optimise the performance criteria of existing sewered and non-sewered services in the city. Depending on how the different criteria are rated, the blended options may be constructed in various ways. In addition, the blended service options use demographic and locational factors such as population density and proximity to existing sewers and treatment plants as a basis for scaling up citywide services. Proposed are six options that blend sewered and non-sewered services. These are discussed in Section 8.6 below.

8.6 Area-by-area optimised blended service approach

The blended service approach improves the status quo by making the optimal incremental improvements needed for safely managed services on an area-by-area basis. The optimised approach has variants or sub-options in which investment is allocated to sewerage and enhanced FSM in planning services. Table 8-11 describes the characteristic features of the blended variant options proposed. The variant options were identified by analysing the baseline scenario to understand what might be practicable to implement in the city. In deciding the different options for intervention, the planning was logically based on things happening within the city from proposed projects to ascertain how that might look when scaled.

Table 8-11. Description of the blended service variant options

Option	Description of the blended variant option[1,2]	Planning units affected by changes[3]
BVO-1	• Upgrade and/or rehabilitate all existing unsafe sanitation infrastructure and services to be safely managed. • All traditional latrines and households practising open defecation shift to improved pit latrines (IPL).	• PU1-2, 5, 25 and 32: upgrade from traditional latrines to IPL. • PU1-35: shift people open defecating to IPL. • PU3-4, 6-24, 26-31, 33-35: upgrade/rehabilitate latrines to IPL. • PU3-4, 6-24, 26-31, 33-35: upgrade/rehabilitate septic tanks in LIHD areas. • PU15 and PU18: rehabilitate sewer infrastructure
BVO-2	• Extend to full sewer coverage all MIMD and HILD areas partly sewered. • Adopt measures in BVO-1 above.	• Adopt PU in BVO-1. • PU38-41, 44A-47, 49-50, 58, 62, 64, 66, 68, 70-71, 73-74, 76-80
BVO-3	• Extend to full sewer coverage in all areas partly sewered. • Adopt measures in BVO-1.	• Adopt PU in BVO-1. • PU7-8, 10, 15, 18-20, 22, 34, 38-41, 44A-47, 49-50, 58, 62, 64, 66, 68, 70-71, 73-74, 76-80A
BVO-4	• Extend to full sewer coverage in all areas partly sewered. • Extend to full sewer coverage in all areas close to the trunk network. • Adopt measures in BVO-1.	• Adopt PU in BVO-1. • PU3, 6-8, 10, 14-16, 18-20, 22, 28-29, 34-35, 37-41, 44A-47, 49-50, 57-58, 62, 64-66, 68, 70-80A, 84
BVO-5	• Extend to full sewer coverage in all areas partly sewered. • Extend to full conventional sewer coverage MIMD and HILD areas close to the trunk network. • Extend to full simplified sewer coverage LIHD areas close to the network. • Adopt measures in BVO-1.	• Adopt PU in BVO-1. • Conventional sewers: PU7-8, 10, 16, 18-20, 22, 34, 37-41, 44A-47, 49-50, 57-58, 62, 64-66, 68, 70-80A, 84 • Simplified sewers: PU3, 6, 14-15, 28-29, 35
BVO-6	• Extend to full sewer coverage all areas partly sewered. • Extend to full simplified sewer coverage in all LIHD, MIMD, and HILD areas close to the trunk network. • Adopt measures in BVO-1.	• Adopt PU in BVO-1. • Conventional sewers: PU7-8, 10, 16, 18-20, 22, 34, 38-41, 44A-47, 49-50, 58, 62, 64, 66, 68, 70-71, 73-74, 76-77, 79-80A • Simplified sewers: PU3, 6, 14-15, 28-29, 35, 37, 57, 65, 72, 75, 78, 84

Notes: [1]All sewered and non-sewered services are safely managed, with existing infrastructure and services upgraded/rehabilitated.
[2]For all cases, septic tanks are the optimal technology in areas with reliable water supply, with IPL in LIHD areas where water supply is unreliable.
[3]The changes happening in the PU are based on the baseline sanitation and water supply situation shown in Figure 8-1 and Table 8-4

Additional capacity at the utility, service provider, local authority, and regulator levels is essential for the area-by-area optimised approach. The capacity is crucial to enhance the environment for enabling, delivering, and sustaining citywide sewered and non-sewered services. All the proposed services need to be well managed, with the overall responsibility for services taken away from individual households and taken up by the public sector, as a sole provider or on a delegated basis. All the greywater, as well as the excreta, is safely handled. All FSM are demand responsive and well regulated, with efficient and effective emptying services. All on-site facilities have no connections to open drains and with well designed and built soak pits for all septic tanks where the hydrogeology allows. All sewers infrastructure are well maintained and operated with no leakages. The safe management of wastewater and faecal sludge is central to this approach.

Table 8-12 presents the cost performance of the area-by-area optimised blended variant options across the different urban settings in Lusaka. The cost data are presented as ranges, showing the city-level performance of the options.

The options BVO-2 to BVO-6 are incremental solutions that build upon the ‘base’ option, BVO-1. BVO-1 has the lowest capital cost intervention as it involves upgrading and rehabilitating existing sanitation infrastructure and services. BVO-2 ranks second by building on BVO-1 with the extension to full sewer coverage in all MIMD and HILD areas currently partly sewered. BVO-3 ranks third by extending to full sewer coverage all LIHD areas partly sewered in addition to measures in BVO-2. BVO-4 ranks as the most costly option by adding to BVO-3 all areas across urban settings that are close to the trunk network to full sewer coverage. BVO-5 is a variant of BVO-3 that extends to full sewer coverage in all areas partly sewered while extending MIMD and HILD areas close to the trunk network with conventional sewers. In LIHD areas, the extension is with simplified sewers for all areas close to the trunk network. The option ranks fifth for capital costs. BVO-6 is a variant of BVO-4 by extending all areas close to the trunk network with simplified sewers, and it ranks as the fourth most capital intensive option (Table 8-12).

Table 8-12. City-level costing for the area-by-area optimised blended service approach options in Lusaka

Sanitation Options	Urban Setting	Baseline Population	% of Pop.	Population Shift	% of Pop.	Sanitation System Costs (US$ 2018 year^{-1})			
						CapEx (capita^{-1})	OpEx (capita^{-1})	Population Total (CapEx)	Population Total (OpEx)
BVO-1	LIHD$_{CS}$	131,126	5	4,574	0.2	55-66	22-24	251,570 - 301,884	2,884,772 - 3,147,024
	MIMD$_{CS}$	102,964	4			54-62	6-20		617,784 - 2,059,280
	HILD$_{CS}$	100,096	4			75-78	9-21		900,864 - 2,102,016
	LIHD$_{SS}$	1,029	0.04	1,029	0.04	64-65	22-23	65,856 - 66,885	22,638 - 23,667
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	17,695,431 - 29,946,114
	LIHD$_{ST}$	86,884	4	86,884	4	27-44	13-17	2,345,868 - 3,822,896	1,129,492 - 1,477,028
	MIMD$_{ST}$	330,416	14			60-61	12-14		3,964,992 - 4,625,824
	HILD$_{ST}$	213,445	9			84-85	12-14		2,561,340 - 2,988,230
	Unserved	93,086	4						
	Total cost liabilities (BVO-1)							**15,524,978 - 29,235,495**	**29,777,313 - 46,369,183**
BVO-2	LIHD$_{CS}$	131,126	5	4,574	0.2	55-66	22-24	251,570 - 301,884	2,884,772 - 3,147,024
	MIMD$_{CS}$	102,964	4	121,456	5	54-62	6-20	6,558,624 - 7,530,272	1,346,520 - 4,488,400
	HILD$_{CS}$	100,096	4	136,796	6	75-78	9-21	10,259,700 - 10,670,088	2,132,028 - 4,974,732
	LIHD$_{SS}$	1,029	0.04	1,029	0.04	64-65	22-23	65,856 - 66,885	22,638 - 23,667
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	16,942,432 - 28,671,808
	LIHD$_{ST}$	86,884	4	57,923	2	27-44	13-17	3,909,789 - 6,371,508	1,882,491 - 2,461,719
	MIMD$_{ST}$	330,416	14	208,960	9	60-61	12-14		2,507,520 - 2,925,440
	HILD$_{ST}$	213,445	9	76,649	3	84-85	12-14		919,788 - 1,073,086
	Unserved	93,086	4						
	Total cost liabilities (BVO-2)							**33,925,223 - 49,984,467**	**28,638,189 - 47,765,876**
BVO-3	LIHD$_{CS}$	131,126	5	274,782	11	55-66	22-24	15,113,010 - 18,135,612	8,829,348 - 9,632,016
	MIMD$_{CS}$	102,964	4	121,456	5	54-62	6-20	6,558,624 - 7,530,272	1,346,520 - 4,488,400
	HILD$_{CS}$	100,096	4	136,796	6	75-78	9-21	10,259,700 - 10,670,088	900,864 - 2,102,016
	LIHD$_{SS}$	1,029	0.04	11,435	0.5	64-65	22-23	731,840 - 743,275	251,570 - 263,005
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	13,856,729 - 23,449,848
	LIHD$_{ST}$	86,884	4	72,404	3	27-44	13-17	4,300,776 - 7,008,672	2,070,744 - 2,707,896
	MIMD$_{ST}$	330,416	14	208,960	9	60-61	12-14		2,507,520 - 2,925,440
	HILD$_{ST}$	213,445	9	76,649	3	84-85	12-14		919,788 - 1,073,086
	Unserved	93,086	4						
	Total cost liabilities (BVO-3)							**49,843,634 - 69,131,749**	**30,683,083 - 46,461,707**

Sanitation Options	Urban Setting	Baseline Population	% of Pop.	Population Shift	% of Pop.	Sanitation System Costs (US$ 2018 year^{-1})			
						CapEx (capita^{-1})	OpEx (capita^{-1})	Population Total (CapEx)	Population Total (OpEx)
BVO-4	LIHD$_{CS}$	131,126	5	386,057	16	55-66	22-24	21,233,135 - 25,479,762	11,277,398 - 12,302,616
	MIMD$_{CS}$	102,964	4	143,991	6	54-62	6-20	7,775,514 - 8,927,442	1,481,730 - 4,939,100
	HILD$_{CS}$	100,096	4	177,908	7	75-78	9-21	13,343,100 - 13,876,824	2,502,036 - 5,838,084
	LIHD$_{SS}$	1,096	0.04	11,435	0.5	64-65	22-23	731,840 - 743,275	251,570 - 263,005
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	12,389,446 - 20,966,755
	LIHD$_{ST}$	86,884	4	88,333	4	27-44	13-17	4,730,859 - 7,709,548	2,237,821 - 2,609,950
	MIMD$_{ST}$	330,416	14	186,425	8	60-61	12-14		2,237,100 - 2,609,950
	HILD$_{ST}$	213,445	9	35,537	1	84-85	12-14		426,444 - 497,518
	Unserved	93,086	4						
							Total cost liabilities (BVO-4)	**60,694,132 - 81,780,681**	**32,843,545 - 50,395,717**
BVO-5	LIHD$_{CS}$	131,126	5	274,782	11	55-66	22-24	15,113,010 - 18,135,612	8,829,348 - 9,632,016
	MIMD$_{CS}$	102,964	4	143,991	6	54-62	6-20	7,775,514 - 8,927,442	1,481,730 - 4,939,100
	HILD$_{CS}$	100,096	4	177,908	7	75-78	9-21	13,343,100 - 13,876,824	2,502,036 - 5,838,084
	LIHD$_{SS}$	1,096	0.04	122,620	5	64-65	22-23	7,847,680 - 7,970,300	2,697,640 - 2,820,260
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	12,390,616 - 20,968,735
	LIHD$_{ST}$	86,884	4	88,333	4	27-44	13-17	4,730,859 - 7,709,548	2,237,821 - 2,609,950
	MIMD$_{ST}$	330,416	14	186,425	8	60-61	12-14		2,237,100 - 2,609,950
	HILD$_{ST}$	213,445	9	35,537	1	84-85	12-14		426,444 - 497,518
	Unserved	93,086	4						
							Total cost liabilities (BVO-5)	**61,689,847 - 81,663,556**	**32,842,735 - 50,284,352**
BVO-6	LIHD$_{CS}$	131,126	5	274,782	11	55-66	22-24	15,113,010 - 18,135,612	8,829,348 - 9,632,016
	MIMD$_{CS}$	102,964	4	121,456	5	54-62	6-20	6,558,624 - 7,530,272	1,346,520 - 4,488,400
	HILD$_{CS}$	100,096	4	136,796	6	75-78	9-21	10,259,700 - 10,670,088	900,864 - 2,102,016
	LIHD$_{SS}$	1,096	0.04	122,620	5	64-65	22-23	7,847,680 - 7,970,300	2,697,640 - 2,820,260
	MIMD$_{SS}$			22,535	1	69	22	1,554,915	495,770
	HILD$_{SS}$			41,112	2	75	23	3,083,400	945,576
	LIHD$_{IPL}$	1,361,187	56	715,538	30	18-35	12-22	12,879,684 - 25,043,830	14,524,826 - 24,580,475
	LIHD$_{ST}$	86,884	4	88,333	4	27-44	13-17	4,906,076 - 7,709,548	3,329,123 - 3,854,774
	MIMD$_{ST}$	330,416	14	186,425	8	60-61	12-14		2,237,100 - 2,609,950
	HILD$_{ST}$	213,445	9	35,537	1	84-85	12-14		426,444 - 497,518
	Unserved	93,086	4						
							Total cost liabilities (VO-6)	**62,027,827 - 77,059,650**	**34,681,909 - 49,709,324**

Notes: Allocation of the population in non-sewered LIHD areas using improved latrines was 90%, while septic tanks were 10%. The allocation followed the current distribution of technologies used in these settings

CS - Conventional Sewerage; SS – Simplified Sewerage; ST - Septic Tanks; IPL – Improved Pit Latrines

The operational cost performance for the whole population is not considerably different among the options. BVO-1 (upgrade and rehabilitation of existing infrastructure and services) marginally ranks as the most cost-effective option (Table 8-12). BVO-3 increases sewer coverage in densely populated areas with lower operational costs. In addition, it reduces improved latrine use, which has higher operational costs. The shift in coverage from improved latrines to sewers occurs in LIHD areas - between BVO-2 and BVO-3 - while services remain the same in MIMD and HILD areas. BVO-2 upgrades and rehabilitates existing infrastructure and service options, with the extension to full sewerage coverage in all MIMD and HILD areas partly sewered, ranks third. The costs for the options BVO-4 to BVO-6 are not considerably different for operating and sustaining services; however, BVO-6 performs better as it has a higher proportion of the sewered population on simplified sewers, which are cheaper.

8.6.1 Characteristics of the area-by-area optimised blended options

The characteristics of each optimised option and the population shift for planning units for the different sanitation services are discussed. BVO-1 is the base option that upgrades and rehabilitates existing infrastructure to levels where services are optimally managed. All sewer service gaps in MIMD and HILD areas are filled. In LIHD areas, sewerage and FSM services are brought to a level where they are safely managed. The option has capital expenditure for those practising open defecation and users of traditional latrines across LIHD PU 1-35, all moving to improved latrines. Hence, adding 34% of the city population (808,624 people) to safely managed FSM services (Table 8-12). The increase in FSM services necessitates expansion in treatment capacity from the current 4% of the city population. Septic tanks in PU 1-35 and sewers in PU 15 and 18 are upgraded and rehabilitated. MIMD and HILD areas have no capital expenditure. All sewered and non-sewered services across urban settings for the whole population have operational expenditure allocated to ensure services are sustained at optimal levels. Figure 8-6 maps the six incremental area-by-area optimised blended service options for the city.

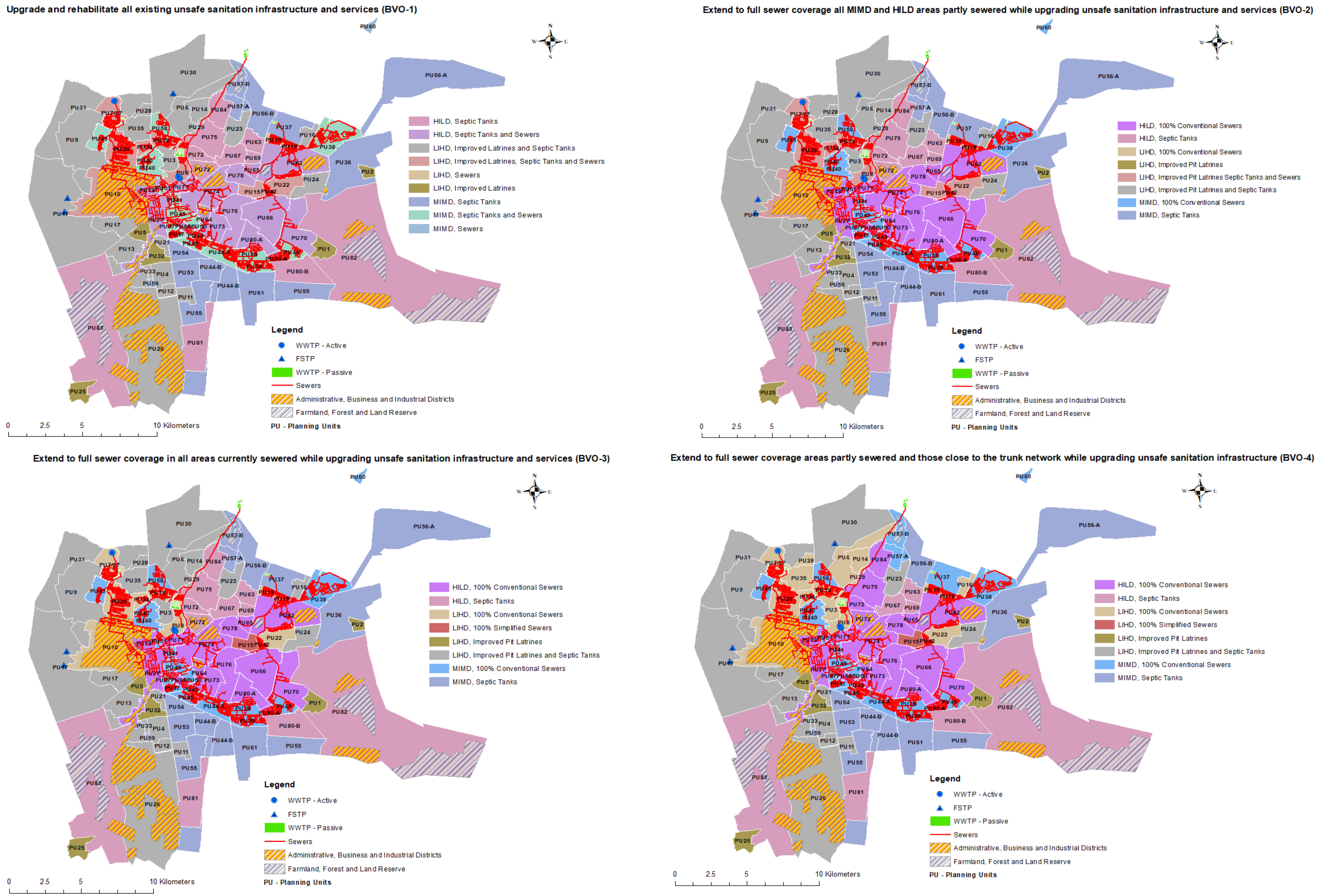


Figure 8-6. Area-by-area optimised blended service options for Lusaka: BVO-1 (Top Left); BVO-2 (Top Right); BVO-3 (Bottom Left); and BVO-4 (Bottom Right)

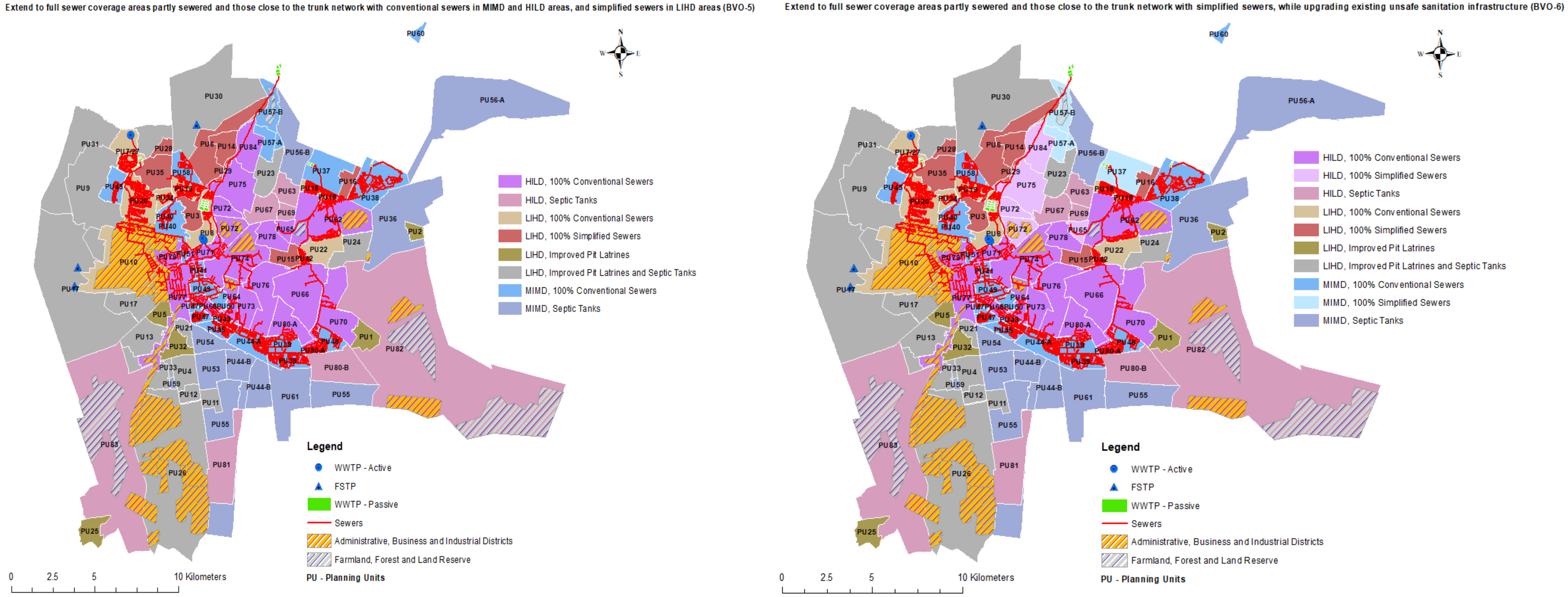


Figure 8-6. Area-by-area optimised blended service options for Lusaka : BVO-5 (Left); BVO-6 (Right);

BVO-2 builds on BVO-1 by extending to full sewer coverage all MIMD and HILD areas that are partly sewered. The incremental shift from septic tanks to sewers in MIMD areas - PU38-41, 44A-47, 49-50 and 58 - is 5% of the population (Table 8-12). In HILD areas - PU62, 64, 66, 68, 70-71, 73-74, 76-80 - the shift is 6%. The extension adds 11% of the city population (258,252 people) in MIMD and HILD areas to sewered services. The current treatment capacity for sewered services is estimated at 23% of the city population (565,601 people) from the two active and five passive WWTP in Lusaka. For the option, the total number of people across all urban settings using sewerage is 593,467 people, 5% above the current treatment capacity. In LIHD areas, 2% of the city population (57,923 people) shift from IPL to septic tanks (Table 8-12).

BVO-3 builds on BVO-2 by extending sewer services to full coverage in all LIHD areas partly sewered. The incremental shift from the IPL and/or septic tanks to conventional sewers in PU7-8, 10, 18-20, 22 and 34 is 11% (274,782 people) (Table 8-12). For simplified sewers (PU15), the shift is 0.5% of the city population (11,435 people). Around 3% of the population (72,404 people) shift from IPL to septic tanks. Services in MIMD and HILD areas remain the same as in BVO-2 above. The option has 874,081 people across all urban settings using sewerage - 54% above the current treatment capacity. Expansion in treatment facilities for non-sewered services is needed for 64% of the city population.

BVO-4 builds on BVO-3 by extending to full sewer coverage all areas close to the trunk network across all urban settings. The incremental shift in LIHD areas from the IPL and/or septic tanks to conventional sewers in PU3, 6-8, 10, 14, 16, 18-20, 22, 28-29 and 34-35 is 16% (386,057 people) (Table 8-12). The shift from septic tanks to sewers in MIMD areas (PU37-41, 44A-47, 49-50 and 57-58) is 6% of the population (143,991 people). In HILD areas (PU62, 64-66, 68, 70-80 and 84), the shift is 7% (177,908 people). Overall, the extension to full sewer coverage in areas partly sewered and those close to the trunk network adds 29% of the city population (713,788 people) to sewered services. The extensions culminate in total sewerage use of 1,049,003 people across the city - 85% above current treatment capacity. Around 4% of the population (88,333 people) shift from IPL to septic tank use in LIHD areas. Treatment facilities for non-sewered services are needed for 57% of the city population.

BVO-5 is a variation of BVO-4. The difference is that BVO-5 extends to full simplified sewer coverage in all LIHD areas close to the current trunk network. Extensions in all areas partly sewered and in MIMD and HILD areas close to the trunk network remain the same as in BVO-4. In LIHD areas (PU3, 6, 14, 16, 28-29 and 35), the shift to simplified sewers is 5% of the city population (122,620 people) (Table 8-12). Thus, the total number of people using sewerage is the same as BVO-4 - 85% above the current treatment capacity.

BVO-6 is a further variation of BVO-4 that extends to full simplified sewer coverage of all LIHD, MIMD and HILD areas close to the current trunk network. The extensions in all areas partly sewered remain the same as in BVO-4, as are the extensions to simplified sewers in LIHD areas in BVO-5. The shift from septic tanks to simplified sewers in MIMD areas (PU37 and 57) is 1% of the city population (22,535 people) (Table 8-12). In HILD areas (PU65, 72, 75, 78 and 84), the shift is 2% of the city population (41,112 people). Thus, the total number of people using sewerage is 85% above the current treatment capacity in this option.

The area-by-area optimised options require expanded treatment capacity for both sewered and non-sewered services. The extra treatment capacity for sewered services ranges from 5% (BVO-2) to 85% (BVO-4 to BVO-6). Plans are underway to construct a new treatment plant in the Northern part of the city with a 2025 capacity of 524,613 people. The new plant will replace one of the active WWTP with a capacity of 231,031 people. Overall, the added capacity with the new plant would be 293,582 people, translating to a total city-level treatment capacity of 859,183 people. For BVO-1 and BVO-2, the added sewerage treatment capacity is sufficient to sustain services. However, the new WWTP falls short of the needed treatment capacity by 2% for BVO-3 and 22% for BVO-4 to BVO-6. Treatment facilities for FSM services would also need expansion as current capacity caters for around 4% of the population.

8.6.2 Overall performance of the area-by-area optimised blended options

Table 8-13 below presents the overall performance of the blended options against cost, the enabling environment, and community-level criteria. Appendix F, Tables 8 to 10 show the complete AHP analysis for the blended options with respect to the three criteria used. When capital costs are the priority, the upgrade/rehabilitation option (BVO-1) (32%) has a better performance than the other options (Appendix F, Table 9). The option is the least-cost intervention as it ensures all existing services are safely managed. BVO-1 and BVO-3 (which extends to full sewer coverage in all areas partly sewered and upgrades existing services), both at 17.4%, have the best operational cost performance among the options.

BVO-2 (33%) - extending to full sewer coverage all MIMD and HILD areas partly sewered and upgrades existing services - has a better fit among the options for policy and legislation (Appendix F, Table 9). The upgrade and rehabilitation option (BVO-1) (39 and 40%) has a better performance for institutional roles, capacity, monitoring and enforcement. It optimises existing services that may be less challenging to strengthen current institutional capacities and roles than the other options expanding infrastructure at a larger scale. The options having a higher proportion of the population on sewerage (BVO-4 to BVO-6) perform better (26%) than options with more people on FSM (BVO-1 to BVO-3) (4-12%) when institutions and services providers are considered. Delivery of sewerage services is by a public sector owned utility that can mobilise the required capabilities to increase coverage while FSM services are unbundled and delivered by the private sector. Effective coordination and proper incentive structures are necessary to ensure FSM services operate profitably to attract private sector players under this business model. The current policy framework for cost recovery from tariffs and fees averages 57% for sewerage and 73% for FSM-Based VTO services (Tables 8-1 and 8-2). Cost recovery fits well with the options with a higher proportion of the population on FSM services (BVO-1) (42%) compared to those with a higher population on sewerage services (BVO-4 to BVO-6) (6%).

Table 8-13. Overall priorities for cost, enabling environment and community-level criteria for the blended service options

Sanitation Alternatives	Overall Priorities		
Cost Priority	Costs have a higher priority with the enabling environment and community-level factors having equal priorities	Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	Costs have a higher priority, with community-level factors having a higher priority than the enabling environment
BVO-1	**0.24**	**0.25**	**0.24**
BVO-2	**0.18**	**0.19**	**0.18**
BVO-3	**0.15**	**0.15**	**0.15**
BVO-4	**0.14**	**0.14**	**0.15**
BVO-5	**0.14**	**0.13**	**0.14**
BVO-6	**0.14**	**0.14**	**0.15**
Enabling Environment Priority	Enabling environment has a higher priority with costs and community-level factors having equal priorities	Enabling environment has a higher priority with costs having a higher priority than community-level factors	Enabling environment has a higher priority, with community-level factors having a higher priority than costs
BVO-1	**0.25**	**0.25**	**0.25**
BVO-2	**0.22**	**0.22**	**0.22**
BVO-3	**0.15**	**0.15**	**0.15**
BVO-4	**0.13**	**0.13**	**0.13**
BVO-5	**0.12**	**0.12**	**0.13**
BVO-6	**0.12**	**0.12**	**0.12**
Community-level Priority	Community-level factors have a higher priority with costs and the enabling environment having equal priorities	Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	Community-level factors have a higher priority, with the enabling environment having a higher priority than costs
BVO-1	**0.20**	**0.20**	**0.20**
BVO-2	**0.15**	**0.15**	**0.16**
BVO-3	**0.13**	**0.13**	**0.13**
BVO-4	**0.17**	**0.17**	**0.17**
BVO-5	**0.17**	**0.17**	**0.17**
BVO-6	**0.17**	**0.17**	**0.17**

Note: The sanitation option scoring highest in each case is highlighted

Figure 8-7 shows the financing gap for the proposed options based on current cost recovery policies for services. The proposition for the optimised approach is to structure services to reflect costs, with safeguards in place to protect the urban poor. These are outlined in Section 9.3 and discussed in Chapter 10.

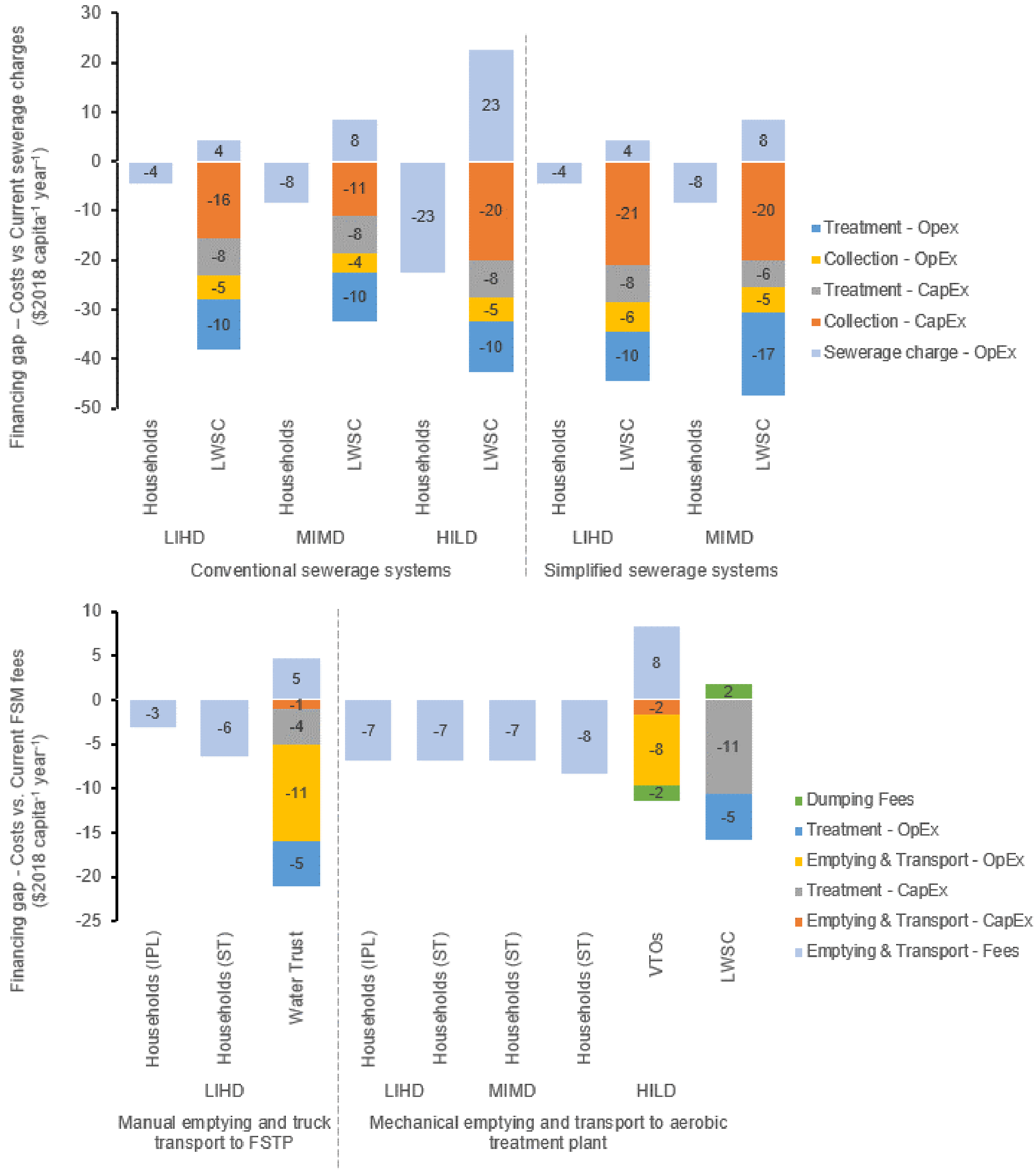


Figure 8-7. Financing gap (costs vs current charges/fees) for operations of the proposed options Sewered (Top); and Non-sewered systems (Bottom)

For sewered systems, utility CapEx is \$11-21 and \$6-8 capita^{-1} year^{-1} for collection and treatment, with OpEx at \$4-6 and \$10-17 capita^{-1} year^{-1}. For FSM, Water Trust (WT) and VTO CapEx is \$1-2 capita^{-1} year^{-1} for emptying and transport, with OpEx at \$8-11 capita^{-1} year^{-1}. For treatment, CapEx for WTs and the utility are \$4-11 capita^{-1} year^{-1}, with OpEx at \$5 capita^{-1} year^{-1}. The financing gap between costs and revenue is discussed in Chapter 10.

The options (BVO-4 to BVO-6) with a higher proportion of the population on sewers (25%) out-perform the options (BVO-1 to BVO-3) with a higher population using FSM services (4-11%) for population density (Appendix F, Table 9). Population density significantly affects the cost and operational performance of sewers compared to FSM-based systems. However, the capital costs for sewered systems are considerably higher than for FSM-based systems (Table 8-12). The options (BVO-4 to BVO-6) with more people on sewers (24%) perform better than the options (BVO-1 to BVO-3) with more people using FSM services (12%) for willingness to pay.

A reliable water supply is essential to the operation of water-borne sanitation systems. The amount of water needed for the water-based sanitation systems is the same that people need to have a decent quality of life. Therefore, the utility needs to be providing sufficient water. Furthermore, it will enable water-borne systems, particularly sewers, to look attractive as the greywater is safely managed. Based on the current situation, the options with more people using on-site systems (14-47%) perform better than the more sewer-based systems (6%) as they are more tolerable to a limited water supply.

Figure 8-8 presents the overall performance of the area-by-area optimised blended service options against the three criteria priorities. When the cost criterion is prioritised, the optimal sanitation solution for the city is the upgrade and rehabilitation option (BVO-1). When criteria within the enabling environment are prioritised, the optimal option is BVO-1. Finally, when community-level criteria are prioritised, BVO-1 is the optimal sanitation solution for the city. BVO-1 fits well across all three criteria as it is the base option that the other blended variant options build on. Excluding the base option shows that BVO-2 - extension to full sewer coverage in all MIMD and HILD areas partly sewered and upgrading existing infrastructure and services - is a better fit for costs and enabling environment criteria. For community-level criteria, the options (BVO-4 to BVO-6) with a higher proportion of the population on sewers among the option is a better fit.

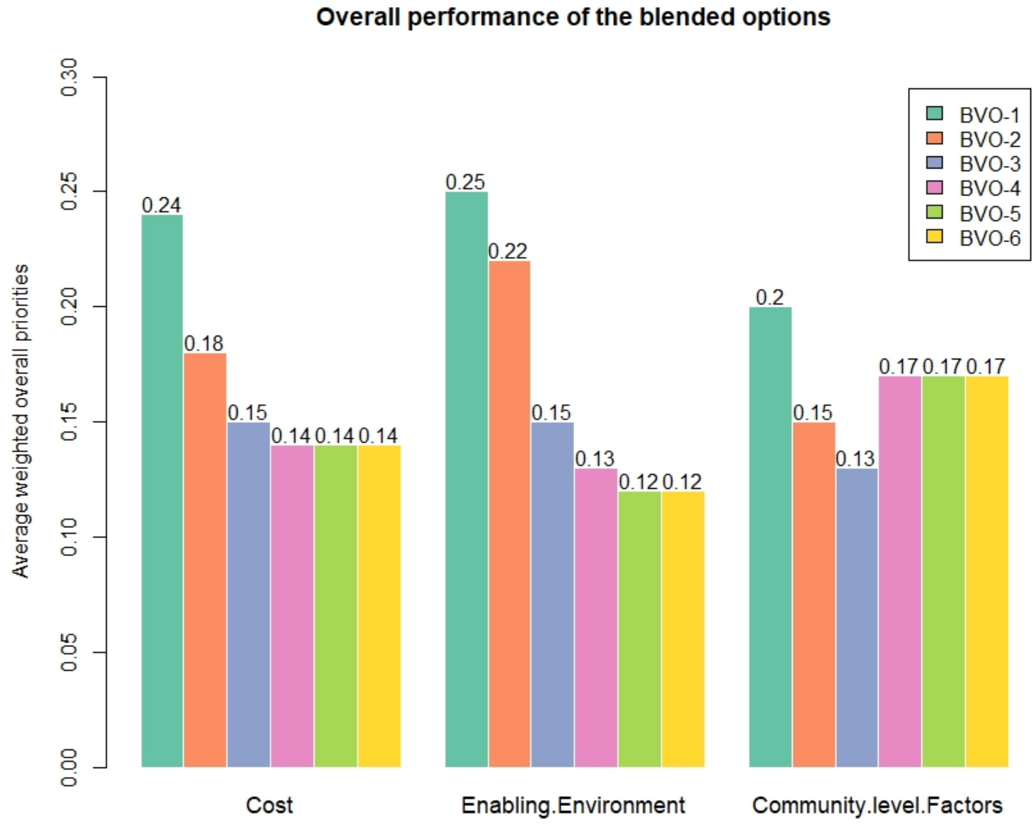


Figure 8-8. Blended service options weighted output of the AHP analysis for cost, enabling environment and community-level criteria priorities

For the decision-maker, the analysis outcomes do not prescribe which blended service options are best as the decision rests on which criteria they prioritise for the city. In summary, the decision-maker trades off the performance of both sewered and non-sewered systems based on the three criteria used to fit their strategic objectives for services delivery for the entire city of Lusaka. The proposition as a first step would be ensuring that existing sanitation infrastructure and services are safely managed systems (BVO-1) - having outlined the blended service options as the most pragmatic approach for the city. Then depending on what city authorities prioritise, any of BVO-2 to BVO-6 would be practical to implement. Chapter 9 outlines the possible risks to rolling out the workable citywide blended service options. It also sets out possible adaptation measures.

Chapter 9: Risks and resilience of the area-by-area optimised blended sanitation options

9.1 Introduction

Having proposed a set of workable options or solutions (BVO-1 to BVO-6) for the city (Chapter 8), further consideration is needed to ensure that implementation will take place and services will be delivered. The due consideration is taking a risk-management approach for the workable options as delivering and sustaining citywide complex investment systems may have challenges. This chapter, therefore, summarises the possible challenges and proposes possible adaptation measures. The chapter describes the risks and the approach to inform plans for resilient citywide sanitation systems. Understanding the inherent risks represents a fundamental approach to incorporating broader city-level responses when planning for and building resilient sanitation systems. Resilience is the capacity of systems to cope and adapt in ways that maintain their essential function (IPCC, 2014, p. 127). The approach provides a basis for considering the extent of policy, institutional capacity, governance, financing, socio-economic and technical (infrastructure, technology and service delivery) dimensions needed at the city level to sustain services.

9.2 Risk identified for the area-by-area optimised blended service options

Delivery of infrastructure and services at scale has several risks. When actualised, risks may strain sanitation systems and service delivery. Therefore, planning for risks is essential to ensure services are designed and delivered safely to maximise the public good. Figures 9-1 and 9-2 present the global and local risks identified that might need overcoming to have resilient citywide sewered and non-sewered sanitation systems in Lusaka.

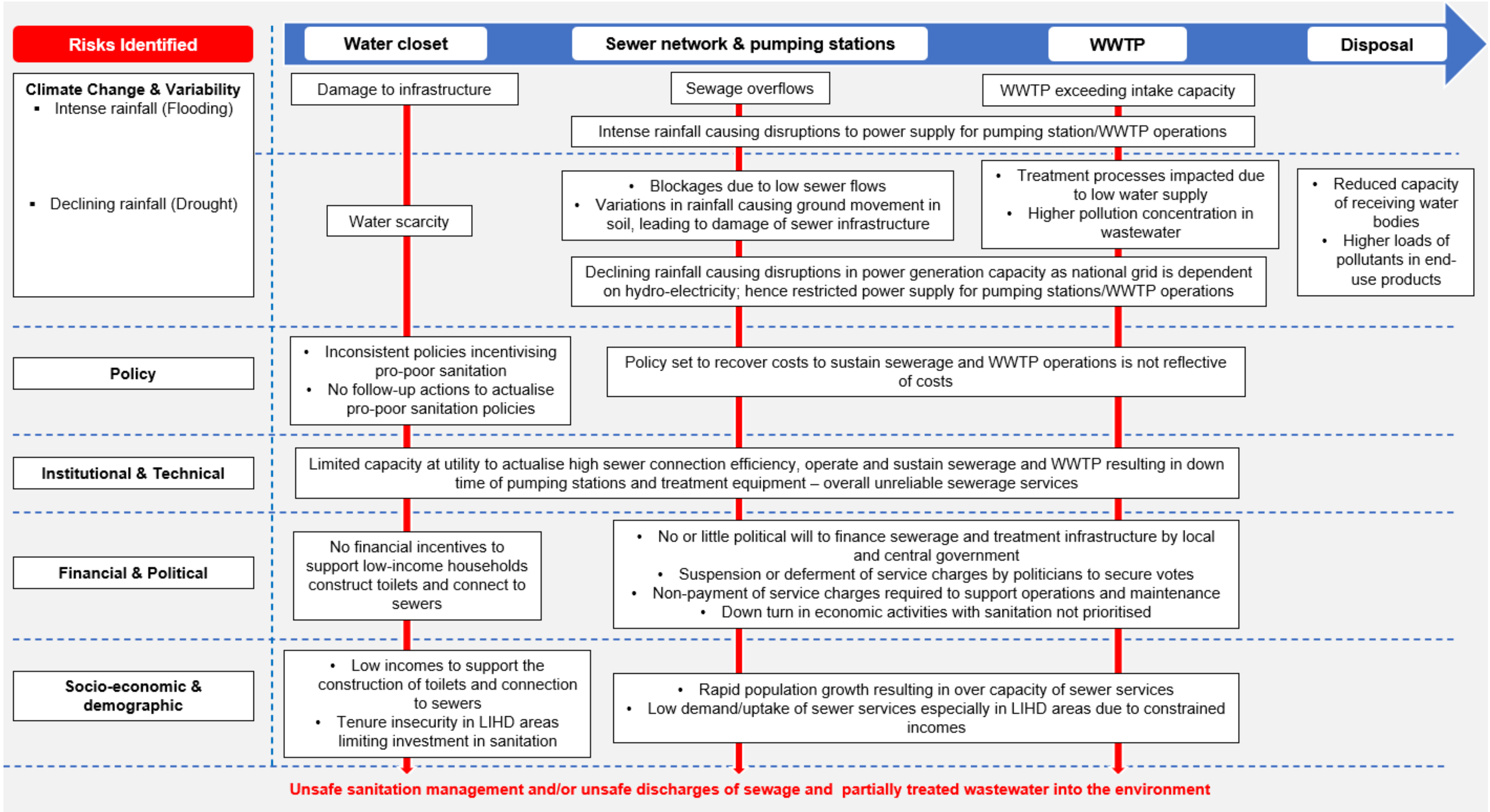


Figure 9-1. Risks identified at each step of the sanitation value chain for the area-by-area sewered options in Lusaka

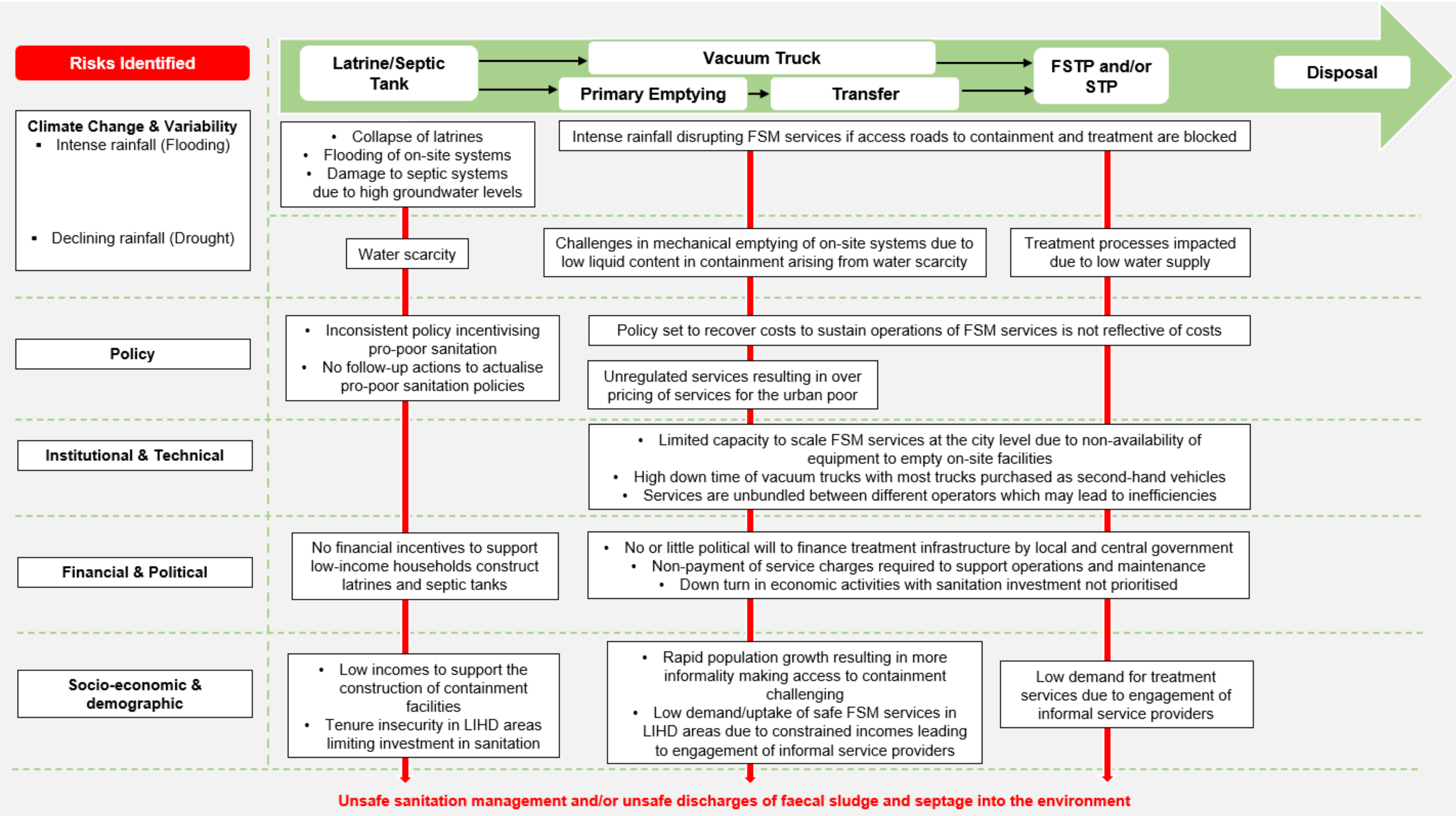


Figure 9-2. Risks identified at each step of the sanitation value chain for the area-by-area non-sewered options in Lusaka

The risks to sanitation infrastructure and services in different urban settings can be complex across the value chain elements. The potential risks of failure for the optimised sanitation systems and services at the global level include climate change and variability leading to extreme rainfall or drought events. Intense rainfall resulting in floods may cause sewage overflows in sewered systems with WWTP exceeding their intake capacity. It can further cause damage to latrine, septic tank or sewerage infrastructure, resulting in stormwater and soil ingress into conveyance systems. Power supplies may be affected, causing disruptions to pump station and treatment operations. FSM services risk disruption when road access to containment and treatment are blocked.

A decline in rainfall leading to drought can cause water scarcity, affecting the optimal functioning of water-dependent systems. The result is insufficient water available for flushing and blockages due to low sewer flows. Variations in rainfall can cause movement in soils, damaging sewerage infrastructure. Rolling out sewers to address service inequalities in LIHD areas can unintentionally put poor households at increased risk of future climate change. The service may provide short-term benefits but create longer-term service challenges with future water scarcity causing the sewerage network to fail and with no alternative facilities as resources may be limited to adapt (Kohlitz et al., 2019).

Local risks may be technical in terms of infrastructure and equipment. They include mechanical failure at pumping stations and treatment plants and high downtime for vacuum trucks. Institutional risks may include limited capabilities to operate and maintain facilities and plants. For FSM, there may be inefficiencies in collection and transport due to unbundled services among different providers. Other risks are governance and financial, with little or no political will to finance sanitation, inconsistent policies, suspension or deferment of payment of service charges by politicians to secure votes. Cost recovery policies may not reflect the cost to operate and sustain services.

Social risk factors include rapid population growth, leading to densification and overwhelming service delivery capacity. With densification is a risk of increased informality in LIHD areas, which might cause difficulty in access with motorised trucks, making the safe collection of faecal sludge and septage challenging. In addition, a downturn in economic activities could lead to low uptake of sewer and non-sewered services due to constrained incomes leading to engagement of informal service providers for FSM systems.

9.3 Pathways for building in resilience for area-by-area blended options

Several pathways for building the resilience of sanitation systems are described for the optimised options for the risks identified. In addition, highlighting approaches linking the vulnerability of the service options to stresses and risks are helpful to identify where to focus adaptation efforts.

Risk assessing and mapping areas within the city most at risk of exposure to hazards such as floods and water scarcity would help identify areas where services are likely to be disrupted. For example, in flood-prone areas, adaptation measures could include raising the height of septic tanks and latrines above ground to avert the washout of waste into the environment following a flood event.

Assessing the vulnerability of populations using socio-economic and service access indicators is essential. Where vulnerabilities exist, support and planning for adaptations related to service access should be strengthened. Facility construction and sewer connectivity may need to be incentivised to ensure no one is left behind. Low-income households may need financial or hardware subsidies for climate-resilient facilities suitable for changing environmental conditions such as rising groundwater table levels. From the governance and institutional perspective, strengthen policy processes for implementing adaptation measures. Measures could include making funds available when needed, institutions being responsive to the available evidence base, and strengthening decision-making and stakeholder engagement processes. These measures could highlight the strengths and gaps in the enabling environment needed to implement services effectively. Figure 9-3 shows possible pathways for adapting the blended service options for risks identified.

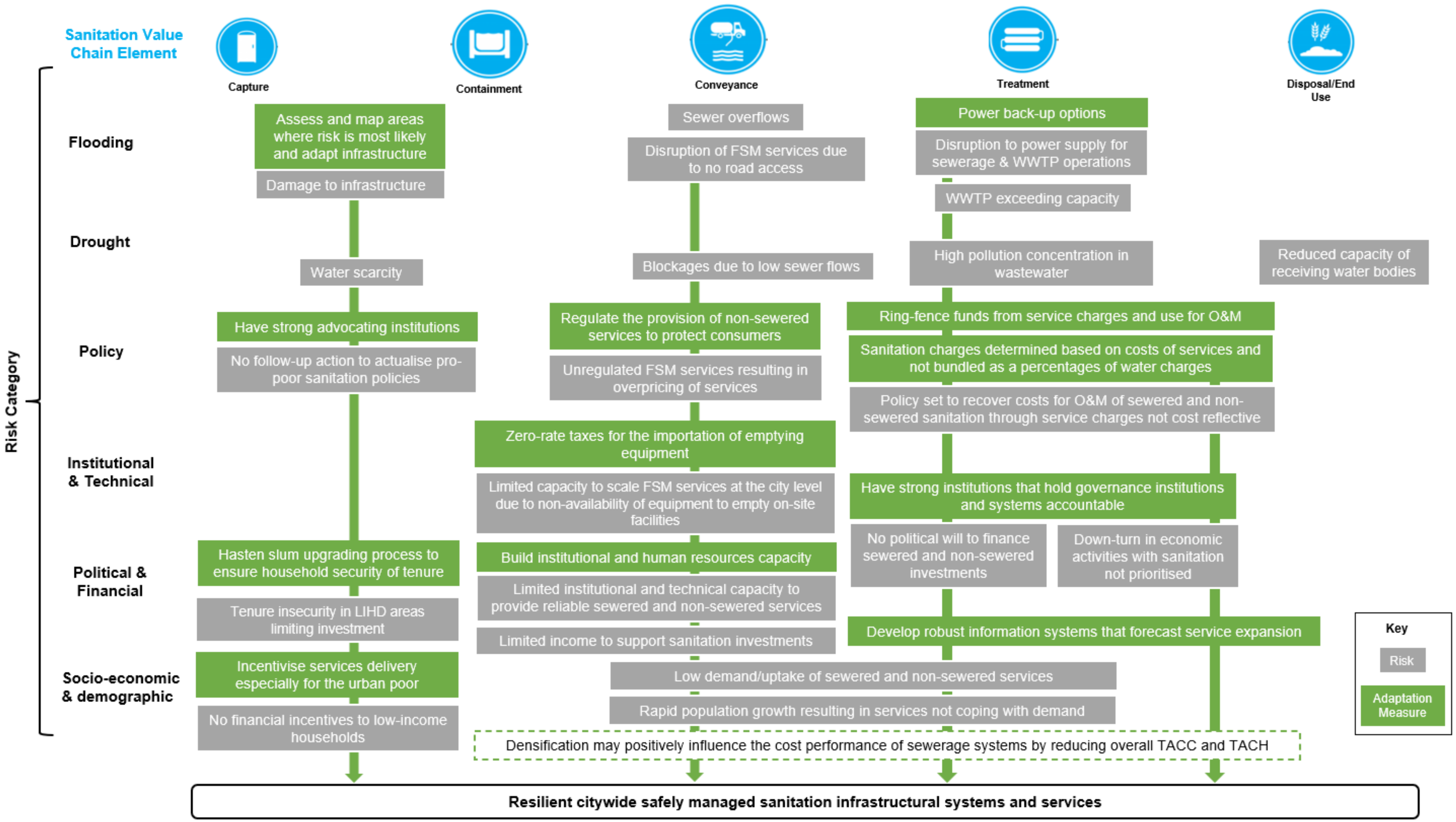


Figure 9-3. Pathways for adapting the city-level area-by-area optimised blended systems and services for the risks identified

Developing a coherent city-level approach to sanitation infrastructure and service delivery choices is essential. City-level assessments regarding climate hazards, institutional, policy, financial and social-oriented challenges should guide the discourse around technology choices for each specific area. Decision-making about the appropriate balance in sewered and non-sewered systems should consider changing climate-related hazards considering expected technology performance and management arrangements. Assessments for new infrastructure should consider a range of risks and development scenarios. What would be the likely change in community size? What would happen if the population grew by 25% over ten years? What are the future risk factors around climate change? What happens if climate change increases water scarcity by 25% or increases flood events? Answering these questions is essential in developing adaptation measures for resilient sanitation systems. Figure 9-3 highlights that global risks from floods and drought are challenging to devise adaptation measures. The risks require broader national level intervention measures to mitigate.

Underpinning the success of effective and efficient service delivery are strong institutions devoid of political interference. The chosen institutional arrangements for service delivery need to consider the capacity of institutions to be responsive to sanitation-related risks. How robust is the decision-making? How will population growth and densification affect the flexibility of different sanitation systems regarding their cost performance in the different urban settings? Sewerage systems are more responsive to densification, with an overall reduction in costs at high connection efficiency. However, the limiting factor is the capacity of treatment facilities. Substantial investments are required to enhance the treatment capacity for sewered services, considering future population growth.

Deploying risk-based management tools for sanitation that bring together actors to identify risks and agree on improvements could be essential for the resilience of systems. The approach encompasses systematic assessments to identify and prioritise critical risks at each stage of the sanitation chain and emphasises incremental improvement over time. This approach could be helpful at the planning stage for expanding services or improving existing system performance.

Developing effective information systems that help make informed decisions to ensure sustained services are essential. These may include early warning systems to avert and minimise damage to sanitation infrastructure. In addition, regularly collecting data on how changing environmental conditions affect sanitation services and access and subsequently making appropriate sanitation provision and support strategies are needed. For example, informative and robust sanitation data indicators could be embedded within the national census, demographic health survey (DHS) and the living conditions monitoring survey (LCMS). The collection of such data during these surveys would help establish the state of sanitation within the population and help plan for services.

Securing sufficient financing for sanitation services at the local level is challenging. Existing pricing structures for services are often poorly designed, and the sanitation sector struggles to compete with funding demands from other sectors. Service charges for operating and sustaining services may need ring-fencing to ensure they are used for intended purposes. Service charges for sanitation should reflect the costs of service provision and not simply billed as a percentage of water charges. However, considerations of affordability and accessibility of equitable services for the urban poor are needed. Several financing mechanisms should be considered, including grants to service providers, hardware subsidies and micro-finance that enable tailored, localised adaptation. For example, providing landlords with access to loans for sanitation facilities will enable them to meet the sanitation requirements whilst keeping rents affordable for the urban poor. Therefore, a clear distinction is needed between a household’s responsibility and that of the public sector to ensure access to safely managed sanitation is not constrained.

Chapter 10: General discussion on planning citywide sanitation services

10.1 Introduction

This thesis presents an approach for generating city-level sanitation options, serving as a strategy for decision-making. Using Lusaka as a case study, the aim was to establish a planning approach for scaling citywide safely managed sanitation. The objectives of the thesis were:

- To review existing sanitation costing approaches and establish the financial costs of sewer-based and faecal sludge management systems.
- To assess the environment enabling the delivery and sustaining of sewered and non-sewered sanitation services.
- To explore the factors influencing household sewer connectivity and access to safely managed faecal sludge management services.
- To establish an approach for generating strategic planning options to scale safely managed sanitation services citywide.

The approach established incorporates costs of appropriate technical options and their fit with the enabling environment. Further, it links the community responsiveness of each option to support strategic decision-making. If implemented, the options would enable incremental sanitation improvements that fit the enabling environment and are responsive to community needs. Thus, the strategic planning process contributes to good health and wellbeing (SDG 3), sustainable sanitation (SDG 6) and sustainable cities (SDG 11).

This chapter discusses the approach from which conclusions are drawn and the contributions to research and practice. Then generalisations on what may be directly transferable, with an outlook on future applications.

10.2 General discussion on planning citywide sanitation using the area-by-area blended service approach

The area-by-area blended service approach pulls together Objectives 1-3 as criteria to assess the performance of several sanitation options. AHP, a participatory tool that uses stakeholder input to decide the relative importance of different criteria, helped structure the performance of options for decision-making by making priorities explicit. However, in this thesis, the researcher had the agency to decide these rankings based on Chapters 4-6. See Chapter 11 Section 11.3 on limitations.

Lusaka city has adopted the principles of citywide inclusive sanitation (CWIS). CWIS is a planning approach that addresses sanitation challenges in a city by encompassing all areas using a mix of technologies (sewered and non-sewered) for the entire service chain and involves all stakeholders (see Gambrill et al., 2020; Narayan and Lüthi, 2018; Schrecongost et al., 2020). The blended service approach proposed in this thesis is a pragmatic step to help the city actualise its CWIS aspirations. Moreover, the approach shows the whole city from several options depending on stakeholder priorities.

In Lusaka, institutional fragmentation and poor coordination among stakeholders hinder sector progress leaving services ineffective, aligning with findings by the Government of Kenya (2015). However, the approach proposes strengthening the capacity and coordination of existing institutions through adequate funding, training and devising suitable communication strategies and coordination mechanisms among stakeholders. Effective coordination is essential to support the buy-in and roll-out of citywide inclusive services. Furthermore, institutional and stakeholder accountability is needed. Therefore, regulators have a crucial role in achieving the needed accountability (e.g., Magawa et al., 2020). This is achievable when the required political will is harnessed at central and local government levels as they drive policy.

The analysis showed that the cost burden is higher for households using on-site sanitation as the public sector does not subsidise sanitation improvements. In contrast, public funds subsidise the delivery and operations of sewerage, thus highlighting inequity in service provision between the two distinct service categories. Rather than directly subsidising sanitation facilities or sewerage connections, public finance should incentivise households to invest in sanitation and leverage private finance (e.g., World Bank, 2017; Trémolet and Binder, 2013; Venugopal et al., 2012). For example, a revolving fund can be created, giving long-tenured loans or at low-interest rates to low-income landlords to help them build sanitation facilities. This illustrates the importance of changing the approach to planning sanitation to meet city-level needs and considering business models and how systems are managed and operated. In addition, creating financially sustainable, resilient business models requires new thinking about types of technical options, who provides services, and who bears the costs.

The current policy on cost recovery is not adequate as charges and/or fees are lower than the costs to deliver services. However, the lifecycle approach to costing sets out the finances needed to deliver sustainable, safely managed services (e.g., Fonseca et al., 2010; Sainati et al., 2020). In addition, the approach outlines the financing gap - costs to deliver less the recovery from charges - which may help advocate for funding from the public sector through transfers and taxes (see OECD, 2009; Leflaive and Hjort, 2020).

For the proposed sewered service options in LIHD areas, the financing gap for operations and maintenance is \$11-12 capita^{-1} year^{-1}, in MIMD areas \$6-13 capita^{-1} year^{-1}, with costs recovered in HILD areas (see Section 8.6.2, Figure 8-7). Full cost recovery (CapEx inclusive) may be challenging to achieve in the short term. For non-sewered services, the operational and maintenance costs gap in LIHD areas is \$10 capita^{-1} year^{-1} for Water Trusts and \$1 capita^{-1} year^{-1} for VTOs. In MIMD and HILD areas, the gap is \$1 and \$2 capita^{-1} year^{-1} for VTOs. The dumping fee (\$2 capita^{-1} year^{-1}) payable by VTOs to the utility does not incentivise service provision as fees are not ring-fenced for treatment. The fee should be waived to make services profitable for VTOs, thus incentivising more private sector players to join and increasing household price efficiency. As the tariffs are inadequate, funding must be leveraged from the central government via transfers and/or taxes to ensure financial resources to operate and sustain services are available. This is essential as an investment in sanitation has a high return on society (see OECD, 2011; Hutton, Guy et al., 2014; Van Minh and Nguyen-Viet, 2011; Perard, 2018).

The operationalisation of FSM as a utility service commenced in 2019; hence, it is a new line of business. Implementing FSM at a city scale needs to be appropriately structured, delivered and regulated as a means of providing safely managed services, as most households in the city use on-site facilities. As with sewerage services, there is a need to structure payments for enhanced FSM services by surcharging it to the water bill so that fees are paid in monthly incremental amounts, allowing for regular desludging. The utility should be positioned to collect the fees, which would help create price parity for emptying and collection services, possibly pegged per cubic meter of waste collected. It may help correct over-pricing by service providers as services will be regulated to protect the urban poor (e.g., Franceys and Gerlach, 2012). The charges should reflect the provision costs to ensure cost recovery or be subsidised by the public sector to sustain services. However, caution is needed as high tariffs on low-income households may hinder their willingness and ability to pay for services. Fees may also be structured so that households with higher incomes subsidise those on lower incomes, and fees should be used for the intended purposes.

The proposed approach ensures the management of grey and blackwater through non-leaking sewers, facilitated by proactive maintenance and the regular emptying of on-site facilities with safe treatment and disposal. Further, the approach ensures FSM services are enhanced, i.e., well delivered and regulated; hence, communities are more likely to embrace services. With improved facilities at the household level, the proposed approach ensures the wastewater and faecal sludge generated is safely managed as the responsibility is with the public sector either as a sole provider or on a delegated service basis.

This approach demonstrates that complex drivers are responsible for the city having different sanitation solutions, as specific local conditions make it challenging to develop a generic decision support tool. Examples of such tools are the CWIS Services Assessment and Planning (CWIS SAP) developed by Athena Infonomics[25] and the FSM Toolbox by the FSM Alliance[26]. Generic support tools consider pre-feasibility planning and different sanitation options as dashboard outputs for decision-making; however, considerable local detail may be lost in the process. The local detail is key to effective planning. This is because the conditions facing different areas within a city are not generic but are specific to those areas. Therefore, a "dashboard approach" masks the realities in areas within the city as the planned solution may be a one-size-fits-all for the city.

As espoused in generic tools, a general approach may not address the specific challenges, making the planning ineffective. For example, in neighbouring areas within a city, one area might have low sewer connectivity rates due to inadequate water supply, while the other might have a challenge of a non-extensive network to facilitate connections. A generic approach may not address the specific challenges faced, leaving service gaps at implementation. What is required to plan citywide services is understanding the complex challenges in the city on an area by area basis from which a holistic approach can be developed based on the context and specific needs. It requires robust qualitative and quantitative data collection to recognise, unpack, and plan for the complexity.

The proposed blended approach is one that decision-makers may not be keen on because it is challenging and requires meticulous planning. However, it is pragmatically the answer as it deals with the specific local conditions on an area basis. The approach uses what exists as a basis for making incremental

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[25] CWIS SAP was developed by Athena Infonomics in collaboration with Eastern and Southern Africa Water and Sanitation Regulators Association (ESAWAS), and Aguaconsult with support from the Bill & Melinda Gates Foundation (BMGF). https://www.cwisplanning.com/home/index.

[26] There were several contributors to the development of the FSM Toolbox, with support from the BMGF. https://www.fsmtoolbox.com/about.

improvements in the city. There is no ‘single magic bullet’ solution, but rather, the proposed approach harnesses the different technology mixes and is a process-oriented solution. It is an iterative data-driven process that generates a mix of pragmatic sanitation solutions. The approach requires stakeholder engagement at all levels, incorporating co-production of local knowledge, which is time-consuming and challenging to assemble (e.g., Ruiz-Mallén, 2020; McGranahan, 2015). Therefore, rather than having a unified “dashboard approach”, this study demonstrates the need to explore and analyse sanitation needs by dividing the city into area-level interventions to deal with the specific challenges in these areas. Then using these area-level interventions as building blocks to a holistic city solution.

In the case of Lusaka, the framework set out to establish the approach to planning citywide sanitation services is presented in Figure 10-1. Three criteria were applied; cost, the enabling environment and community responsiveness, with three specific case options whose performance were evaluated using multi-criteria analysis. The optimal outputs were several blended sanitation solutions that decision-makers can consider. The approach identifies feasible measures in different areas as cost-effective, safely managed solutions. The overall solution is developed incrementally with room for adaptation to accommodate changes such as demographics.

The blended service approach that incrementally optimises systems emphasises the quality of services, regardless of the type of technical option adopted. It may be less challenging for a city because the systems are designed as area-based interventions with services implemented based on what is feasible in specific areas or contexts. The area-based interventions, when aggregated, culminate into city-level safely managed services. So, for example, in an area within the city with varying topography, segments of that area may have sewers where these are less challenging to install and blended with enhanced FSM (household and/or communal septic tanks with regular desludging) in low-lying areas where sewers are expensive to implement and operate. The overall outcome is a city-level, safely managed system linked with different sewered and non-sewered sanitation technologies.

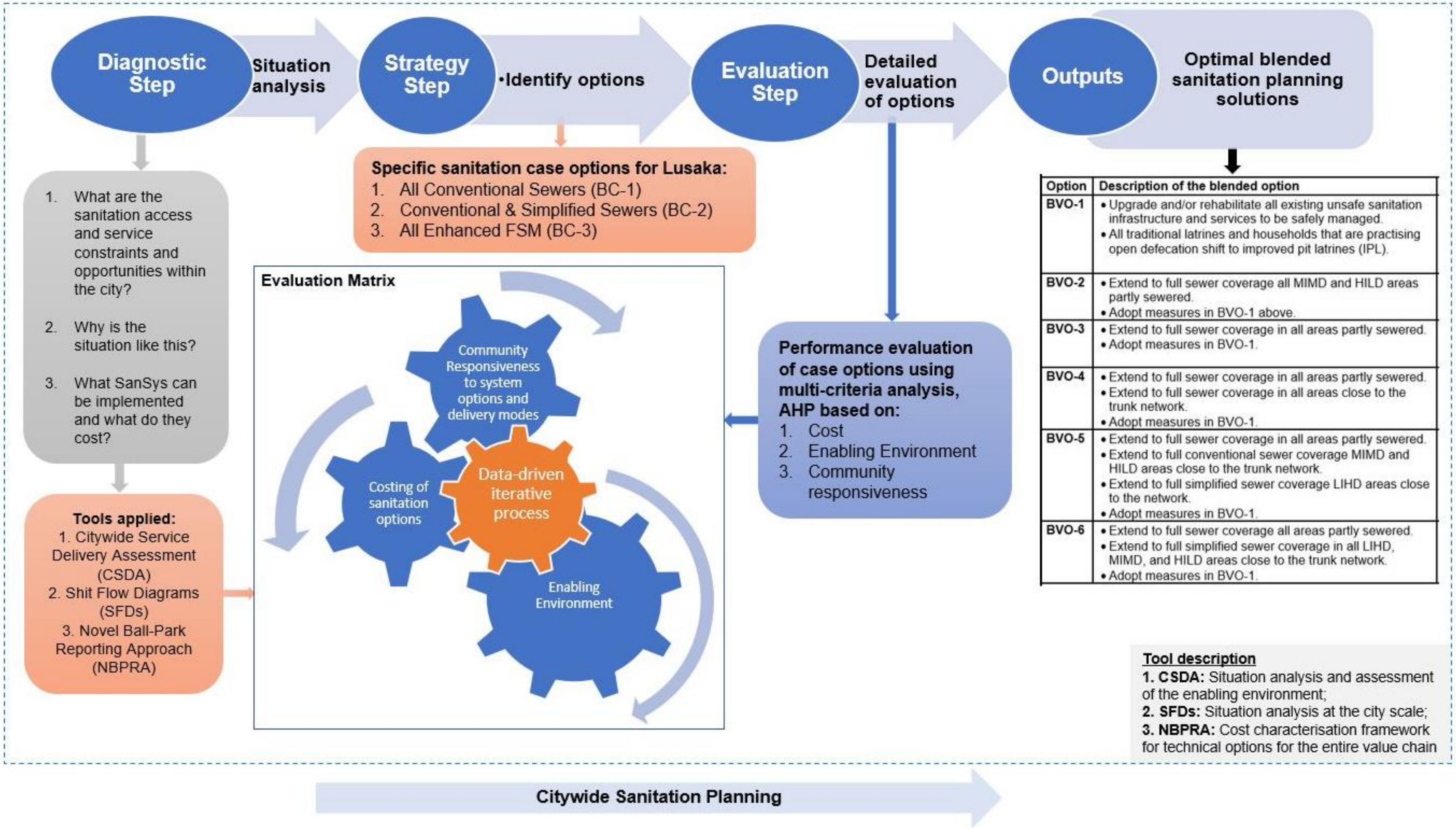

Figure 10-1. Framework for planning citywide safely managed sanitation in Lusaka (Adapted from Schertenleib et al. (2021))

10.3 Applicability of approach in other contexts and its relevance to CWIS

Is this yet another urban sanitation planning tool? How does it differ from existing approaches? How applicable is it in other contexts? Working out how to optimise citywide sanitation services is complex. Central to this approach is understanding the existing situation to help plan for feasible implementation. From the situation analysis, steps can be made to process what is feasible considering the existing enabling environment (institutional capacities, resources, policies) and set the stage for sanitation improvement in the city.

The approach to sanitation planning and implementation is a step-by-step process recommended for other contexts. What is needed is going through an iterative, inductive - “learning as you go” - process, which existing planning tools do not fully embrace (e.g., IWA, 2006; Parkinson et al., 2014). This approach pulls complex data into information that is now very useful for stakeholder engagement. This is because much pre-work is usefully done by attaching the performance of options, in this case, using the AHP framework. Therefore, having the performance of options set out could plausibly be argued as a basis to engage stakeholders in the drive to make incremental improvements and have citywide safely managed services.

For stakeholders in a city of a similar or different context, what steps would they need to take to actualise a holistic citywide approach? To deliver citywide services, what elements within this approach are valuable? Fundamental to this approach is robust data collection to inform what is ‘missing’ to meet city safely managed sanitation goals and what would be feasible and practical to implement rather than a prescription of ‘rigid’ steps to follow. The iterative nature of the process allows for an adaptive approach in the face of ‘changing evidence’ from the data collection. Based on the experience of planning for and generating citywide sanitation service options, an adaptable framework that follows an inductive, iterative process based on the context of the city should be applied. Figure 10-2 shows a generic framework of the planning process that needs to occur at the city level.

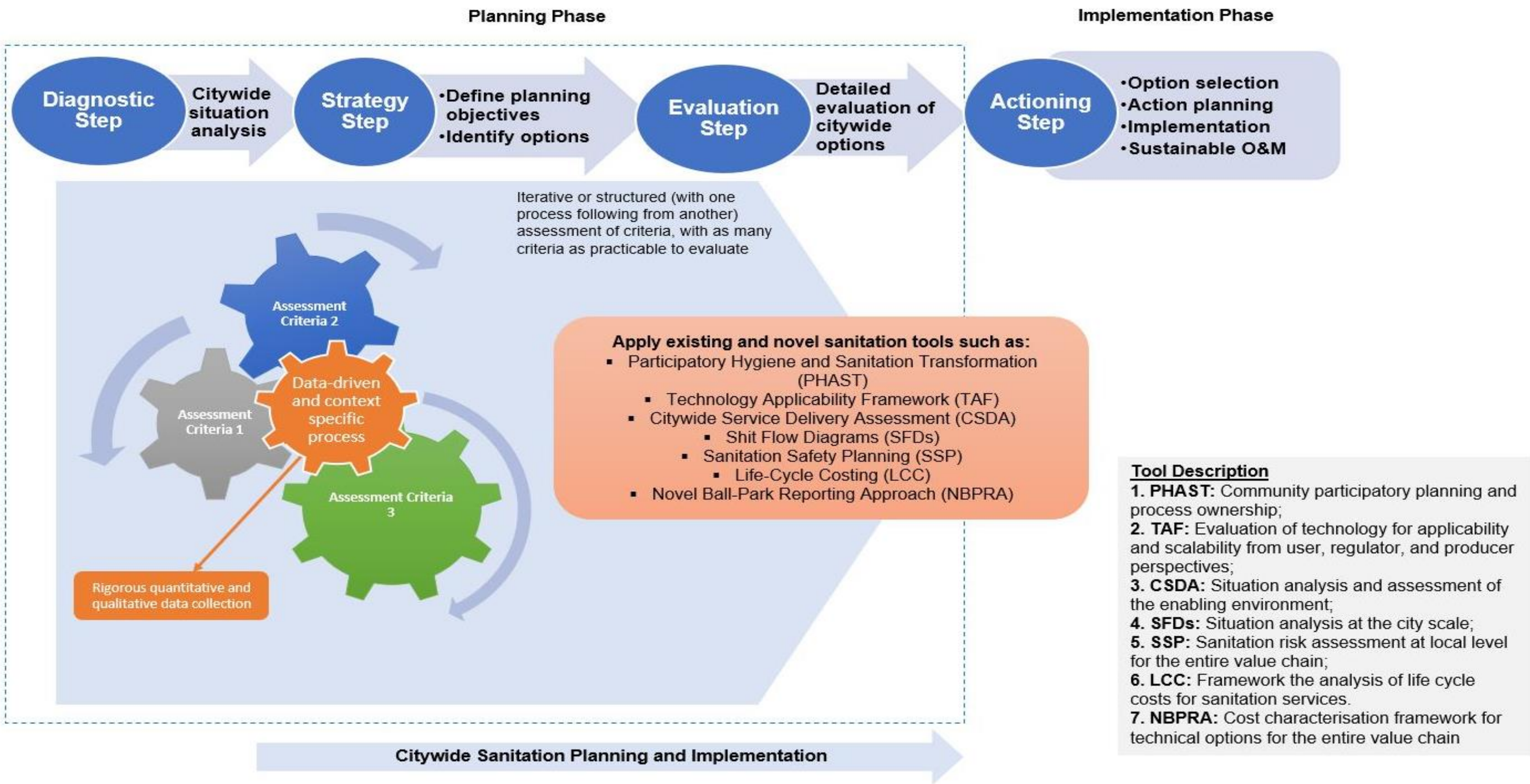

Figure 10-2. A generic framework for planning citywide safely managed sanitation services

Several adaptive steps were identified, considering their relevance to the planning process in selecting appropriate sanitation solutions based on the city context. Develop detailed decision-making parameters with relevant performance criteria for that specific context, informed by a situation analysis. The parameters should be based on a specific set of qualitative and quantitative information required against each selected criterion. It is helpful to initiate suitable sanitation interventions for specific areas – planning units – within the city. Then derive or identify a mix of options for the planning units within the city based on the performance assessment. This step involves a rigorous data-driven iterative process. The cost estimation for each option and alternative scenarios are worked out to explore the scope of financing/funding needed. Through structured consultations, the optimal solutions should be discussed among stakeholders. Then decision-makers can select the optimal option based on their existing capacity, future plans, resource availability and stakeholder aspirations. The output will strengthen the overall city sanitation planning process and make it more robust and inclusive.

The approach acknowledges the need to deliver cost-effective and efficient services to sustain healthy environments as cities rapidly urbanise. It uses a mix of sewered and non-sewered options on an area basis to make sanitation improvements, extending coverage citywide. The planning and implementation of sanitation infrastructure and services should follow a cohesive and holistic approach using a robust, data-driven, inductive and iterative process for citywide interventions while forecasting possible future changes and scenarios.

For any context, the iterative process helps arrive at a decision that supports the optimal pathway for a city given its context. The approach has elements of a rapid assessment tool (situational analysis) to guide citywide interventions and thus serves as a step before detailed engineering studies and designs - the action phase. The citywide approach should consider a different mix of solutions (e.g., centralised, decentralised and condominial sewer systems, FSM and DEWATS) for effective and efficient service delivery that consider the topography and development trends, including settlement patterns. These should be optimised for the entire sanitation value chain.

The area-by-area optimised blended service is the fundamental approach at the centre of CWIS. The approach builds on existing services by filling gaps and extending services to populations without safely managed sanitation. The appropriate infrastructure is put in place to ensure safely managed services. For example, the payments for sewerage and FSM are structured similarly, with services well-regulated to enhance delivery.

10.4 What does this mean for urban sanitation planning?

It is recognised that successful sanitation planning needs to be based on a sound understanding of the existing situation in any given context (IWA, 2006). Urban sanitation approaches and tools are constrained because every city has existing sanitation and institutional systems. This thesis proposes optimisation within existing complex systems as the basis for any improvements. The steps outlined in Figure 10-2 may need to happen within the planning process, and these may be done in any order to suit the context and situation. Therefore, the approach is not prescriptive but rather a reflection on the experience of understanding a complex process that needs to be happening within context.

A strategic approach to sanitation planning is possible when an adaptable and responsive institutional framework is in place (e.g. Wright, 1997; Kalbermatten et al., 1982). There is a need for time and space to allow stakeholders to interact and agree on priorities, identify problems and explore the possibilities for responding to those problems. Adopting an “adaptive” approach to planning through a data-driven iterative process is crucial to successful strategic planning efforts. The process is fundamental to the strategic sanitation approach, which is meant to be flexible and adaptive to incorporate lessons from new experiences and innovations, as noted by Wright (1997).

Understanding the existing situation as the basis for improvements is essential. Therefore, planning needs to recognise the diversity of the urban environment, which will influence the approach for sanitation system upgrades in different parts of the city. The iterative process based on available data and information informs the level of planning detail. Consequently, the planning process plays an essential role in improving the information base, an input for future implementation and service monitoring (Tayler and Parkinson, 2005).

The blended service approach for citywide sanitation proposed is for urban planning to use the best of what exists by optimising the different technology mixes in different parts of the city. The approach is critical to the strategy for the various options as it allows for flexible solutions and phase-wise incremental improvements to meet city needs. This makes the requirement even more pressing for city-level systems because they are much more complex. The systems are technical, quality control, organisational, and management. The highlight is that there are different aspects of the whole system that an entity or entities within the city need to have responsibility over. The proposition is pragmatic optimisation, where what is already in place becomes one of the features and drivers from which service improvements are made.

Using the urban sanitation planning lens helped set the study in context. The body of literature is growing, but approaches do not get traction. Therefore, this approach does not create another ‘novel planning approach’ but instead demonstrates the need for adaptive planning by pulling together strands of existing approaches and tools to fit a specific context. The basis of the approach is that previous attempts to solve sanitation challenges have not been entirely successful. The approach steps in by answering how we can harness existing approaches and tools to make incremental step-wise improvements rather than waiting for the perfect opportunity to make wholesome changes.

Furthermore, the approach demonstrates that sanitation challenges must be addressed through multi-technology and multi-criteria approaches. The approach should encompass technical, health and cost criteria and include socio-economic, socio-cultural, institutional and environmental aspects, as noted by Schertenleib et al. (2021). In addition, a multi-criteria sustainability-based approach helps make trade-offs visible to support decision-making (e.g., Kvarnström and Petersens, 2004). Finally, a multi-technology and multi-criteria approach to urban sanitation planning provides a mix of solutions, implemented according to the specific needs and conditions in a given context.

Chapter 11: Conclusions and Recommendations

11.1 Introduction

This research aimed to establish an approach for planning the scaling of citywide safely managed sanitation, focusing on Lusaka city. Discussed are the conclusions drawn from the research.

11.2 Conclusions

The first objective reviewed existing sanitation costing approaches to establish the financial costs of sewer-based and faecal sludge management systems. The literature review showed that the sector does not have a standard approach for reporting costs, making cost comparisons between contexts for benchmarking purposes challenging. Also, service delivery costs are not fully understood nor reported for the entire value chain. As a reflection, the costing landscape has not probably changed since the costing review was conducted.

Lifecycle costing approaches should be embraced sector-wide as they characterise costs for the entire value over the infrastructure lifetime. They help establish the total costs to implement and sustain sanitation services. Connection efficiency is an essential driver of costs for sewered systems. The higher the connection efficiency, the lower the costs for services. For non-sewered services, service coverage is a critical factor for cost efficiency. When emptying and transport services operate at full capacity, costs of service provision are reduced. *This study concludes that service providers should aim for high sewer connectivity and full-service coverage for emptying and transporting faecal sludge at area and city levels to improve cost efficiency*.

The second objective assessed the environment enabling the delivery and sustaining of sanitation services. This study concludes that appropriate institutional capacities must be in place for policy and regulation to work. Weaknesses are not in the non-existence of policies and regulations but rather in implementation and enforcement. Further, coordination among stakeholders is essential if sanitation services are to be delivered efficiently and effectively at scale. The political will to finance and support sanitation is crucial as the policymakers set the tone for progress. The role of central and local government in sanitation cannot be overstated as their priorities directly affect service delivery. *Overall, a sound and robust enabling environment is the key driver to delivering and sustaining services at the city level, as the success or failure to deliver services is dependent on it*.

The third objective explored the factors influencing household sewer connectivity and access to safely managed FSM services. *The study concludes that sanitation should be delivered with complementary services, such as water supply, to enhance service uptake. Further, attention should be given to the inequity in services provision among the different population segments, i.e., LIHD, MIMD and HILD.* For sanitation services to be inclusive, the right incentives and how they are structured is crucial to attaining access to safely managed services for all, with the public sector taking responsibility for services.

The fourth objective was to generate strategic planning options to scale citywide safely managed sanitation in Lusaka. *This study concludes that a blend of sewered and non-sewered services is the most practical approach to scale citywide services by making optimised incremental improvements on what already exists in the city. The approach is centred on a rigorous data-driven process that feeds into planning sustained services as rapidly urbanising cities are dynamic.*

The overall conclusion from this study is that current urban sanitation planning is inadequate as the sector struggles at optimising existing systems. However, having applied multi-criteria analysis, there is a recognition that a blended approach to services will probably be the best solution. Also, rigid non-adaptive planning methods that do not fit the context are not the way to go, with cities needing the support to deliver citywide solutions, which are very complex.

11.3 Contribution to planning theory and practice

This thesis contributes to a theoretical description of how implementing a citywide approach to sanitation access and services can be undertaken at scale.

i. The thesis demonstrates that responsive urban planning details the specific needs and challenges across different population segments in the city, and these are addressed by context-specific solutions as a pathway to a holistic citywide planning approach.
ii. The thesis contributes to the understanding that the one-size-fits-all or generic decision support tools (dashboard outputs) to planning are not the answer but rather building up solutions based on the context. An iterative data-driven process should anchor urban sanitation planning to enable context-specific solutions. Successful interventions will remain elusive, devoid of critically addressing the context-specific challenges faced regardless of the approach.
iii. The thesis demonstrates that optimising existing sanitation and institutional systems is a more pragmatic approach to making the incremental sanitation improvements needed at the city level.
iv. The thesis demonstrates that leveraging the strength of existing sanitation planning tools can be adequate to surmount the challenges in specific contexts - by mixing and matching tools for context-specific problems as every context will be different.

11.4 Research approach limitations

The approach does not substitute for the technical skillsets needed for comprehensive in-situ planning for implementation. Instead, it structures several decision criteria and technical options into the planning process. The criteria used were based on the study context and available information. However, selecting other criteria in planning services might have a different outcome for option performance. Therefore, applying the approach in different contexts requires expert skills and local knowledge to provide suitable criterion inputs.

The approach does not guarantee the needed local leadership, human and financial resources as these must be built within the city to produce the intended outcomes. Moreover, it requires that sanitation be placed high on the political agenda with buy-in from policymakers, as a lack of prioritisation renders the approach ineffective.

The approach provides suitable and feasible options for different areas within a city (i.e., low, medium and high income and dense areas). However, several challenges may exist, such as the performance of the options with other services, e.g., stormwater and solid waste management. These challenges should be addressed when integrating the approach within the broader strategic planning framework for urban services.

The approach can only become effective if taken up in practice. The COVID-19 global pandemic specifically impacted the scope-testing of the research approach in Lusaka as fieldwork could not proceed. Beyond the impact of not conducting further fieldwork, an ongoing online dialogue with the city authorities and stakeholders in Lusaka was challenging because they dealt with a COVID-19 crisis. If COVID-19 had not happened, the researcher would have been in Lusaka to engage stakeholders and test the approach.

11.5 Research implications and recommendations

11.5.1 Lusaka specific

Ideally, the first step is finding ways to communicate the outputs and engage with the CWIS process currently underway in the city. There is also a need to garner the necessary political will to overcome planning challenges, with governance systems playing a pivotal role in improving service access. In addition, institutional capacities need strengthening to improve existing systems and make the necessary incremental changes at the city level. Further, sanitation needs, especially for the urban poor, must be integrated into the broader policy and strategic urban planning framework, as low-income areas are a part of the city landscape rather than fragmented and standalone problems.

11.5.2 Sector-wide

Sector stakeholders will require multi-criteria and multi-stakeholder approaches to planning and implementation to improve outcomes with interventions tailored to meet specific needs in different areas in a city. Delivering services will require a coordinated approach and an understanding of prevailing conditions and how these fit within existing institutional systems to actualise the necessary improvements. Furthermore, cities are constrained as there is a shortage of active management of urban sanitation systems. As such, that might be an area for further research. However, much more pressing is for cities to invest in ongoing monitoring and evaluation of their sanitation systems - action research. Researchers need to support cities in conducting action research and better ways of collecting information from consumers. Also, better quality control methods and monitoring how sanitation systems pollute the environment to help devise ways of optimising for safely managed services are needed. Further, the sector should align towards a unified or standardised lifecycle costing methodology to make costs across contexts more comparable.

11.5.3 Suggestions for future work

The further work from this research is implementing the approach in practice and evaluating its effectiveness. Currently, there is an opportunity because cities around the developing world are adopting CWIS. For example, in Sub-Saharan Africa and Bangladesh, several cities are planning and implementing citywide sanitation. Therefore, there is a need to fund it as operational research for funders and promoters of CWIS. In Lusaka, for example, steps will be taken to scope test the research outcomes with stakeholders in the city.

Furthermore, there is a need to look at the cost-efficiency of systems regarding the value of improving operational interventions (what exists) compared to investing in new technology. This will help inform the most pragmatic way of delivering optimal solutions.

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APPENDIX A: Systematic Review of Costing Approaches

A-1. Data sources and search strategy

	Source searched	Search strategy	Number
Database	Science Citation Index; Social Science Citation Index; Arts and Humanities Citation Index	1. (method* OR methodolog* OR approac* OR techniqu* OR procedur* OR practic*) AND (cost* OR “estimat* cost” OR “structure cost*” OR apprais* OR “asses* cost”) AND (sanitation OR toilet* OR latrine* OR “toilet facilit*” OR “fe*cal sludge” OR sewage OR “excreta disposal” OR “waste disposal” OR sewe*age OR “rest room” OR bathroom OR lavator*) AND (urban OR “low-income” OR “peri-urban” OR slum* OR “informal settlemen*” OR cit* OR tow*) 2. #1 AND (shared OR public OR commu* OR common OR joint OR limited OR unimprov*)	1242
	Scopus	1. (method* OR methodolog* OR approac* OR techniqu* OR procedur* OR practic*) AND (cost* OR “estimat* cost” OR “structure cost*” OR apprais* OR “asses* cost”) AND (sanitation OR toilet* OR latrine* OR “toilet facilit*” OR “fe*cal sludge” OR sewage OR “excreta disposal” OR “waste disposal” OR sewe*age OR “rest room” OR bathroom OR lavator*) AND (urban OR “low-income” OR “peri-urban” OR slum* OR “informal settlemen*” OR cit* OR tow*) 2. #1 AND (shared OR public OR commu* OR common OR joint OR limited OR unimprov*)	2799
Grey Literature	Google Scholar ProQuest ETHoS OpenGrey	What approaches are used to cost urban sanitation What methods are used to cost urban sanitation	26
Reference Lists			4
Hand searching	World Bank’s Open Knowledge Repository	Costing of sanitation	8
	IRC WASH	Costing of sanitation	7
	World Health Organisation	Costing of sanitation	2
	Sustainable Sanitation Alliance	Costing of sanitation	0

A-2. Reasons for exclusion of studies (at the eligibility stage after reading through full-text)

	Author	Reason for Exclusion
1	Auerbach, D.;	The paper describes an approach to dealing with sanitation in informal settlements but lacks descriptions of costing sanitation.
2	Buckley, R. M.; Kallergis, A.;	The study looks at urban sanitation and how it relates to the SDG's with no costing data
3	Daudey, L.;	The study is a literature review
4	Hutton, G.; Bartram, J.;	The study is a summary of Hutton & Bartram (2008) on Regional and global costs of attaining WSS Target 10 of the MDGs
5	Hutton, Guy;	The study utilises the same data set as Hutton & WHO (2012)
6	Hutton, Guy; Bartram, Jamie;	Duplicate of an already included study
7	Hutton, Guy; Haller, Laurence; Bartram, J	The study is similar to Hutton & WHO (2012), which is part of the included studies, and the difference is that this study is an earlier version while Hutton & WHO is an updated version
8	Jenkins, M. W.; Cumming, O.; Cairncross, S.;	The study measured strong interest in and willingness to pay for the new pit emptying service
9	Unassigned	Full-text Article not found
10	Kennedy-Walker, R.; Holderness, T.; Alderson, D.; Evans, B.; Barr, S.;	The study details the optimisation of the spatiotopological configuration of a road-based faecal sludge transportation network by travel time
11	Ketema, A. A.; Lechner, M.; Tilahun, S. A.; Langergraber, G.;	Full-text Article not found and request made to Author no feedback
12	Mara, D.;	The study looks at sustainable sanitation in low-income urban areas
13	Mara, D.; Evans, B.;	A review paper on the scope and challenges of the SDGs sanitation and hygiene targets
14	Morris, E. K.;	The study focuses on the willingness to pay of peri-urban households to improve the method of waste collection
15	Nigam, A.; Ghosh, G.;	Full-text Article not found and request made to Author no feedback
16	Norström, A.; Erlandsson, Å; Kärrman, E.;	The study focuses on environmental decisions for selecting wastewater systems where the cost for the systems can be assessed and evaluated about their environmental impact.
17	Parkinson, J.; Quader, M.;	The study focuses on improving the traditional manual desludging of leach pits and septic tanks.
18	Reddy, V. R.; Fonseca, C.; Batchelor, C. H.;	It is a book on sustainable water and sanitation services using the life-cycle approach to planning and management
19	Rosemarin, A.;	The study looks at global trends in urbanisation concerning the availability of adequate sanitation and water supply services.
20	Schmitt, RJP.; Morgenroth, E.; Larsen, T. A.;	The study focuses on the planning of sanitation services in informal urban settlements
21	Sijbesma, Christine; Diaz, Carlos; Fonseca, Catarina; Pezon, Christelle;	It is an essay covering a literature review, personal and documented experiences; the authors present an overview of traditional and innovative financing approaches and mechanisms for urban poor sanitation and discuss their advantages and limitations.
22	Simiyu, S.; Swilling, M.; Rheingans, R.; Cairncross, S.;	The focus was on investigating the social and economic dynamics that hinder the provision and uptake of sanitation. The study also identified characteristics of residents with sanitation facilities and estimated the cost of sanitation as revealed in rental prices.
23	Trémolet, Sophie; Kolsky, Pete; Perez, Eddy;	The focus of the study is financing approaches for sanitation when it comes to cost. It gives ballpark figures on investment and operational expenditure without delving into the details of the approaches used
24	Van Dijk, M. P.; Etajak, S.; Mwalwega, B.; Ssempebwa, J.;	The focus of the study is on financing sanitation and cost recovery, and there is no indication of costing sanitation
25	Van Ryneveld, MB;	The same dataset as Vanryneveld (1994) as the only differences are the additions of affordability, willingness to pay and subsidy
26	Willetts, J.; Paddon, M.; Nam, N. D. G.; Trung, N. H.; Carrard, N.;	The study assesses the sustainability of sanitation options and does not include any costing data
27	World Bank,	It is a summary report of 6 included studies
28	World Health Organization; UNICEF;	It is a global WASH assessment report that does not contain costing approaches for sanitation
29	Mills, F; Willetts, J; Evans, B; Carrard, N; Kohlitz, J;	The study discusses the drivers for citywide sanitation investment decisions and does not look at approaches when outlining costs
30	Libey, A; Marieke, A; Thomas, E;	The study focuses on the life cycle costs of water services and not sanitation
31	Sharma, B. K; Chandel, M. K;	The study focuses on the life cycle cost analysis of municipal solid waste management and not sanitation
32	Burt, Z; Sklar, R; Murray, A	No explicit costing approach was used to report the costs associated with emptying services

A-3. Methodological quality assessment

		Authors																															
		Carrard et al., 2021	Dodane et al., 2012	Kennedy-Walker et al., 2016	Remington et al., 2018	Delaire et al., 2020	Dube' et al., 2012	Klutse', et al., 2010	Isunju, 2013	Sainati et al., 2020	Willetts et al., 2010	Nyarko et al., 2011	Ulrich et al., 2016	Manga et al., 2020	Alivelu et al., 2012	Burr et al., 2011	Balasubramanya et al., 2017	von Munch, 2007	McConville et al., 2019	Tilmans et al., 2015	Hutton & Varughese, 2016	Rodriguez et al., 2011	Winara et al., 2011	Chuan et al., 2012	Rodriguez et al., 2012	World Bank, 2012	Nguyen et al., 2012	Heng et al., 2012	Mayumbelo, 2006	Hutton, 2012	Hutton & Bartram, 2008	Hutton & Haller, 2004	van Ryneveld, 1994
1	**OBJECTIVES AND HYPOTHESES**																																
1.1	Are the objectives of the study clearly stated?	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	**DESIGN**																																
2.1	Is the study design suitable for the objectives?	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.2	Who/what was studied?	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.3	Was this the right sample to answer the objectives?	√	√	√		√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.4	Is the study large enough to achieve its objectives?		√	√		√		√	√	√	√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2.5	Have sample size estimates been performed?																																
2.6	Has ethical approval been obtained if appropriate?	√				√			√								√																
3	**MEASUREMENT AND OBSERVATION**																																
3.1	Is it clear what was measured, how it was measured and what the outcomes were?	√	√	√		√		√		√	√			√		√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√
3.2	Are the measurements valid?	√	√	√	√		√	√		√	√			√	√	√	√	√	√			√	√	√	√	√	√	√	√		√	√	√
3.2	Are the measurements reliable?		√	√	√			√		√	√			√			√		√			√	√	√	√		√	√	√				
3.4	Are the measurements reproducible?	√	√	√				√		√	√			√			√		√			√	√	√	√		√	√					
4	**PRESENTATION OF RESULTS**																																
4.1	Are the basic data adequately described?	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.2	Are the results presented clearly, objectively and in sufficient detail to enable readers to make their own judgement?	√	√	√		√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4.3	Are the results internally consistent, i.e. do the numbers add up properly?	√	√	√	√	√		√		√	√			√			√	√	√			√	√	√	√		√	√	√		√	√	√
5	**ANALYSIS**																																
5.1	Are the data suitable for analysis?	√	√	√		√		√		√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5.2	Are the methods appropriate to the data?	√	√	√		√		√		√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	**DISCUSSION**																																
6.1	Are the results discussed in relation to existing knowledge on the subject and study objectives?	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6.2	Is the discussion biased?																																
6.3	Has a sensitivity analysis been performed (was an appropriate allowance made for uncertainties)?	√	√	√		√					√																		√	√		√	
7	**INTERPRETATION**																																
7.1	Do the data justify the authors' conclusions?	√	√	√	√	√		√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7.2	Does this paper help answer the problem?	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√		√	√	√

APPENDIX B: Methodology

B-1. Ethical Approval and Permission Letters for Data Collection

The Secretariat
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 1642
Email: MEECResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Mofwe Kapulu
School of Civil Engineering
Faculty of Engineering
University of Leeds
LEEDS LS2 9JT

**MaPS and Engineering joint Faculty Research Ethics Committee (MEEC FREC)
University of Leeds**

11 June 2019

Dear Mofwe

Title of study	**Assessment of the Costs of Shared Sanitation in Low Income Urban Areas**
Ethics reference	**MEEC 18-036**

I am pleased to inform you that the above application for ethical review has been reviewed by representatives of the MaPS and Engineering joint Faculty Research Ethics Committee and following receipt of your response to their initial comments, I can confirm a conditional favourable ethical opinion as of the date of this letter *subject to the following condition/s which must be fulfilled prior to the study commencing:*

- **Evidence of any in-country permission/approval that is required in Zambia should be submitted once available**

The study documentation must be amended as required to meet the above conditions and submitted for file and possible future audit. Once you have addressed the conditions and submitted for file/future audit, you may commence the study and further confirmation of approval is not provided.

Please note, failure to comply with the above conditions will be considered a breach of ethics approval and may result in disciplinary action.

The following documentation was considered:

Document	Version	Date
Mofwe Kapulu_Ethical Review Application_v2.0	2.0	20/05/2019
Risk Assessment_383460 signed	1.0	22/03/2019
Participant_Information_Sheet_Key Informants_v2	2.0	20/05/2019
Participant_Information_Sheet_Households_v2	2.0	20/05/2019
Focus Group Discussion Guide	1.0	22/03/2019
Household Questionnaire	2.0	20/05/2019
Key Informant Interview Guide	1.0	22/03/2019
Consent_Form_Households_v1	1.0	22/03/2019
Consent_Form_Key Informants_v2	2.0	20/05/2019
Data Mangement Plan_v1	1.0	22/03/2019
Research_Assistant_Contract_v1	1.0	20/05/2019

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes.

You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to MEECResearchEthics@leeds.ac.uk.

Yours sincerely

Rachel E de Souza, Research Ethics & Governance Administrator, The Secretariat
On behalf of Dr Dawn Groves, Chair, MEEC FREC

CC Student supervisor

ERES CONVERGE

Plot No. 1, Cnr Joseph Mwilwa & Great East Road
Rhodes Park, Lusaka - Zambia
Tel: +260 955 155 633
+260 955 155 634
Cell: +260 977 493220
Email: eresconvergeltd@gmail.com

I.R.B. No. 00005948
EW.A. No. 00011697

7th August, 2019

Ref. No. 2019-Jun-014

The Principal Investigator
Mr. Mofwe Kapulu
Flat 3, Plot 18
Saise Road, Longacres,
LUSAKA.

Dear Mr. Kapulu,

RE: ASSESSMENT OF THE COSTS OF SHARED SANITATION IN LOW-INCOME URBAN AREAS.

Reference is made to your protocol dated 7th August, 2019. The IRB resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	**Ordinary**	Approval No. **2019-Jun-014**
Approval and Expiry Date	Approval Date: 7th August, 2019	Expiry Date: 6th August, 2020
Protocol Version and Date	Version - Nil.	6th August, 2020
Information Sheet, Consent Forms and Dates	• English, Nyanja, Bemba.	6th August, 2020
Consent form ID and Date	Version - Nil	6th August, 2020
Recruitment Materials	Nil	6th August, 2020
Other Study Documents	Questionnaire.	6th August, 2020
Number of participants approved for study	600	6th August, 2020

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

Conditions of Approval

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to the IRB within 5 days.
- All protocol modifications must be IRB approved prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to the IRB within 5 working days.
- All recruitment materials must be approved by the IRB prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. Documents must be received by the IRB at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Any documents received less than 30 days before expiry will be labelled "late submissions" and will incur a penalty.
- Every 6 (six) months a progress report form supplied by ERES IRB must be filled in and submitted to us.
- A reprint of this letter shall be done at a fee.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of ERES Converge IRB, we would like to wish you all the success as you carry out your study.

Yours faithfully,
ERES CONVERGE IRB

Dr. Jason Mwanza
Dip. Clin. Med. Sc., BA., M.Soc., PhD
CHAIRPERSON

Lusaka Water and Sewerage Company Ltd.

Telephone : +260211 257579/257580/257581
: +260 211 257582/257583/250666
Telefax : +260 211 252578/251549
E-mail : lwsc@lwsc.com.zm

All Correspondence to be addressed to the Managing Director

Stand # 871/2
Katemo Road, Rhodes Park
P.O. Box 50198
Lusaka, Zambia

3rd May, 2019
HRS/430/1422/.HRM/WSC-cm

Ms/r Mofwe Kapulu
Postgraduate Researcher
University of Leeds,
Scholl of Civil Engineering

Dear Sir/Madam

RE: REQUEST TO COLLECT DATA – PhD STUDY

Reference is made to the above subject.

We acknowledge receipt of your letter regarding your request to collect data from our organisation for PhD study on "costs of sanitation in low-income Urban Areas".

We are pleased to inform you that your application has been approved on condition that;

i) You avail us the research proposal. This will help us align ourselves to the research work as we facilitate your data collection.

ii) You will be required to submit a hard copy of the final report for the research to Lusaka Water and Sewerage Company Management.

iii) The data to be collected from our organisation is purely for your academic purpose and should be treated as confidential.

We look forward to hosting you.

Regards,

Ngoza C. Nkwabilo (Mrs.)
DIRECTOR HUMAN RESOURCES AND ADMINISTRATION

CC: File

LUSAKA CITY COUNCIL

OFFICE OF THE TOWN CLERK

P O Box 30077
CIVIC CENTRE
LUSAKA, ZAMBIA 10101

TELEPHONE: 260 01 252926
TELEFAX: 260 01 252141

Our Ref: HK/cmm
TCD/7/59/1

21st June, 2019

Dear Sir/Madam

RE: TO WHOM IT MAY CONCERN – MR. MOFWE KAPULU

THIS SERVES TO CONFIRM THAT the above named is a student at University of Leeds pursuing Phd Water and Sanitation Engineering.

He is conducting a research on **"assessing the costs of shared sanitation in low income urban areas of Lusaka".**

Any assistance rendered to him will be highly appreciated.

Yours faithfully
LUSAKA CITY COUNCIL

Alex Mwansa
TOWN CLERK

B-2. Key Informant Interview Guide

ASSESSMENT OF THE COSTS OF SHARED SANITATION IN LOW-INCOME URBAN AREAS

KEY INFORMANT INTERVIEW GUIDE

Good morning/afternoon. My name is Mofwe Kapulu. I am a Postgraduate Researcher from the University of Leeds. I am assessing the costs of sanitation in low-income urban areas of Lusaka.

[Researcher explains the project by discussing the information sheet and seeks informant consent].

Now that I have been through the information sheet with you and received your consent, may I begin the interview now? Yes ☐ No ☐

Participant's code	:
Interview date (dd/mm/2019)	........../........./2019
Time	Start:... End:...

IMPLEMENTATION INFORMATION

1. How were the communities of Chazanga, Kanyama, Kalingalinga or Mtendere chosen as sites for project implementation?
2. Were there any discussions held with the communities to decide on the preferred types of technologies to be implemented?
3. What local needs and priorities were considered before project implementation?
4. What were the reasons for choosing the technologies implemented? Were the adopted technology choices responsive to the local context (e.g. hydro-geological, social, financial, institutional and environmental)?
5. Who were the partner organisations in choosing the technology to be implemented?
6. How were the sanitation projects being financed and what components of the sanitation value chain were funded?
7. What are the costs of the various sanitation components that were funded and can you provide documentation? What support other than funding is being offered?
8. What costs are accruing to you for supporting the sanitation interventions?
9. Is the project subsidised? Are subsidies offered by financiers/donors an opportunity cost (hidden cost) to other sectors within the economy?

SERVICE INFORMATION

10. What service do you provide for the sanitation value chain? (e.g. construction of sanitation facilities, emptying, transportation, treatment).
11. What assets and resources do you use to provide this service? (e.g. sewer, treatment plant, employees, vacuum truck, administration offices)
12. Are these resources exclusively allocated to the sanitation service? If not, to what extent are these resources dedicated to the sanitation service?
13. How much do these resources cost? We are interested in capital expenditure (CAPEX), operational expenditure (OPEX) and capital maintenance expenditure (CAPMANEX) calculated on an annual basis to avoid the seasonality within the year.
14. How much do you pay for regulatory permits such as licenses?
15. How much do you spend in financing interests and tax for the sanitation services? Do you benefit from any form of subsidies?
16. Finally, based on the specific technology and assets you have, I am going to ask you specific questions characterising your service:

    - If your business involves the emptying of faecal sludge: how many households do you serve; how many trips do you make every year; which area(s) do you serve; what proportion of your business can be attributed to shared sanitation facilities; and how much does it cost you to run this service on an annual basis.

    - If your business involves the transportation of faecal sludge using vacuum trucks or any other form of transport: how many households do you serve; how many trips do you make every year; which area(s) do you serve; what proportion of your business can be attributed to shared sanitation; and how much does it cost you to run this service on an annual basis.

    - If you run a treatment plant: how much material associated to sanitation do you process every year; what is the capacity of the plant; what kind of material do you receive as input; what is your output material; and how much does it cost you to run this service on an annual basis.

17. What non-monetary (hidden) costs are accruing to you in providing the service?
18. **Utility:** Is the failure to repair leaking sewers a hidden cost to the utility in that the may be losing revenue as end users may refuse to pay bills? Is the failure to maintain utility infrastructure a hidden cost in that when systems failure, the cost of replacement is higher than when there is preventive maintenance?
19. **Pit emptiers and handlers of faecal waste:** are they suffering illnesses due to there line of work? Do they have protective equipment? Do they have medical insurance? Are they given vaccines or milk after working? Are pit emptiers shamed for the work they do (stigma)? Does it force them to work at night? Does this result in high turn over of staff?

B-3. Household Survey Questionnaire (Survey by Researcher)

ASSESSMENT OF THE COSTS OF SHARED SANITATION IN LOW-INCOME URBAN AREAS

HOUSEHOLD QUESTIONNAIRE

Good morning/afternoon. My name is Mofwe Kapulu. I am a Postgraduate Researcher from the University of Leeds. I am assessing the costs of shared sanitation in low-income urban areas of Lusaka.

I want to speak with the household head[1] or an adult present (if a household head or adult not present, make an appointment for another time). Please note that your participation in this research is voluntary. If you are uncomfortable to discuss any topic or question, feel free to say so. Also, note that refusing to participate will not affect you or your family in any way. You may ask questions about this study at any time.

[Researcher explains the project by discussing the information sheet and seeks participant consent].

Now that I have been through the information sheet with you and received your consent, may I begin the interview now? **Yes** ☐ **No** ☐

Signature of Interviewee: ______________________________

Instructions: please tick the box or fill the space as appropriate

HOUSEHOLD IDENTIFIER INFORMATION	
House I.D No.	....
Survey Strata No.	....
Survey location	☐ 1. Chazanga ☐ 2. Kanyama ☐ 3. Kalingalinga ☐ 4. Mtendere
Survey date (dd/mm/2019)	........../........./2019
Time	Start:... End:...
GPS Coordinates	Northings:...................................... Eastings:................................

[1] Household head is the person responisble for decision-making at the household level e.g. decisions to do with sanitation investment. The term household head is not gender specific.

A. HOUSEHOLD SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS		
Q1	Gender *(Interviewer Assessment)*	☐ 1. Male ☐ 2. Female
Q2	Position of Respondent	☐ 1. Household head ☐ 2. Spouse ☐ 3. Other, specify ....
Q3	Age of household head (in years)	☐ 1. 17 and below ☐ 2. 18 - 25 ☐ 3. 26 - 45 ☐ 4. 46 - 59 ☐ 5. 60 and above ☐ 99. I do not know
Q4	For how long have you been living in this house? (in years)	☐ 1. Less than 1 ☐ 2. 1-2 ☐ 3. 2-3 ☐ 3. 3-4 ☐ 4. 5 and more
Q5	What is the highest level of education for the household head?	☐ 1. Never been to school ☐ 2. Primary ☐ 3. Secondary ☐ 4. Technical and Vocational College ☐ 5. University ☐ 99. I do not know
Q6	What is the source of income for the household head?	☐ 1. Farming ☐ 2. Business/Trading ☐ 3. Domestic work (e.g. maid, gardener etc.) ☐ 4. Skilled work (e.g. mason, plumber, artisan) ☐ 5. Professional work (e.g. teacher, nurse etc.) ☐ 6. Other, specify ....
Q7	What is the total monthly income of your household? (in ZMW)	☐ 1. 500 and below ☐ 2. 501 - 1500 ☐ 3. 1501 - 2500 ☐ 4. 2501 - 3500 ☐ 5. 3501 - 4500 ☐ 6. 4501 – 5500 ☐ 7. 5501 – 6500 ☐ 8. 6501 and above ☐ 88. Refused to disclose
Q8	What type of property is your household living in?	☐ 1. Owner occupied ☐ 2. Rented ☐ 3. Rent free but not owned ☐ 4. Other, specify ....
Q9	If rented, how much does your household pay monthly? (in ZMW)	....
Q10	No. of girls below 5 years	....
Q11	No. of girls above 5 but less than 18 years	....

Q12	No. of women above 18 but less than 60	....
Q13	No. of women above 60	....
Q14	No. of boys below 5 years	....
Q15	No. of boys above 5 but less than 18 years	....
Q16	No. of men above 18 but less than 60	....
Q17	No. of men above 60	....
B. HOUSEHOLD SANITATION CHARACTERISTICS		
Q18	What kind of toilet does your household use? ***[Select one]*** ***(Researcher to show the respondent a visual representation of the various sanitation technologies)***	☐ 1. Flush to the piped sewer system ☐ 2. Flush to the septic tank ☐ 3. Pour-flush/squat pan to the septic tank ☐ 4. Pour-flush/squat pan discharging to a pit ☐ 5. Composting (UDDT) toilet ☐ 6. VIP/pit latrine with slab ☐ 7. Pit latrine without slab ☐ 8. Other, specify ……………………………...
Q19	I would like to see your toilet – kindly show it to me? ***If No proceed to Q25***	☐ 1. Yes ☐ 2. No
Q20	Observations about the toilet: ***Interviewer: Tick for all observations.***	☐ 1. Offers privacy by having a door ☐ 2. Adequately illuminated during the day and night ☐ 3. Visible faecal residues in and around the drop hole or the toilet pan ☐ 4. Visible faecal residues on the floor, wall or door ☐ 5. Visible, used anal cleansing material (e.g. tissue paper) ☐ 6. Surface flow of sewage ☐ 7. The toilet smells bad (stinks) ☐ 8. Clean with no visible faecal residue in and around the drop hole, toilet pan, floor, wall or door
Q21	Observe if there is a hand washing facility in the toilet	☐ 1. Yes ☐ 2. No
Q22	If the toilet has a door, is it locked?	☐ 1. Yes ☐ 2. No
Q23	Who keeps the keys?	....
Q24	Where do users go if they cannot access the toilet facility?	....
Q25	Is the toilet private or shared? ***If 1, proceed to question 32.***	☐ 1. Private (used by one household) ☐ 2. Shared (used by more than one household)
Q26	If shared, how many toilet comapartments are there?	☐ 1. 1 ☐ 2. 2 ☐ 3. 3 or more
Q27	If more than 1, is toilet use separated by gender?	☐ 1. Yes ☐ 2. No

Q28	How many households share the facility or facilities?	....
Q29	How many people use the facility or facilities?	....
Q30	What is the reason(s) for sharing the sanitation facility? ***Interviewer: Tick for all responses given***	☐ 1. Cannot afford to build a private toilet ☐ 2. There is no space to build ☐ 3. We are tenants and can move anytime ☐ 4. It is cheaper to live in a house without a toilet ☐ 5. Other, specify ....
Q31	On average, how much time do you spend waiting to use the toilet?	☐ 1. I never have to wait ☐ 2. Less than 5 minutes ☐ 3. 5-15 minutes ☐ 4. 15-30 minutes ☐ 5. More than 30 minutes
Q32	Has there been any disease or illness suffered that you might attribute to toilet use? ***If No proceed proceed Q38***	☐ 1. Yes ☐ 2. No
Q33	If Yes, are you able to specify the type of disease or illness?	....
Q34	On average, how long did the disease or illness last? (in days)	☐ 1. 1 ☐ 2. 2 ☐ 3. 3 ☐ 4. 4 and more
Q35	On average, how long did school going children or adults in employment stay away from school or work as a result of the disease or illness? (in days)	☐ 1. 1 ☐ 2. 2 ☐ 3. 3 ☐ 4. 4 and more
Q36	Was any treatment sought for the disease or illness? ***If No proceed to Q38.***	☐ 1. Yes ☐ 2. No
Q37	If Yes, how much did the treatment cost? (in ZMW)	....
C. SANITATION INFRASTRUCTURE AND COSTS		
Q38	What type of superstructure does the toilet have? ***[Select one]***	☐ 1. Concrete/cement blocks/bricks ☐ 2. Timber/metal sheets ☐ 3. Reed/thatch ☐ 4. Plastic/fabric/sack ☐ 5. None ☐ 6. Other, specify..
Q39	What type of roof does the toilet have? ***[Select one]***	☐ 1. Concrete/cement blocks or tiles ☐ 2. PVC or metal sheets ☐ 3. Timber or thatch ☐ 4. Plastic/fabric/sack ☐ 5. None ☐ 6. Other, specify ....
Q40	Are you on metered water supply? ***If No proceed to Q43.***	☐ 1. Yes ☐ 2. No.
Q41	Do you pay a sanitation fee?	☐ 1. Yes ☐ 2. No
Q42	If yes, can I see your last water bill? • Note the total amount on the water bill • Note the sanitation fee on the bill	1. Monthly bill (in ZMW).................................... 2. Water Consumption (in m^3)............................ 3. Sanitation fee (in ZMW)................................

ON-SITE SANITATION SYSTEMS		
Q43	Are you aware of the Kanyama OSS Project or the Kanyama or Chazanga FSM Project?	☐ 1. Yes ☐ 2. No
Q44	If Yes, are you a beneficiary of the project?	☐ 1. Yes ☐ 2. No
Q45	Was the cost of your toilet facility subsidised?	☐ 1. Yes ☐ 2. No
Q46	Who paid for the subsidy?	☐ 1. Government ☐ 2. Utility Company ☐ 3. Non-Governmental Organisation (NGO) ☐ 4. Family outside the household ☐ 5. Other, specify .... ☐ 99. I do not know
Q47	How much was the subsidy? (in ZMW)	....
Q48	What were the expenses incurred by the household in building the toilet facility including materials, labour etc. [*excluding the subsidy*]? (in ZMW)	1. Materials... 2. Labour..
Q49	What were the expenses incurred by the household in building the septic tank including materials, labour etc. [*excluding the subsidy*]? (in ZMW)	1. Materials... 2. Labour..
Q50	In order to build your sanitation facility, did you borrow any money? ***If No proceed to Q54***	☐ 1. Yes ☐ 2. No
Q51	If Yes, how much did you borrow? (in ZMW)	....
Q52	How much did you pay back or are you still paying back? (in ZMW)	....
Q53	Over what period? (in months)	....
Q54	Are you able to estimate the dimensions of your pit or septic tank? ***If No proceed to Q56***	☐ 1. Yes ☐ 2. No.
Q55	What are the dimensions **(length x width x depth or diameter x depth)**? (in meters)	....
Q56	For how long have you been using your sanitation facility?	Years:.............................. Months:............................
Q57	When was the facility built if known?	Year:................................ Month:............................
Q58	Does your facility receive greywater from laundry or dishes?	☐ 1. Yes ☐ 2. No
Q59	Was any household labour used in the construction of the toilet or septic tank? ***If No proceed to Q61***	☐ 1. Yes ☐ 2. No
Q60	If Yes, how much time on average was spent on the activities? (in hours)	....
Q61	What kind of maintenance activities are carried out? ***Interviewer: Tick for all responses given***	☐ 1. Empty pit ☐ 2. Empty septic tank (desludge) ☐ 3. Dig new pit when the pit is full ☐ 4. Cleaning (***if not done skip to Q70***) ☐ 5. Other, specify ....

Q62	If cleaning is done, who does the cleaning of the toilet facility?	☐ 1. Anybody ☐ 2. Female household members ☐ 3. Male household members ☐ 4. Other, specify ....
Q63	On average, how much time is spent cleaning the toilet? (in minutes)	☐ 1. Less than 15 ☐ 2. 15-30 ☐ 3. 30-45 ☐ 4. 45-60 ☐ 5. More than 60
Q64	How often is the toilet cleaned?	☐ 1. Everyday ☐ 2. Once in two days ☐ 3. Once a week ☐ 4. Whenever dirty ☐ 5. Other, specify ....
Q65	Are the people involved in the cleaning paid for the activity?	☐ 1. Yes ☐ 2. No.
Q66	If Yes, how much are they paid? (in ZMW)	....
Q67	If the facilities are shared, what system is in place for cleaning the toilet? ***For private toilets proceed to Q73***	☐ 1. There is a rota for households to follow ☐ 2. It is voluntary (users clean as they deem fit) ☐ 3. Other, specify ....
Q68	***If 1***, who prepares the rota?	....
Q69	Do households/users abide by the agreed cleaning arrangement? ***If Yes, proceed to Q71***	☐ 1. Yes ☐ 2. No
Q70	What are the perceived reasons for non compliance?	☐ 1. Lack of time ☐ 2. Lack of interest ☐ 3. Tired of cleaning while others will not ☐ 4. Inadequate water ☐ 5. Other, specify ....
Q71	If a dispute arises around the cleaning or use of the shared facility, how is it handled?	☐ 1. Landlord intervenes to mediate ☐ 2. A meeting is called for all households ☐ 3. Nothing is done ☐ 4. Other, specify...
Q72	On average, how long does it take your pit or septic tank to fill up?	☐ 1. It has never filled up (***skip to Q86***) ☐ 2. Within 6 months ☐ 3. 6-12 months ☐ 4. 12-24 months ☐ 5. 24-36 months ☐ 6. Over 36 months ☐ 99. I don't know
Q73	The last time your facility was full, what did you do?	☐ 1. Empty the pit ☐ 2. Empty the septic tank (desludge) ☐ 3. Dig new pit (***skip to Q86***) ☐ 4. Others, specify...
Q74	Who was responsible for organising the emptying of the facility?	☐ 1. Landlord ☐ 2. Tenant(s) ☐ 3. Other, specify ....

Q75	Who emptied the facility last time?	☐ 1. A private vacuum truck operator ☐ 2. Formal pit emptiers through the Water Trust ☐ 3. Informal pit emptiers ☐ 4. A member of the household ☐ 5. A Community Based Organisation ☐ 6. Other, specify ....
Q76	How was your facility emptied?	☐ 1. With a vacuum truck ☐ 2. With a vacutug ☐ 3. With a hand pump/gulper ☐ 4. With buckets and modified garden tools ☐ 5. Other, specify ....
Q77	What was the primary reason for choosing this form of emptying?	☐ 1. It is the only form of emptying I can afford ☐ 2. It is the simplest method of emptying ☐ 3. The facility is not accessible for other forms of emptying ☐ 4. I prefer the quality of this service ☐ 5. It is the most responsible form of emptying for health and the environment ☐ 6. I have always used this method ☐ 7. It was recommended to me ☐ 8. Other, specify ....
Q78	Was it difficult to access your plot for emptying?	☐ 1. Yes ☐ 2. No.
Q79	If Yes, did this difficulty increase the fees paid for emptying?	☐ 1. Yes ☐ 2. No
Q80	Which part of the content of the facility was emptied?	☐ 1. All of the liquids and solids ☐ 2. It was mixed and then partly emptied ☐ 3. All of the liquid ☐ 4. A part of the liquid ☐ 5. Other, specify ....
Q81	Are you satisfied with the form of emptying you had chosen? ***If Yes proceed to Q83***	☐ 1. Yes ☐ 2. No.
Q82	If No, why are you not satisfied with the form of emptying you chose? ***Interviewer: Tick for all responses given***	☐ 1. It is expensive ☐ 2. It takes long to empty ☐ 3. It is a dirty process ☐ 4. It is not a safe mode of emptying ☐ 5. The service was not good ☐ 6. The equipment used was not good ☐ 7. Other, specify ....
Q83	How much was paid for the emptying? (in ZMW)	....
Q84	Who paid for the emptying?	☐ 1. Landlord ☐ 2. Tenant(s) ☐ 3. Landlord and Tenant(s) ☐ 4. Other, specify ....
Q85	What happened to the emptied content of the facility?	☐ 1. It was dumped in ditches/open drains ☐ 2. It was buried in the backyard ☐ 3. It was dumped in a water body or pond ☐ 4. It was transported to the treatment plant ☐ 5. It was dumped on abandoned land ☐ 6. Other, specify ....

Q86	What part of the sanitation facility have you had to replace?	☐ 1. Pit ☐ 2. Septic tank/slab ☐ 3. Toilet walls ☐ 4. Toilet roof ☐ 5. Toilet slab/latrine slab ☐ 6. Other, specify ………………………………. ☐ 7. None (***End here***)
Q87	Why did you decide to replace your system?	☐ 1. It was full ☐ 2. It was overflowing ☐ 3. It smelled bad ☐ 4. As a preventive measure ☐ 5. The structure was weak/broken ☐ 6. It was not physically accessible for emptying ☐ 7. Other, specify ……………………………….
Q88	Who replaced the facility/built the new one?	☐ 1. A formal service provider ☐ 2. An NGO ☐ 3. A member of the community ☐ 4. A member of the household ☐ 5. Other, specify ……………………………….
Q89	What were the expenses incurred by the household in replacing the facility including materials, labour? (in ZMW)	1. Materials....................................... 2. Labour..
SEWER NETWORK SYSTEMS		
Q90	Are you aware of the Mtendere Sewer Reticulation Project or the Kalingalinga Sanmark Project?	☐ 1. Yes ☐ 2. No
Q91	If Yes, are you a beneficiary of the project?	☐ 1. Yes ☐ 2. No
Q92	Was the cost of the toilet facility subsidised?	☐ 1. Yes ☐ 2. No
Q93	Who paid for the subsidy?	☐ 1. Government ☐ 2. Utility Company ☐ 3. Non-Governmental Organisation (NGO) ☐ 4. Family outside the household ☐ 5. Other, specify .... ☐ 99. I do not know
Q94	How much was the subsidy? (in ZMW)	....
Q95	What were the expenses incurred by the household in building the sanitation facility including materials, labour [*excluding the subsidy*]? (in ZMW)	1. Materials....................................... 2. Labour..
Q96	Was any household labour used in the construction of the sanitation facility? ***If No proceed to Q98***	☐ 1. Yes ☐ 2. No
Q97	If Yes, how much time on average was spent on the activities? (in hours)	....
Q98	In order to build your sanitation facility, did you borrow any money? ***If No proceed to Q102***	☐ 1. Yes ☐ 2. No

Q99	If Yes, how much did you borrow? (in ZMW)	....
Q100	How much did you pay back or are you still paying back? (in ZMW)	....
Q101	Over what period? (in months)	....
Not connected in a sewer network area		
Q102	Why are you not connected to the sewer network? ***Interviewer: Tick for all responses given*** ***If not connected to the sewer network and system being used is on-site, go back to Q54***	☐ 1. It is costly or expensive to connect ☐ 2. My toilet is not appropriate to connect ☐ 3. The water bill is very high when connected ☐ 4. I have requested the utility, but they have not come to connect ☐ 5. The service quality is not good ☐ 6. I am ok with my current system: specify system .... ☐ 7. Other, specify .... ☐ 99. I don't know
Connected to the sewer system		
Q103	How long have you been using this toilet facility?	Years:………………… Months:……………………......
Q104	When was the facility built?	Year:………………… Month:…………................
Q105	How long have you been connected to the sewer network?	Year:………………… Month:…………………….....
Q106	Was a connection fee paid?	☐ 1. Yes ☐ 2. No
Q107	Who made the connection?	☐ 1. Utility plumber ☐ 2. I hired a plumber ☐ 3. Other, specify ....
Q108	How much did you pay? (in ZMW)	....
Q109	Were any materials bought in order to connect your toilet to the sewer network?	☐ 1. Yes ☐ 2. No
Q110	What materials were bought?	....
Q111	How much did the materials cost? (in ZMW)	....
Q112	Who paid for the connection?	☐ 1. Landlord ☐ 2. Tenant(s) ☐ 3. Landlord and Tenant(s) ☐ 4. Other, specify ....
Q113	What kind of maintenance activities are carried out? ***Interviewer: Tick for all responses given***	☐ 1. Unblocking of sewer ☐ 2. Sealing of leakages ☐ 3. Cleaning (***if not done skip to Q123***) ☐ 4. Other, specify ....

Q114	Who does the cleaning of the facility?	☐ 1. Anybody ☐ 2. Female household members ☐ 3. Male household members ☐ 4. Other, specify ....
Q115	On average, how much time is spent cleaning the toilet? (in minutes)	☐ 1. Less than 15 ☐ 2. 15-30 ☐ 3. 30-45 ☐ 4. 45-60 ☐ 5. More than 60
Q116	How many times is the toilet cleaned?	☐ 1. Everyday ☐ 2. Once in two days ☐ 3. Once a week ☐ 4. Whenever dirty ☐ 5. Other, specify ....
Q117	Are the people involved in the cleaning paid for the activity?	☐ 1. Yes ☐ 2. No.
Q118	If Yes, how much are they paid? (in ZMW)	....
Q119	If the facilities are shared, what system is in place for cleaning the toilet? ***For private toilets proceed to Q124***	☐ 1. There is a rota for households to follow ☐ 2. It is voluntary (users clean as they deem fit) ☐ 3. Other, specify ....
Q120	***If 1***, who prepares the rota?	....
Q121	Do users abide by the agreed cleaning arrangement? ***If Yes, proceed to Q123***	☐ 1. Yes ☐ 2. No
Q122	What are the perceived reasons for non compliance?	☐ 1. Lack of time ☐ 2. Lack of interest ☐ 3. Tired of cleaning while others will not ☐ 4. Inadequate water ☐ 5. Other, specify ....
Q123	If a dispute arises around the cleaning or use of the shared facility, how is it handled?	☐ 1. Landlord intervenes to mediate ☐ 2. A meeting is called for all households ☐ 3. Nothing is done ☐ 4. Other, specify...
Q124	Are there any blockages between your toilet and the sewer network?	☐ 1. Yes ☐ 2. No
Q125	How frequent are sewer blockages? (in any time unit)	....
Q126	Who does the unblocking?	☐ 1. The service provider (utility) ☐ 2. Informal workers ☐ 3. Household member ☐ 4. Other, specify ....
Q127	How long is the response time from reporting to unblocking?	....
Q128	If not the service provider, how much does it cost to unblock the sewer? (ZMW)	....

Q129	What part of the sanitation system have you had to replace?	☐ 1. Flush/pour flush toilet or squat pan ☐ 2. Toilet slab ☐ 3. Toilet walls ☐ 4. Toilet roof ☐ 5. Other, specify ……………………………… ☐ 6. None (*End here*)
Q130	Why did you decide to replace it?	☐ 1. It was leaking ☐ 2. It was overflowing ☐ 3. It smelled bad ☐ 4. As a preventive measure ☐ 5. The structure was weak/broken ☐ 6. Other, specify ………………………………
Q131	Who replaced the facility?	☐ 1. The service provider (utility) ☐ 2. An informal service provider ☐ 3. An NGO ☐ 4. A member of the community ☐ 5. A member of the household ☐ 6. Other, specify ………………………………
Q132	What were the total expenses incurred by the household in replacing the facility including materials, labour etc.? (in ZMW)	1. Materials…………………………… 2. Labour………………………………

End of interview. Thank you for your time and cooperation!

B-4. Selected Questionnaire Variables Analysed from Lusaka Sanitation Mapping Assessment (Survey by LWSC)

Category	Variable	Variable Labels	Response Categories
Location/Setting	Ward	Name of the Ward	
	Urban setting	Urban Setting	1= Low-income, high-density 2= Medium-income, medium-density 3=High-income, low-density
Socio-economic and Demographic Factors	Age	Age of household head	
	Gender	Gender of household head	1=Male 2=Female
	Household size	Household size	
	Length of stay	For how long have you been living in this house?	1=Less than 6 months 2=6 – 12 months 3=1 – 5 years 4= Over 5 years
	Tenure status	Is the house rented or owned?	1= Rented 2=Owned,
	Level of education	What is the family's head highest level of education?	1=None 2=Basic 3=Primary 4=Secondary 5=Technical 6=University
	Income level	Estimate the total income of your household?	
Water, Sanitation and Hygiene (WaSH) Factors and Practices	Water source type	What is your main source of water supply?	1= Individual water connection 2=Neighbours tap 3=Public water tap 4=Well 5=River/pond/lagoon
	Sanitation facility type	Facility that the adults usually defecate in	1=Water closet connected to the sewer system 2=Water closet connected to a septic tank 3=Pour flush/squat pan connected to septic tank 4=Pour flush/squat pan discharging into a pit 5=Ventilated Improved Pit (VIP) latrine 6=Simple Improved pit latrine 7=Traditional pit latrine made from wood, metal drums or tires 8=Bush, river or abandoned plot 9=Other, please specify
	Hygiene status	Verify if there is soap in the toilet.	1=Yes 3=No
	Water availability	Verify if there is water available in the toilet.	1=Yes 2=No
	Facility ownership	Does your household own this facility?	1=Yes 2=No
	Access type	Is this facility shared with other households?	1=Yes 2=No
	Living arrangement	How many households share this facility?	
	Facility users	How many people use it?	
	Fill-up time	How quickly does your facility fill up on average?	
	Fill-up action	If your system fills up, what do you do?	1=Empty it 2=Replace it
	Emptying responsibility	Who was responsible for organising the	1=Owner

Category	Variable	Variable Labels	Response Categories
		emptying/replacing of the facility?	2=Tenants
	Safely managed emptying service - 1	Who emptied the facility last time?	1=A vacuum tanker 2=The water trust 3=An informal service Provider 4=A member of the household 5= A community-based organisation
	Safely managed emptying service - 2	How was your facility emptied?	1=With a vacuum truck 2=With a trash pump 3=With a Vacutug 4=With a hand pump 5=With a bucket
	Safely managed emptying service - 3	Are there leaks of faecal sludge when being transported out of your yard by the emptiers?	1= Yes 2= No
	Safely managed emptying service - 4	What happened to the emptied content of the facility?	1= It is dumped in the ditch 2= It is dumped in the trash 3= It is dumped in a river or pond 4= It is buried in the backyard 5= It is transported to the LWSC treatment plant 6=It is dumped on abandoned land
	Plot access	Was it challenging to have access to your plot for emptying?	1=Yes 2=No
	Facility access	Was it challenging to access your toilet pit or septic tank for emptying?	1=Yes 2=No
	Choice of emptying	What was the primary reason for you to choose this form of emptying?	1=It is the only form of emptying I can afford 2= It is the cheapest method of emptying 3=It is the simplest method of emptying 4=The facility is not accessible for other forms of emptying 5= Prefer the quality of this service 6= Because proper equipment is used with this form of emptying 7= It is the most responsible form of emptying towards the environment 8= have always done it like that 9= I do not know of any other forms of emptying 10=It was recommended to me by a neighbour
	Emptying cost	How much did you pay for the emptying	
	Payment responsibility	Who paid for the emptying?	1= The owner of the house 2= The tenants 3=Both the tenants and the owner of the house 4= Other, please specify
	Infrastructure labour costs	How much did the labour for the facility cost?	
	Infrastructure material costs	How much did the materials for the facility cost?	
	Total infrastructure costs	How much did you pay the total costs for the facility?	
	Sewer connectivity	Connected to sewer system	1= Yes 2= No
	Sewer non-connectivity	Why are you not connected?	1= It is very expensive to connect 2= My toilet is not appropriate to connect 3= The water bill comes very high 4= I have requested, but LWSC did not come to connect 5= The service quality is not good 6= Pipes are distant from my plot 7= I am ok with my current system

APPENDIX C: Dataset for Chapter 4

C-1. Containment costs for sewer-based systems

Area: Mtendere LIHD

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of structure including labour and material costs and installation of capture technology	HHS[27] and KII[28]	20	**7,910** (5,000 – 12,000)	ZMW	2018	194.51	194.51	4.515	4.515	1,752	141	141
CapEx	Infrastructure	Sewer connections costs	Project Implementation data	20	5,043	ZMW	2018	194.51	194.51	4.515	4.515	1,117	90	90
													Total Annualised Cost, ToT_{AV}	**230**
													Number of people served, N_p	6
													Number of households served, N_{p-h}	1
													TACH	**230**
													TACC	**38**

Area: Kalingalinga LIHD

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of structure including labour and material costs and installation of capture technology	HHS	20	**5,689** (2,000 – 15,000)	ZMW	2013	121.34	194.51	4.515	2.816	2,020	162	162
CapEx	Infrastructure	Sewer connections costs	Project Implementation data	20	4,523	ZMW	2013	121.34	194.51	4.515	2.816	1,606	129	129
													Total Annualised Cost, ToT_{AV}	291
													Number of people served, N_p	7
													Number of households served, N_{p-h}	1
													TACH	**291**
													TACC	**42**

[27] Household Survey
[28] Key Informant Interview

Area: Other LIHD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction including labour and material costs, and installation of capture technology	Mtendere and Kalingalinga Ave	20	6,800	ZMW	2016	169.78	194.51	4.515	3.941	1,725	138	138
CapEx	Infrastructure	Sewer connections costs	KII	20	2,900	ZMW	2016	169.78	194.51	4.515	3.941	736	59	59
													Total Annualised Cost, ToT_{AV}	197
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**197**
													TACC	**33**

Area: MIMD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction including labour and material costs, and installation of capture technology	KII	20	12,000	ZMW	2019	212.31	194.51	4.515	4.928	2,435	195	195
CapEx	Infrastructure	Sewer connections costs	KII	20	2,900	ZMW	2019	212.31	194.51	4.515	4.928	588	47	47
													Total Annualised Cost, ToT_{AV}	243
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**243**
													TACC	**40**

Area: HILD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of structure including labour and material costs and installation of capture technology	KII	20	12,000	ZMW	2019	212.31	194.51	4.515	4.928	2,435	195	195
CapEx	Infrastructure	Sewer connections costs	KII	20	2,900	ZMW	2019	212.31	194.51	4.515	4.928	588	47	47
													Total Annualised Cost, ToT_{AV}	243
													Number of people served, N_p	5
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**243**
													TACC	**49**

C-2. Containment costs for FSM-based systems

C-2.1: Improved Pit Latrines (IPL)

Area: Chazanga

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a pit and superstructure; installation of squat pan or equivalent (labour inclusive)	HHS	20	**4748** (500 – 8,995)	ZMW	2019	212.31	194.51	4.515	4.928	963	77	77
													Total Annualised Cost, ToT_{AV}	77
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**77**
													TACC	**13**

Area: Kanyama

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a pit and superstructure; installation of squatting pan or equivalent (labour inclusive)	HHS	20	**10,447** (900 – 19,995)	ZMW	2019	212.31	194.51	4.515	4.928	2,120	170	170
													Total Annualised Cost, ToT_{AV}	170
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**170**
													TACC	**28**

Area: Other LIHD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a pit and superstructure; installation of squat pan or equivalent (labour inclusive)	KII	20	8,750	ZMW	2019	212.31	194.51	4.515	4.928	1,775	126	126
													Total Annualised Cost, ToT_{AV}	126
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**126**
													TACC	**21**

C-2.2: Septic Tanks (ST)

Area: Chazanga LIHD

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a septic tank and superstructure; installation of flush/pour-flush or equivalent (labour inclusive)	HHS	25	**9,246** (3,495 – 14,996)	ZMW	2019	212.31	194.51	4.515	4.928	1,876	133	133
													Total Annualised Cost, ToT_{AV}	133
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**133**
													TACC	**22**

Area: Kanyama LIHD

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a septic tank and superstructure; installation of flush/pour-flush or equivalent (labour inclusive)	HHS	25	**12,996** (1,992 – 24,000)	ZMW	2019	212.31	194.51	4.515	4.928	2,637	187	187
													Total Annualised Cost, ToT_{AV}	187
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**187**
													TACC	**31**

Area: MIMD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a septic tank and superstructure; installation of flush/pour-flush or equivalent (labour inclusive)	KII	20	20,000	ZMW	2019	212.31	194.51	4.515	4.928	4,058	288	288
													Total Annualised Cost, ToT_{AV}	288
													Number of people served, N_p	6
													Number of households served, $N_{p\text{-}h}$	1
													TACH	288
													TACC	**48**

Area: HILD Areas

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of a septic tank and superstructure; installation of flush/pour-flush	KII	20	25,000	ZMW	2019	212.31	194.51	4.515	4.928	5,072	360	360
													Total Annualised Cost, ToT_{AV}	360
													Number of people served, N_p	5
													Number of households served, $N_{p\text{-}h}$	1
													TACH	**360**
													TACC	**72**

C-3. Detailed costs of community-scale secondary conventional sewers by area (excluding trunk network)

Area: Mtendere

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction for 89km network	Implementation data	35	5,680,655.68	USA	2016	110.07	115.16	1	0.956	5,943,348	362,972	362,972
CapEx	Infrastructure	Civil works for one pumping station (US$142,993.57), electrical and mechanical works (inclusive of 3 x 105kW pumps with a combined throughput of 305m³/h) US$241,169.38. Total cost of US$384,162.95	Project Implementation data	25	384,162.95	USA	2016	110.07	115.16	1	0.956	401,929	28,518	28,518
OpEx	Staffing	Personnel costs for operating and maintaining the sewer network. 1 Plumber (ZMW 5,000 per month for 12 months), 1 General worker (ZMW 5,000 per month for 12 months) and 1 Superintendent (ZMW 11,000 per month for 12 months). Workforce shared between areas	KII		243,252	ZMW	2019	212.31	194.51	4.515	4.928	49,356		49,356
OpEx	Consumables	Fuel to run vehicle dedicated to sewer operations. Vehicles allocated using 100 litres per month at ZMW 13.43/litre	KII		16,116	ZMW	2019	212.31	194.51	4.515	4.928	3,270		3,270
OpEx	Other OpEx	Vehicle maintenance. Quarterly service for at ZMW 3,000	KII		12,000	ZMW	2019	212.31	194.51	4.515	4.928	2,435		2,435
OpEx	Taxes	Vehicle road tax and roadworthiness. ZMW 625/year for road tax and ZMW 54/year for roadworthiness	KII		679	ZMW	2019	212.31	194.51	4.515	4.928	138		138
OpEx	Administrative Charges	Sewer network and pumping station management and admin costs at Head Office. In 2018, mgt. and admin were 27% of overall utility expenditure.	Utility financial records		281,507	ZMW	2018	194.51	194.51	4.515	4.515	62,344		62,344
OpEx	Consumables	Sewer maintenance (materials) for 89km network. Maintenance of sewer at ZMW415.18/km of network	Utility financial records		36,951	ZMW	2018	194.51	194.51	4.515	4.515	8,183		8,183
OpEx	Staffing	Personnel costs for operating pumping station. 1 Operator (ZMW 5,000 per month for 12 months)	KII		60,000	ZMW	2019	212.31	194.51	4.515	4.928	12,174		12,174
OpEx	Consumables	Fuel to run a standby diesel Genset. Genset to run sewer pumping station using 640 litres per month at ZMW 13.43/litre.	KII		103,142	ZMW	2019	212.31	194.51	4.515	4.928	20,927		20,927
OpEx	Other OpEx	Electricity to run pumps (160,714kWh/year. Cost of electricity tax inclusive in 2019 was ZMW 1.12/kWh. Total Cost = ZMW 180,000/year)	Calculated		180,000	ZMW	2019	212.31	194.51	4.515	4.928	36,525		36,525
													Total Annualised Cost, ToT_{AV}	588,680
													Number of people served, N_p	30,444
													Number of households served, N_{p-h}	5,074
													TACH	**116**
													TACC	**19**

Area: Chunga-Lilanda and George

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 187km network	Planning data	35	22,875,998	USA	2015	108.69	115.16	1	0.944	24,233,049	1,480,128	1,480,128
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	984,100	USA	2015	108.69	115.16	1	0.944	1,042,478	73,975	73,975
OpEx	Other OpEx	All operational liabilities	Planning data		432,703	USA	2015	108.69	115.16	1	0.944	458,372		458,372
													Total Annualised Cost, ToT_{AV}	2,012,475
													Number of people served, N_p	61,027
													Number of households served, $N_{p\text{-}h}$	10,171
													TACH	**198**
													TACC	**33**

Area: Kanyama Extension

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 36km network	Planning data	35	5,402,310	USA	2015	108.69	115.16	1	0.944	5,722,786	349,541	349,541
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,117,030	USA	2015	108.69	115.16	1	0.944	2,242,617	159,138	159,138
OpEx	Other OpEx	All operational liabilities	Planning data		152,026	USA	2015	108.69	115.16	1	0.944	161,044		161,044
													Total Annualised Cost, ToT_{AV}	669,723
													Number of people served, N_p	27,456
													Number of households served, $N_{p\text{-}h}$	4,576
													TACH	**146**
													TACC	**24**

Area: Matero (West)

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 49km network	Planning data	35	6,603,003	USA	2015	108.69	115.16	1	0.944	6,995,528	427,229	427,229
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	301,400	USA	2015	108.69	115.16	1	0.944	319,317	22,656	22,656
OpEx	Other OpEx	All operational liabilities	Planning data		160,740	USA	2015	108.69	115.16	1	0.944	170,295		170,295
													Total Annualised Cost, ToT_{AV}	620,181
													Number of people served, N_p	43,092
													Number of households served, $N_{p\text{-}h}$	7,182
													TACH	**86**
													TACC	**14**

Area: Industries I

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 13km network	Planning data	35	1,970,746	USA	2015	108.69	115.16	1	0.944	2,087,900	127,512	127,512
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,256,626	USA	2015	108.69	115.16	1	0.944	2,390,775	169,631	169,631
OpEx	Other OpEx	All operational liabilities	Planning data		129,652	USA	2015	108.69	115.16	1	0.944	137,359		137,359
													Total Annualised Cost, ToT_{AV}	434,502
													Number of people served, N_p	27,414
													Number of households served, $N_{p\text{-}h}$	4,569
													TACH	**96**
													TACC	**16**

Area: Industries II

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 23km network	Planning data	35	3,473,233	USA	2015	108.69	115.16	1	0.944	3,679,705	224,726	224,726
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,345,170	USA	2015	108.69	115.16	1	0.944	2,484,582	176,287	176,287
OpEx	Other OpEx	All operational liabilities	Planning data		194,172	USA	2015	108.69	115.16	1	0.944	205,715		205,715
													Total Annualised Cost, ToT_{AV}	606,728
													Number of people served, N_p	43,716
													Number of households served, $N_{p\text{-}h}$	7,286
													TACH	**84**
													TACC	**14**

Area: Chipata

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 33.5km network	Planning data	35	4,677,139	USA	2015	108.69	115.16	1	0.944	4,955,179	302,621	302,621
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	128,140	USA	2015	108.69	115.16	1	0.944	135,757	9,632	9,632
OpEx	Other OpEx	All operational liabilities	Planning data		97,197	USA	2015	108.69	115.16	1	0.944	102,975		102,975
													Total Annualised Cost, ToT_{AV}	415,229
													Number of people served, N_p	28,968
													Number of households served, $N_{p\text{-}h}$	4,828
													TACH	**86**
													TACC	**14**

Area: Garden

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 11km network	Planning data	35	1,530,326	USA	2015	108.69	115.16	1	0.944	1,621,299	99,015	99,015
OpEx	Other OpEx	All operational liabilities	Planning data		30,561	USA	2015	108.69	115.16	1	0.944	32,378		32,378
													Total Annualised Cost, ToT_{AV}	131,393
													Number of people served, N_p	30,146
													Number of households served, $N_{p\text{-}h}$	5,024
													TACH	**26**
													TACC	**4**

Area: Chawama and Kuomboka

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 30km network	Planning data	35	3,994,271	USA	2015	108.69	115.16	1	0.944	4,231,716	258,438	258,438
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,655,975	USA	2015	108.69	115.16	1	0.944	2,813,863	199,651	199,651
OpEx	Other OpEx	All operational liabilities	Planning data		190,507	USA	2015	108.69	115.16	1	0.944	201,832		201,832
													Total Annualised Cost, ToT_{AV}	659,921
													Number of people served, N_p	44,610
													Number of households served, $N_{p\text{-}h}$	7,435
													TACH	**89**
													TACC	**15**

Area: Matero (Central)

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 9km network	Planning data	35	1,308,363	USA	2015	108.69	115.16	1	0.944	1,386,141	84,654	84,654
OpEx	Other OpEx	All operational liabilities	Planning data		26,693	USA	2015	108.69	115.16	1	0.944	28,280		28,280
													Total Annualised Cost, ToT_{AV}	112,934
													Number of people served, N_p	7,980
													Number of households served, $N_{p\text{-}h}$	1,330
													TACH	**85**
													TACC	**14**

Area: Industries I (Central)

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 14km network	Planning data	35	2,020,432	USA	2015	108.69	115.16	1	0.944	2,140,540	130,726	130,726
OpEx	Other OpEx	All operational liabilities	Planning data		42,374	USA	2015	108.69	115.16	1	0.944	44,893		44,893
													Total Annualised Cost, ToT_{AV}	175,619
													Number of people served, N_p	27,878
													Number of households served, $N_{p\text{-}h}$	4,646
													TACH	**38**
													TACC	**6**

Area: Sikanze

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 9.5km network	Planning data	35	1,239,589	USA	2015	108.69	115.16	1	0.944	1,313,278	80,204	80,204
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	252,620	USA	2015	108.69	115.16	1	0.944	267,637	18,990	18,990
OpEx	Other OpEx	All operational liabilities	Planning data		38,683	USA	2015	108.69	115.16	1	0.944	40,983		40,983
													Total Annualised Cost, ToT_{AV}	140,176
													Number of people served, N_p	3,226
													Number of households served, $N_{p\text{-}h}$	538
													TACH	**261**
													TACC	**43**

Area: Villa Elizabeth

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 2.2km network	Planning data	35	335,895	USA	2015	108.69	115.16	1	0.944	355,863	21,733	21,733
OpEx	Other OpEx	All operational liabilities	Planning data		6,436	USA	2015	108.69	115.16	1	0.944	6,819		6,819
													Total Annualised Cost, ToT_{AV}	28,552
													Number of people served, N_p	1,668
													Number of households served, $N_{p\text{-}h}$	334
													TACH	**86**
													TACC	**17**

Area: Northmead

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 4km network	Planning data	35	507,819	USA	2015	108.69	115.16	1	0.944	538,007	32,857	32,857
OpEx	Other OpEx	All operational liabilities	Planning data		10,837	USA	2015	108.69	115.16	1	0.944	11,481		11,481
													Total Annualised Cost, ToT_{AV}	44,338
													Number of people served, N_p	2,476
													Number of households served, $N_{p\text{-}h}$	495
													TACH	**90**
													TACC	**18**

Area: Rhodes Park and Rhodes Park East

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 19km network	Planning data	35	6,141,441	USA	2015	108.69	115.16	1	0.944	6,506,528	397,365	397,365
OpEx	Other OpEx	All operational liabilities	Planning data		71,977	USA	2015	108.69	115.16	1	0.944	76,256		76,256
													Total Annualised Cost, ToT_{AV}	473,621
													Number of people served, N_p	21,822
													Number of households served, $N_{p\text{-}h}$	4,368
													TACH	**109**
													TACC	**22**

Area: Shakespear

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 4km network	Planning data	35	545,565	USA	2015	108.69	115.16	1	0.944	577,997	35,299	35,299
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	112,060	USA	2015	108.69	115.16	1	0.944	118,722	8,424	8,424
OpEx	Other OpEx	All operational liabilities	Planning data		14,814	USA	2015	108.69	115.16	1	0.944	15,695		15,695
													Total Annualised Cost, ToT_{AV}	59,417
													Number of people served, N_p	1,437
													Number of households served, $N_{p\text{-}h}$	287
													TACH	**207**
													TACC	**41**

Area: Prospect Hill South

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 15.5km network	Planning data	35	2,052,662	USA	2015	108.69	115.16	1	0.944	2,174,686	132,812	132,812
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	171,020	USA	2015	108.69	115.16	1	0.944	181,187	12,856	12,856
OpEx	Other OpEx	All operational liabilities	Planning data		50,079	USA	2015	108.69	115.16	1	0.944	53,056		53,056
													Total Annualised Cost, ToT_{AV}	198,723
													Number of people served, N_p	5,788
													Number of households served, $N_{p\text{-}h}$	1,158
													TACH	**172**
													TACC	**34**

Area: Kamanga

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 13km network	Planning data	35	1,640,912	USA	2015	108.69	115.16	1	0.944	1,738,458	106,171	106,171
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	228,640	USA	2015	108.69	115.16	1	0.944	242,232	17,187	17,187
OpEx	Other OpEx	All operational liabilities	Planning data		42,935	USA	2015	108.69	115.16	1	0.944	45,487		45,487
													Total Annualised Cost, ToT_{AV}	168,845
													Number of people served, N_p	5,254
													Number of households served, $N_{p\text{-}h}$	876
													TACH	**193**
													TACC	**32**

Area: Kaunda Square Stage I

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 1.8km network	Planning data	35	234,364	USA	2015	108.69	115.16	1	0.944	248,296	15,164	15,164
OpEx	Other OpEx	All operational liabilities	Planning data		4,925	USA	2015	108.69	115.16	1	0.944	5,218		5,218
													Total Annualised Cost, ToT_{AV}	20,382
													Number of people served, N_p	2,525
													Number of households served, $N_{p\text{-}h}$	421
													TACH	**48**
													TACC	**8**

Area: Chamba Valley

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 30km network	Planning data	35	7,123,974	USA	2015	108.69	115.16	1	0.944	7,547,469	460,937	460,937
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	307,280	USA	2015	108.69	115.16	1	0.944	325,547	23,098	23,098
OpEx	Other OpEx	All operational liabilities	Planning data		127,652	USA	2015	108.69	115.16	1	0.944	135,240		135,240
													Total Annualised Cost, ToT_{AV}	619,275
													Number of people served, N_p	19,581
													Number of households served, $N_{p\text{-}h}$	3,916
													TACH	**158**
													TACC	**32**

C-4. Detailed costs of community-scale secondary simplified sewers by area (excluding trunk network)

Area: Kalingalinga

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction for 3.2km network	Project report	25	513,000	USA	2013	106.83	115.16	1	0.928	553,000	39,234	39,234
OpEx	Staffing	Personnel costs for operating and maintaining the sewer network. Mtendere and Kalingalinga use the same workforce. Costs were assumed proportional to network length, with Mtendere having 96.5% and Kalingalinga 3.5%	KII		8,820	ZMW	2019	212.31	194.51	4.515	4.928	1,790		1,790
OpEx	Consumables	Fuel to run the vehicle for sewer operations. Vehicles allocated using 100 litres per month at ZMW 13.43/litre	KII		16,116	ZMW	2019	212.31	194.51	4.515	4.928	3,270		3,270
OpEx	Other OpEx	Vehicle maintenance (Quarterly for ZMW 3,000)	KII		12,000	ZMW	2019	212.31	194.51	4.515	4.928	2,435		2,435
OpEx	Taxes	Vehicle road tax and roadworthiness. ZMW 625/year for road tax and ZMW 54/year for roadworthiness	KII		679	ZMW	2019	212.31	194.51	4.515	4.928	138		138
OpEx	Administrative Charges	Sewer and pumping station management and admin costs. In 2018, costs were 27% of overall expenditure	Utility records		10,515	ZMW	2018	194.51	194.51	4.515	4.515	2,329		2,329
OpEx	Consumables	Sewer maintenance (materials) for a 3.2km network. Maintenance of sewer at ZMW415.18/km of network	Utility records		1,329	ZMW	2018	194.51	194.51	4.515	4.515	294		294
													Total Annualised Cost, ToT_{AV}	49,489
													Number of people served, N_p	1092
													Number of households served, $N_{p\text{-}h}$	156
													TACH	**317**
													TACC	**45**

Area: Kanyama

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	37.5km sewer construction	Planning data	25	7,148,418	USA	2015	108.69	115.16	1	0.944	7,573,366	537,349	537,349
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,450,000	USA	2015	108.69	115.16	1	0.944	2,595,644	184,167	184,167
CapEx	Infrastructure	Communal Interceptor tanks	Planning data	25	340,840	USA	2015	108.69	115.16	1	0.944	361,102	25,621	25,621
OpEx	Other OpEx	All operational liabilities	Planning data		214,817	USA	2015	108.69	115.16	1	0.944	227,587		227,587
													Total Annualised Cost, ToT_{AV}	974,724
													Number of people served, N_p	28,130
													Number of households served, $N_{p\text{-}h}$	4,688
													TACH	**208**
													TACC	**35**

Area: Industries I

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 17km network	Planning data	25	4,296,522	USA	2015	108.69	115.16	1	0.944	4,551,935	322,971	322,971
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	2,500,000	USA	2015	108.69	115.16	1	0.944	2,648,616	187,926	187,926
CapEx	Infrastructure	Communal interceptor tanks of various sizes	Planning data	25	319,696	USA	2015	108.69	115.16	1	0.944	338,701	24,032	24,032
OpEx	Other OpEx	All operational liabilities	Planning data		131,696	USA	2015	108.69	115.16	1	0.944	139,525		139,525
													Total Annualised Cost, ToT_{AV}	674,453
													Number of people served, N_p	26,385
													Number of households served, $N_{p\text{-}h}$	4,398
													TACH	**153**
													TACC	**26**

Area: Industries II

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 10.5km network	Planning data	25	2,942,211	USA	2015	108.69	115.16	1	0.944	3,117,115	221,167	221,167
CapEx	Infrastructure	Communal Interceptor (communal) tanks of various sizes	Planning data	25	1,725,000	USA	2015	108.69	115.16	1	0.944	1,827,545	129,669	129,669
OpEx	Other OpEx	All operational liabilities	Planning data		58,221	USA	2015	108.69	115.16	1	0.944	61,682		61,682
													Total Annualised Cost, ToT_{AV}	412,518
													Number of people served, N_p	19,500
													Number of households served, $N_{p\text{-}h}$	3,250
													TACH	**127**
													TACC	**21**

Area: Chawama

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of 25km network	Planning data	25	4,474,886	USA	2015	108.69	115.16	1	0.944	4,740,902	336,379	336,379
CapEx	Infrastructure	Construction of pumping stations and rising mains	Planning data	25	1,575,000	USA	2015	108.69	115.16	1	0.944	1,668,628	118,393	118,393
CapEx	Infrastructure	Communal Interceptor (communal) tanks of various sizes	Planning data	25	277,329	USA	2015	108.69	115.16	1	0.944	293,815	20,847	20,847
OpEx	Other OpEx	All operational liabilities	Planning data		134,579	USA	2015	108.69	115.16	1	0.944	142,579		142,579
													Total Annualised Cost, ToT_{AV}	618,198
													Number of people served, N_p	20,500
													Number of households served, $N_{p\text{-}h}$	3,417
													TACH	**181**
													TACC	**30**

C-5. Detailed costs for conventional trunk sewers

Area: Western trunk and Chunga to Ngwerere connection

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of the network	Planning data	35	16,496,017	USA	2015	108.69	115.16	1	0.944	17,476,648	1,067,329	1,067,329
CapEx	Infrastructure	Construction of pumping stations	Planning data	25	3,685,183	USA	2015	108.69	115.16	1	0.944	3,904,254	277,016	277,016
OpEx	Other OPEX	Routine maintenance of assets	Planning data		211,461	USA	2015	108.69	115.16	1	0.944	224,032		224,032
OpEx	Other OPEX	Preventive maintenance	Planning data		24,812	USA	2015	108.69	115.16	1	0.944	26,286		26,286
OpEx	Other CAPEX	Electricity to run pumps	Planning data		71,914	USA	2015	108.69	115.16	1	0.944	76,189		76,189
OpEx	Other CAPEX	SCADA/Communication	Planning data		500	USA	2015	108.69	115.16	1	0.944	530		530
OpEx	Staffing	Personnel costs	Planning data		33,618	USA	2015	108.69	115.16	1	0.944	35,616		35,616
OpEx	Administrative Charges	In 2018, ere 27% of total expenditure	Utility records		92,606	USA	2015	108.69	115.16	1	0.944	98,111		98,111
													Total Annualised Cost, ToT_{AV}	1,805,110
													Number of people served, N_p	202,704
													Number of households served, $N_{p\text{-}h}$	33,784
													TACH	**53**
													TACC	**9**

Area: Central trunk and Manchichi to Ngwerere connection

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction of the network	Planning data	35	20,189,051	USA	2015	108.69	115.16	1	0.944	21,389,220	1,306,276	1,306,276
OpEx	Other OPEX	Routine maintenance of assets	Planning data		100,945	USA	2015	108.69	115.16	1	0.944	106,946		106,946
OpEx	Other OPEX	Preventive maintenance	Planning data		22,082	USA	2015	108.69	115.16	1	0.944	23,395		23,395
OpEx	Staffing	Personnel costs	Planning data		33,618	USA	2015	108.69	115.16	1	0.944	35,616		35,616
OpEx	Admin.	Costs were 27% of total exp.	Utility records		36,908	USA	2015	108.69	115.16	1	0.944	39,102		39,102
													Total Annualised Cost, ToT_{AV}	1,511,336
													Number of people served, N_p	175,998
													Number of households served, $N_{p\text{-}h}$	29,333
													TACH	**52**
													TACC	**9**

Area: Eastern trunk to Kaunda Square ponds

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Sewer construction	Synthesised based on data from other areas	35	1,776,960	USA	2015	108.69	115.16	1	0.944	1,882,372	114,960	114,960
OpEx	Other OPEX	Routine maintenance of assets	Synthesised based on data from other areas		8,890	USA	2015	108.69	115.16	1	0.944	9,417		9,417
OpEx	Other OPEX	Preventive maintenance	Synthesised based on data from other areas		19,500	USA	2015	108.69	115.16	1	0.944	20,657		20,657
OpEx	Staffing	Personnel costs	Synthesised based on data from other areas		33,618	USA	2015	108.69	115.16	1	0.944	35,612		35,612
OpEx	Admin.	Costs were 27% of total exp.	Utility records		16,472	USA	2015	108.69	115.16	1	0.944	17,449		17,449
													Total Annualised Cost, ToT_{AV}	198,095
													Number of people served, N_p	57,804
													Number of households served, $N_{p\text{-}h}$	9,634
													TACH	**20**
													TACC	**4**

C-6. Detailed costs for emptying and transport - FSM

C-6.1: Manual emptying with truck transport

Area: Kanyama

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
OpEx	Equipment	Emptying tools (ZMW1,180/half-year for four types of tools)	KII		2,360	ZMW	2019	212.31	194.51	4.515	4.928	479		479
OpEx	Equipment	Emptying tools (ZMW8,000 per quarter a year)	KII		32,000	ZMW	2019	212.31	194.51	4.515	4.928	6,493		6,493
OpEx	Staffing	Pit emptiers	KII		114,502	ZMW	2018	194.51	194.51	4.515	4.515	25,358		25,358
OpEx	Staffing	Driver	KII		21,672	ZMW	2017	180.95	194.51	4.515	4.200	5,159		5,159
OpEx	Staffing	Manager	Project report		58,092	ZMW	2018	194.51	194.51	4.515	4.515	12,865		12,865
OpEx	Staffing	FSM Coordinator	Project report		52,164	ZMW	2018	194.51	194.51	4.515	4.515	11,552		11,552
OpEx	Staffing	Administrative Clerk	KII		9,312	ZMW	2018	194.51	194.51	4.515	4.515	2,062		2,062
CapEx	Equipment	Truck	KII	10	11,649	GBR	2016	112.08	117.58	0.687	0.655	17,785	2,303	2,303
CapEx	Equipment	Pushcart	KII	3	3,000	ZMW	2016	169.78	194.51	4.515	3.941	761	280	280
OpEx	Consumables	Fuel for truck	KII		27,322	ZMW	2017	180.95	194.51	4.515	4.200	6,504		6,504
OpEx	Consumables	Maintenance - Truck	KII		3,000	ZMW	2018	194.51	194.51	4.515	4.515	664		664
OpEx	Consumables	Maintenance (major) - Truck	KII		34,000	ZMW	2018	194.51	194.51	4.515	4.515	7,530		7,530
OpEx	Consumables	Maintenance - Pushcart	KII		8,790	ZMW	2014	130.81	194.51	4.515	3.036	2,895		2,895
OpEx	Taxes	Road tax	KII		625	ZMW	2018	194.51	194.51	4.515	4.515	138		138
OpEx	Taxes	Carbon Emission Tax	KII		275	ZMW	2018	194.51	194.51	4.515	4.515	61		61
OpEx	Taxes	Vehicle Road Fitness (Worthiness)	KII		54	ZMW	2018	194.51	194.51	4.515	4.515	12		12
OpEx	Taxes	Vehicle Insurance	KII		450	ZMW	2018	194.51	194.51	4.515	4.515	100		100
OpEx	Staff Development	Vaccination for personnel (ZMW11000 every six months)	KII		22,000	ZMW	2018	194.51	194.51	4.515	4.515	4,872		4,872
OpEx	Consumables	Milk expenses	Project report		14,112	ZMW	2019	212.31	194.51	4.515	4.928	2,863		2,863
OpEx	Other OPEX	Stationery, cleaning reagents, PPE, communication, and bank charges	Project report		24,240	ZMW	2017	180.95	194.51	4.515	4.200	5,771		5,771
OpEx	Consumables	Water and cement	Project report		3,080	ZMW	2018	194.51	194.51	4.515	4.515	682		682
OpEx	Consumables	Sanitising surroundings after an emptying event	Project report		5,780	ZMW	2017	180.95	194.51	4.515	4.200	1,376		1,376
OpEx	Staffing	Marketing staff	Project report		37,896	ZMW	2017	180.95	194.51	4.515	4.200	9,022		9,022
OpEx	Staffing	Support staff	Project report		29,760	ZMW	2017	180.95	194.51	4.515	4.200	7,085		7,085
													Total Annualised Cost, ToT_{AV}	84,344
													Number of people served, N_p	4,896
													Number of households served, $N_{p\text{-}h}$	816
													TACH	**103**
													TACC	**17**

Area: Chazanga

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
OpEx	Equipment	Emptying tools (ZMW1,800/half-year for four types of tools)	KII		3,600	ZMW	2019	212.31	194.51	4.515	4.928	730		730
OpEx	Equipment	Emptying tools (ZMW8,000 per quarter a year)	KII		32,000	ZMW	2019	212.31	194.51	4.515	4.928	6,493		6,493
OpEx	Staffing	Pit emptiers	KII		114,502	ZMW	2018	194.51	194.51	4.515	4.515	25,358		25,358
OpEx	Staffing	Driver	KII		21,672	ZMW	2017	180.95	194.51	4.515	4.200	5,159		5,159
OpEx	Staffing	Manager	Project report		43,200	ZMW	2017	180.95	194.51	4.515	4.200	10,284		10,284
OpEx	Staffing	FSM Coordinator	Project report		36,000	ZMW	2017	180.95	194.51	4.515	4.200	8,570		8,570
OpEx	Staffing	Administrative Clerk	KII		9,312	ZMW	2017	180.95	194.51	4.515	4.200	2,217		2,217
CapEx	Equipment	Truck	KII	10	11,649	GBR	2016	169.78	117.58	0.687	0.655	17,785	2,303	2,303
CapEx	Equipment	Pushcart	KII	3	3,000	ZMW	2016	169.78	194.51	4.515	3.941	761	280	280
OpEx	Consumables	Fuel for truck	KII		18,200	ZMW	2017	180.95	194.51	4.515	4.200	4,333		4,333
OpEx	Consumables	Maintenance - Truck	KII		10,520	ZMW	2018	194.51	194.51	4.515	4.515	2,330		2,330
OpEx	Consumables	Maintenance (major) - Truck	KII		11,890	ZMW	2018	194.51	194.51	4.515	4.515	2,633		2,633
OpEx	Consumables	Maintenance - Pushcart	KII		1,407	ZMW	2015	130.81	194.51	4.515	3.036	421		421
OpEx	Taxes	Road tax	KII		625	ZMW	2018	194.51	194.51	4.515	4.515	138		138
OpEx	Taxes	Carbon Emission Tax	KII		275	ZMW	2018	194.51	194.51	4.515	4.515	61		61
OpEx	Taxes	Vehicle Road Fitness (Worthiness)	KII		54	ZMW	2018	194.51	194.51	4.515	4.515	12		12
OpEx	Taxes	Vehicle Insurance	KII		450	ZMW	2018	194.51	194.51	4.515	4.515	100		100
OpEx	Staff Development	Vaccination for personnel (ZMW11000 every six months)	KII		22,000	ZMW	2018	194.51	194.51	4.515	4.515	4,872		4,872
OpEx	Consumables	Milk expenses	Project report		7,490	ZMW	2018	194.51	194.51	4.515	4.515	1,659		1,659
OpEx	Other OPEX	Stationery, cleaning reagents, PPE, communication and bank charges	Project report		10,583	ZMW	2018	194.51	194.51	4.515	4.515	2,344		2,344
OpEx	Consumables	Water and cement	Project report		6,840	ZMW	2018	194.51	194.51	4.515	4.515	1,515		1,515
OpEx	Consumables	Sanitising surroundings after an emptying event	Project report		5,780	ZMW	2017	180.95	194.51	4.515	4.200	1,376		1,376
OpEx	Staffing	Marketing staff	Project report		3,158	ZMW	2017	180.95	194.51	4.515	4.200	752		752
OpEx	Staffing	Support staff	Project report		29,760	ZMW	2017	180.95	194.51	4.515	4.200	7,085		7,085
													Total Annualised Cost, ToT_{AV}	71,311
													Number of people served, N_p	3,744
													Number of households served, $N_{p\text{-}h}$	624
													TACH	**114**
													TACC	**19**

Area: Lusaka Sanitation Program (LSP) modelled

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Equipment	2x2T truck (1 truck at ZMW430,000 inclusive of import duty and taxes)	Planning data	8	860,000	ZMW	2018	194.51	194.51	4.515	4.515	190,460	29,468	29,468
OpEx	Other OpEx	All operational liabilities. Average costs incurred in Chazanga and Kanyama	Synthesised based on data from other areas		446,902	ZMW	2018	194.51	194.51	4.515	4.515	98,973		98,973
													Total Annualised Cost, ToT_{AV}	128,441
													Number of people served, N_p	8,064
													Number of households served, $N_{p\text{-}h}$	1,344
													TACH	**96**
													TACC	**16**

C-6.2: Mechanical desludging unit with transport

Area: Citywide for LIHD areas (Lusaka Sanitation Program (LSP) modelled)

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Equipment	$3x3m^3$ Tractor with slurry tanker and HP washer (1 unit, ZMW 520,000 inclusive of import duty and taxes)	Planning data	8	1,560,000	ZMW	2018	194.51	194.51	4.515	4.515	345,485	53,454	53,454
OpEx	Other OpEx	Operational liabilities (50% of investment)	Planning data		780,000	ZMW	2018	194.51	194.51	4.515	4.515	172,743		172,743
													Total Annualised Cost, ToT_{AV}	226,197
													Number of people served, N_p	12,960
													Number of households served, $N_{p\text{-}h}$	2,160
													TACH	**104**
													TACC	**17**

C-6.3: Mechanical emptying and transport

Service provider: Lusaka Sanitation Program (LSP) modelled

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Equipment	4x $6m^3$ Vacuum truck (ZMW310,000 inclusive of taxes)	Planning data	7	1,240,000	ZMW	2018	194.51	194.51	4.515	4.515	274,616	47,459	47,459
OpEx	Other OpEx	All operational liabilities (average from actual costs incurred by MIMA and Geochi)	Planning data		1,146,886	ZMW	2018	194.51	194.51	4.515	4.515	253,995		253,995
													Total Annualised Cost, ToT_{AV}	301,454
													Number of people served, N_p	24,192
													Number of households served, $N_{p\text{-}h}$	4,032
													TACH	**78**
													TACC	**13**

Service provider: X Limited

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Equipment	15m^3 Vacuum truck ($30,000 inclusive of import duty and taxes)	KII	10	30,000	USA	2017	112.41	115.16	1	0.976	30,733	3,980	3,980
CapEx	Equipment	11m^3 Vacuum truck ($20,000 inclusive of import duty and taxes)	KII	10	20,000	USA	2016	110.07	115.16	1	0.956	20,925	2,710	2,710
CapEx	Equipment	9m^3 Vacuum truck ($18,000 inclusive of import duty and taxes)	KII	10	18,000	USA	2015	108.69	115.16	1	0.944	19,070	2,470	2,470
CapEx	Equipment	8m^3 Vacuum truck ($15,000 inclusive of import duty and taxes)	KII	10	15,000	USA	2014	108.57	115.16	1	0.943	15,911	2,060	2,060
CapEx	Equipment	6m^3 Vacuum truck ($14,000 (inclusive of import duty and taxes)	KII	10	14,000	USA	2013	106.83	115.16	1	0.928	15,091	1,954	1,954
OpEx	Staffing	Driver (5 persons, ZMW 30,000 per year per driver)	KII		150,000	ZMW	2019	212.31	194.51	4.515	4.928	30,435		30,435
OpEx	Staffing	Operator/helper (10 persons, ZMW 14,400 per year per operator)	KII		144,000	ZMW	2019	212.31	194.51	4.515	4.928	29,217		29,217
OpEx	Consumables	Fuel (5 trucks, average consumption ZMW 7,000 per truck per month)	KII		420,000	ZMW	2019	212.31	194.51	0.687	4.928	85,218		85,218
OpEx	Consumables	Truck maintenance (Average ZMW 15,000 truck per 3 months per year)	KII		300,000	ZMW	2019	212.31	194.51	4.515	4.928	60,870		60,870
CapEx	Land	Land value	KII	99	80,000	ZMW	2013	121.34	194.51	4.515	2.816	28,400	1,431	1,431
CapEx	Infrastructure	Business office (owned by the business)	KII	50	65,000	ZMW	2015	130.81	194.51	4.515	3.036	19,439	1,065	1,065
CapEx	Equipment	Office assets	KII	10	22,000	ZMW	2016	169.78	194.51	4.515	3.941	5,582	723	723
OpEx	Administrative Charges	Disposal license (ZMW 1500 for 3 years/truck)	KII		2,500	ZMW	2016	169.78	194.51	4.515	3.941	634		634
OpEx	Staffing	1 Director, 1 Ops Manager, 3 Office Admins (ZMW 19,500 per month for 12 months)	KII		234,000	ZMW	2019	212.31	194.51	4.515	4.928	47,478		47,478
OpEx	Taxes	Road Tax (For all 5 trucks per year)	KII		3,660	ZMW	2019	212.31	194.51	4.515	4.928	743		743
OpEx	Taxes	Carbon Emission Tax (5 trucks, ZMW 275 per truck per year)	KII		1,375	ZMW	2019	212.31	194.51	4.515	4.928	279		279
OpEx	Taxes	Vehicle Fitness (5 trucks, ZMW 54 per year per truck)	KII		270	ZMW	2019	212.31	194.51	4.515	4.928	55		55
OpEx	Consumables	Vehicle Insurance (5 trucks, ZMW 193 per 3 months per truck - 3rd party)	KII		3,860	ZMW	2019	212.31	194.51	4.515	4.928	783		783
													Total Annualised Cost, ToT_{AV}	272,105
													Number of people served, N_p	31,680
													Number of households served, $N_{p\text{-}h}$	5,280
													TACH	**54**
													TACC	**9**

Service provider: Y Limited

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Equipment	12m³ Vacuum truck (ZMW300,000 inclusive of import duty and taxes)	KII	4	300,000	ZMW	2018	194.51	194.51	4.515	4.515	66,439	18,737	18,737
CapEx	Equipment	9m³ Vacuum truck (ZMW200,000 (inclusive of import duty and taxes)	KII	5	200,000	ZMW	2016	169.78	194.51	4.515	3.941	50,744	11,721	11,721
CapEx	Equipment	3m³ Vacuum truck (ZMW130,000 (inclusive of import duty and taxes)	KII	6	130,000	ZMW	2018	194.51	194.51	4.515	4.515	28,790	5,672	5,672
CapEx	Equipment	1.8m³ Vacuum truck (ZMW145,000 (inclusive of import duty and taxes)	KII	6	145,000	ZMW	2016	169.78	194.51	4.515	3.941	36,790	7,248	7,248
OpEx	Staffing	Driver (4 persons, ZMW 36,000 per year per driver)	KII		144,000	ZMW	2019	212.31	194.51	4.515	4.928	29,217		29,217
OpEx	Staffing	Operator/helper (4 persons, ZMW 30,000 per year per operator)	KII		120,000	ZMW	2019	212.31	194.51	4.515	4.928	24,348		24,348
OpEx	Consumables	Fuel (Average consumption ZMW 5,700 per week for all 4 trucks for 52 weeks)	KII		296,400	ZMW	2019	212.31	194.51	4.515	4.928	60,139		60,139
OpEx	Consumables	Truck maintenance (Average ZMW 7,000 per 3 months per truck)	KII		112,000	ZMW	2019	212.31	117.58	0.687	4.928	22,725		22,725
OpEx	Other OPEX	Office Rental, Marketing & Communication (ZMW 6,300 per month for 12 months)	KII		75,600	ZMW	2019	212.31	194.51	4.515	4.928	15,339		15,339
CapEx	Equipment	Office assets	KII	7	80,000	ZMW	2016	169.78	194.51	4.515	3.941	20,298	3,508	3,508
OpEx	Administrative Charges	Disposal license (ZMW 1500 for 3 years/truck)	KII		2,000	ZMW	2016	169.78	194.51	4.515	3.941	507		507
OpEx	Staffing	Office personnel (5 personnel at ZMW 22,500 per month for 12 months)	KII		270,000	ZMW	2019	212.31	194.51	4.515	4.928	54,783		54,783
OpEx	Taxes	Road Tax (For all 4 trucks per year)	KII		4,680	ZMW	2019	212.31	194.51	4.515	4.928	950		950
OpEx	Taxes	Carbon Emission Tax (4 trucks, ZMW 275 per truck per year)	KII		1,100	ZMW	2019	212.31	194.51	4.515	4.928	223		223
OpEx	Administrative Charges	Vehicle Fitness (4 trucks, ZMW 54 per year per truck)	KII		216	ZMW	2019	212.31	194.51	4.515	4.928	44		44
OpEx	Consumables	Vehicle Insurance ((For all 4 trucks per year)	KII		12,110	ZMW	2019	212.31	194.51	4.515	4.928	2,457		2,457
													Total Annualised Cost, ToT_{AV}	257,618
													Number of people served, N_p	23,040
													Number of households served, $N_{p\text{-}h}$	3,840
													TACH	**67**
													TACC	**11**

C-7. Detailed costs for treatment

C-7.1: Anaerobic treatment using bio-digesters and drying Beds

Area: Kanyama

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of 50m³ bio-digester + drying beds	Project data	20	1,031,602	ZMW	2012	113.42	194.51	4.515	2.633	391,777	31,437	31,437
OpEx	Consumables	Plant maintenance	KII		6,750	ZMW	2017	180.95	194.51	4.515	4.200	1,607		1,607
OpEx	Consumables	Solid waste collection by a contracted solid waste management company	KII		14,400	ZMW	2017	180.95	194.51	4.515	4.200	3,428		3,428
OpEx	Staffing	Technical Support/Operations & Maintenance 32 hours per month for 12 months at ZMW 1,600 per month (for 5 years)	Project data		19,200	ZMW	2017	180.95	194.51	4.515	4.200	4,571		4,571
CapEx	Land	Land value	KII	99	100,000	ZMW	2015	144.04	194.51	4.515	3.343	29,906	1,507	1,507
OpEx	Staffing	Personnel costs for plant operations	KII		14,650	ZMW	2017	180.95	194.51	4.515	4.200	3,488		3,488
CapEx	Other CAPEX	Drying bed performance (Monitoring of Sludge Quality - Round 1 & 2, follows the construction lifetime)	Project data	20	33,850	GBR	2014	110.55	117.58	0.687	0.646	52,396	4,204	4,204
CapEx	Other CAPEX	Development of O&M Manuals (follows the construction lifetime)	Project data	20	3,318	GBR	2014	110.55	117.58	0.687	0.646	5,136	412	412
CapEx	Infrastructure	Construction of 70m³ sludge holding tank	Project data	20	946,534	ZMW	2015	144.04	194.51	4.515	3.343	283,071	22,714	22,714
OpEx	Consumables	Sludge transfer to drying beds	KII		70,104	ZMW	2015	144.04	194.51	4.515	3.343	20,965		20,965
													Total Annualised Cost, ToT_{AV}	94,334
													Number of people served, N_p	8,010
													Number of households served, $N_{p\text{-}h}$	1,335
													TACH	**71**
													TACC	**12**

Citywide service: Lusaka Sanitation Program (LSP) modelled anaerobic FSM

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of five FSTPs	Planning data	20	2,540,452	USA	2016	110.07	115.16	1	0.956	2,657,737	213,280	213,280
OpEx	Other OpEx	All operational liabilities	Planning data		1,016,181	USA	2016	110.07	115.16	1	0.956	1,062,950		1,062,950
													Total Annualised Cost, ToT_{AV}	1,276,230
													Number of people served, N_p	112,698
													Number of households served, $N_{p\text{-}h}$	18,783
													TACH	**68**
													TACC	**11**

Area: Chazanga

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of 50m^3 bio-digester + drying beds	Planning data	20	1,063,485	ZMW	2014	130.81	194.51	4.515	3.036	350,247	28,101	28,101
OpEx	Consumables	Plant maintenance	KII		9,000	ZMW	2017	180.95	194.51	4.515	4.200	2,143		2,143
OpEx	Consumables	Solid waste management company contracted	KII		6,650	ZMW	2017	180.95	194.51	4.515	4.200	1,583		1,583
OpEx	Staffing	Technical Support/Operations & Maintenance (32 hours per month for 12 months at ZMW 1,600 per month (for 5 years)	Project data		19,200	ZMW	2017	180.95	194.51	4.515	4.200	4,571		4,571
CapEx	Land	Land value	KII	99	100,000	ZMW	2015	144.04	194.51	4.515	3.343	29,906	1,507	1,507
OpEx	Staffing	Personnel costs for plant operations	KII		11,450	ZMW	2017	180.95	194.51	4.515	4.200	2,726		2,726
CapEx	Other CAPEX	Drying bed performance (Monitoring of Sludge Quality - Round 1 & 2, follows the construction lifetime)	Project data	20	33,850	GBR	2014	110.55	117.58	0.687	0.646	52,396	4,204	4,204
CapEx	Other CAPEX	Development of O&M Manuals (follows the construction lifetime)	Project data	20	3,318	GBR	2014	110.55	117.58	0.687	0.646	5,136	412	412
													Total Annualised Cost, ToT_{AV}	45,247
													Number of people served, N_p	7,182
													Number of households served, $N_{p\text{-}h}$	1,197
													TACH	**37**
													TACC	**6**

C-7.2: Aerobic treatment using trickling filters

Citywide service: Manchichi trickling filter (aerobic) sludge treatment plant

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure	Construction of treatment plant with trickling filter (aerobic processes which require machines)	KII	50	37,068,000	GBR	2016	112.08	117.58	0.687	0.655	56,592,366	2,989,831	2,989,831
OpEx	Other OpEx	Operational expenses[29]	KII		8,527,764	ZMW	2018	194.51	194.51	4.515	4.515	1,888,762		1,888,762
													Total Annualised Cost, ToT_{AV}	4,878,593
													Number of people served, N_p	282,678
													Number of households served, $N_{p\text{-}h}$	47,113
													TACH	**95**
													TACC	**16**

[29] In calculating OpEx, the plant treats wastewater, septage and faecal sludge. The total number of people served is 361,590 (60,265 households)

C-7.3: Aerobic and anaerobic treatment using trickling filters with bio-digesters

Western and Central sewersheds: New Ngwerere trickling filter and sludge treatment plant

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure and Buildings	Cost of WWTP including civil works, mechanical & electrical equipment, power supply, access roads, dredging and fencing at cost $84,279,237	Planning data	50	84,279,237	USA	2015	108.69	115.16	1	0.944	89,289,343	4,890,979	4,890,979
OpEx	Other OPEX	Maintenance of infrastructure and equipment, electricity to run the plant, chlorine gas for operations, personnel and management and administration costs	Planning data		44,422,355	ZMW	2019	212.31	194.51	4.515	4.928	9,014,276		9,014,276
													Total Annualised Cost, ToT_{AV}	13,905,255
													Number of people served, N_p	524,610
													Number of households served, N_{p-h}	87,435
													TACH	**156**
													TACC	**26**

C-7.3: Aerobic treatment using waste stabilisation ponds

Eastern sewershed: Kaunda Square waste stabilisation ponds

Cost Type	Category	Description	Data Source	Lifetime	Input Cost	Currency	Year	CPI_{year}	CPI_{2018}	PPP_{2018}	C_F	CapEx/OpEx Output Value ($2018)	Annualised CapEx Value, $CapEx_{av}$ ($2018)	Output
CapEx	Infrastructure and Buildings	Construction of WSPs with sewer interceptor	Project data	35	12,615,420	USA	2014	108.57	115.16	1	0.943	13,381,218	870,467	870,467
OpEx	Staffing	Personnel costs O&M sewer network. 4 Operators (ZMW 5,000 per month for 12 months), 4 General workers (ZMW 5,000 per month for 12 months), 4 Superintendent (ZMW 11,000 per month for 12 months) and 35 Causal Daily Employees (ZMW 1,050 per month for 12 months)	KII		1,449,000	ZMW	2019	212.31	194.51	4.515	4.928	294,001		294,001
OpEx	Consumables	Fuel dedicated to sewer operations	KII		19,339	ZMW	2019	212.31	194.51	4.515	4.928	3,924		3,924
OpEx	Consumables	Vehicle maintenance	KII		24,000	ZMW	2019	212.31	194.51	4.515	4.928	4,870		4,870
OpEx	Taxes	Vehicle road tax and roadworthiness	KII		1,358	ZMW	2019	212.31	194.51	4.515	4.928	276		276
OpEx	Administration	Management and admin costs - Head Office	KII		297,998	ZMW	2018	194.51	194.51	4.515	4.515	65,996		65,996
OpEx	Consumables	Maintenance of sewer ponds	KII		198,666	ZMW	2019	212.31	117.58	4.515	4.928	40,309		40,309
OpEx	Consumables	Insecticides	KII		6,000	ZMW	2019	212.31	117.58	4.515	4.928	1,217		1,217
													Total Annualised Cost, ToT_{AV}	1,281,060
													Number of people served, N_p	156,000
													Number of households served, N_{p-h}	26,000
													TACH	**54**
													TACC	**9**

C-8. Charges/fees for sewered and FSM systems

A. Sewerage charges

Urban Setting	Annual water charges ($2018)	Sewerage charges ($2018)	Annual per capita cost ($2018)
LIHD Area	87	26	**4**
MIMD Area	169	51	**8**
HILD Area	376	113	**23**

B. FSM fees

System	Technology emptied	Urban setting	FSM fee ($2018)	Annual per capita cost ($2018)
Manual emptying with truck transport	IPL	LIHD	57	**3**
	ST		114	**6**
Mechanical desludging[30]	IPL	LIHD	83	**5**
Mechanical emptying and transport	IPL and ST	LIHD	124	**7**
	ST	MIMD	124	**7**
	ST	MIMD	124	**8**
Dumping at Manchichi wastewater treatment plant			33	**2**

[30] Mechanical desludging of pit latrines is charged at $23.81 per m^3 of sludge with a containment on average 3.5m^3

C-9. Community-scale secondary sewer costs – conventional

A. System with pumping

Area Served	Topography	Distance to treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Connection Efficiency (%)	Number of Connections	TACC ($2018)
Chunga-Lilanda and George	Flat	10.75	61027	7.789	7789	77	10171	**33.0**
Kanyama Extension	Flat	14.01	27456	2.550	10767	89	4576	**24.4**
Matero West	Flat	10.25	43092	8.173	5272	80	7182	**14.4**
Industries I	Flat	13.91	27414	4.751	5770	91	4569	**15.8**
Industries II	Flat	15.49	43716	7.350	5948	91	7286	**13.9**
Chipata	Flat	6.38	28968	3.177	9118	76	4828	**14.3**
Chawama and Kuomboka	Flat	17.35	44610	1.544	28892	91	7435	**14.8**
Sikanze	Hilly	12.72	3226	0.869	3712	56	538	**43.5**
Shakespear	Hilly	11.66	1437	1.448	992	56	287	**41.3**
Prospect Hill South	Hilly	12.07	5788	2.090	2769	61	1158	**34.3**
Kamanga	Flat	2.28	5254	0.695	7560	58	876	**32.1**
Chamba Valley	Flat	1.32	19581	15.225	1286	75	3961	**31.6**
Mtendere	Hilly	4.17	30444	5.450	10987	51	5074	**19.3**

B. System without pumping

Area Served	Topography	Distance to treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Connection Efficiency (%)	Number of Connections	TACC ($2018)
Garden	Hilly	9.26	30146	1.927	15644	94	5024	**4.4**
Matero	Hilly	8.31	7980	1.443	5530	77	1330	**14.2**
Industries I	Flat	8.61	27878	5.021	5552	91	4646	**6.3**
Villa Elizabeth	Hilly	11.63	1668	1.384	1205	77	334	**17.1**
Northmead	Hilly	10.42	2476	1.881	1316	67	495	**17.9**
Rhodes Park and Rhodes East	Hilly	11.07	21822	8.562	2549	77	4364	**21.7**
Kaunda Square Stage I	Flat	1.28	2525	0.725	3483	100	421	**8.1**

C-10. Community-scale secondary sewer costs assuming 100% connection efficiency - conventional

A. System with pumping

Area Served	Topography (m)	Distance to Treatment	Population Served	Area Coverage (km^2)	Population Density (people/km^2)	Number of Connections	TACC ($2018)
Chunga-Lilanda and George	Flat	10.75	78823	7.789	10120	13137	**25.5**
Kanyama Extension	Flat	14.01	30823	2.55	12087	5137	**21.7**
Matero West	Flat	10.25	53550	8.173	6552	8925	**11.6**
Industries I	Flat	13.91	30100	4.751	6336	5017	**14.4**
Industries II	Flat	15.49	48008	7.35	6532	8001	**12.6**
Chipata	Flat	6.38	38301	3.177	12056	6384	**10.8**
Chawama and Kuomboka	Flat	17.35	48815	1.544	31616	8136	**13.5**
Sikanze	Hilly	12.72	5806	0.869	6681	968	**24.1**
Shakespear	Hilly	11.66	2587	1.448	1787	517	**23.0**
Prospect Hill South	Hilly	12.07	9438	2.09	4516	1886	**21.0**
Kamanga	Flat	2.28	9013	0.695	12968	1502	**18.7**
Chamba Valley	Flat	1.32	26290	15.225	1727	5258	**23.6**
Mtendere	Hilly	4.17	59880	5.45	10987	9980	**9.8**

B. System without pumping

Area Served	Topography (m)	Distance to Treatment (km)	Population Served	Area Coverage (km^2)	Population Density (people/km^2)	Number of Connections	TACC ($2018)
Garden	Hilly	9.26	32140	1.927	16679	5357	**4.1**
Matero East	Hilly	8.31	10356	1.443	7177	1726	**10.9**
Industries I	Flat	8.61	30564	5.021	6087	5094	**5.7**
Villa Elizabeth	Hilly	11.63	2161	1.384	1561	432	**13.2**
Northmead	Hilly	10.42	3714	1.881	1974	743	**11.9**
Rhodes Park and Rhodes Park East	Hilly	11.07	28368	8.562	3313	5674	**16.7**
Kaunda Square Stage I	Flat	1.28	2525	0.725	3483	421	**8.1**

C-11. Community-scale secondary sewer costs – simplified

A. System with pumping

Area Served	Topography	Distance to treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Connection Efficiency (%)	Number of Connections	TACC ($2018)
Kanyama	Flat	14.01	28130	2.55	11031	89	4688	**34.7**
Industries I	Flat	8.61	26385	4.751	5554	86	4398	**25.6**
Chawama and Kuomboka	Flat	17.35	20500	1.544	13277	82	3417	**30.2**

B. System without pumping

Area Served	Topography	Distance to treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Connection Efficiency (%)	Number of Connections	TACC ($2018)
Industries II	Flat	15.49	19500	3.35	5821	88	3250	**21.2**
Kalingalinga	Hilly	4.87	1092	0.231	4727	73	156	**45.3**

C-12. Community-scale secondary sewer costs assuming 100% connection efficiency - simplified

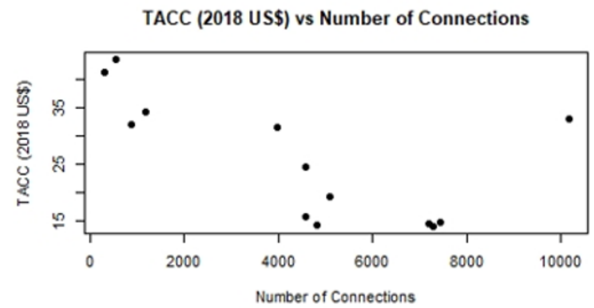
A. System with pumping

Area Served	Topography (m)	Distance to Treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Number of Connections	TACC ($2018)
Kanyama	Flat	14.01	36495	2.55	14312	6082	**22.7**
Industries I	Flat	8.61	35677	4.751	7509	5946	**18.9**
Chawama and Kuomboka	Flat	17.35	29905	1.544	19368	4984	**20.7**

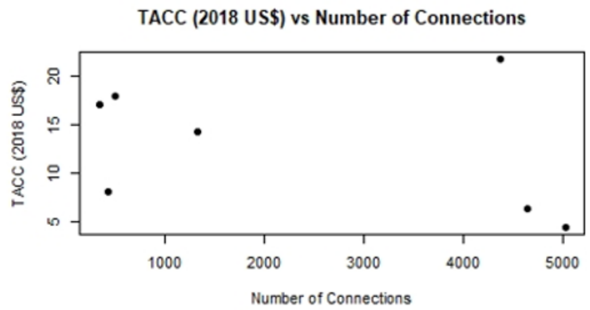
B. System without pumping

Area Served	Topography (m)	Distance to Treatment (km)	Population Served	Area Coverage (km^2)	Population Density ($people/km^2$)	Number of Connections	TACC ($2018)
Industries II	Flat	15.49	27187	3.35	8115	4531	**15.2**
Kalingalinga	Hilly	4.87	1996	0.231	8640	332	**24.8**

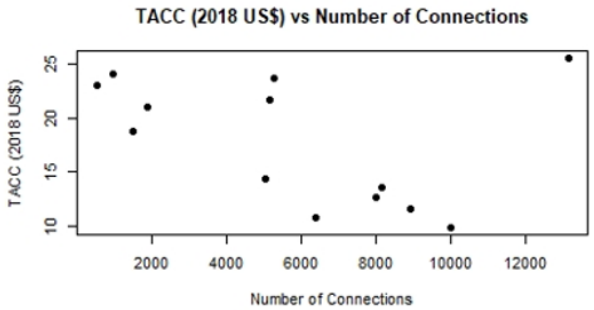
C-13. TACC against the number of connections



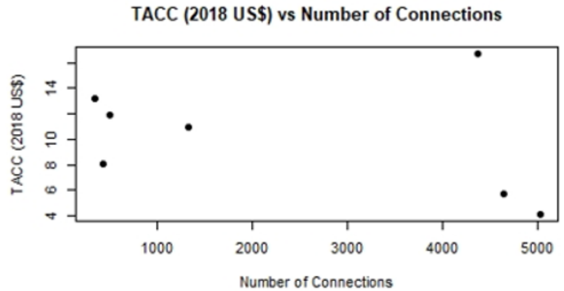
a) Actual connection efficiency with pumping



b) Actual connection efficiency without pumping



c) 100% modelled connection efficiency with pumping



d) 100% modelled connection efficiency without pumping

Figure C-1. TACC against the number of connections for community-scale secondary conventional sewerage, excluding the costs of trunk sewers. a) actual connection efficiency with pumping, b) actual connection efficiency without pumping, c) 100% modelled connection efficiency with pumping, and d) 100% modelled connection efficiency without pumping

C-14. Outputs of regression analysis

1. Conventional sewerage with pumping at 100% connection efficiency

```
Call:
lm(formula = TACC ~ Population.Served, data = FCE_CSWP)

Residuals:
   Min     1Q Median     3Q    Max 
-6.496 -3.760 -1.422  3.669 12.113 

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)    
(Intercept)       2.099e+01  2.762e+00   7.601 1.06e-05 ***
Population.Served -9.648e-05  6.778e-05  -1.423    0.182    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.502 on 11 degrees of freedom
  (18 observations deleted due to missingness)
Multiple R-squared:  0.1555,	Adjusted R-squared:  0.07875 
F-statistic: 2.026 on 1 and 11 DF,  p-value: 0.1824
```

```
Call:
lm(formula = DTACC ~ Distance.to.treatment, data = FCE_CSWP)

Residuals:
   Min     1Q Median     3Q    Max 
-7.607 -4.567  0.902  4.861  8.113 

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)    
(Intercept)           18.26650    3.76362   4.853 0.000508 ***
Distance.to.treatment  0.05769    0.33308   0.173 0.865645    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.885 on 11 degrees of freedom
  (18 observations deleted due to missingness)
Multiple R-squared:  0.00272,	Adjusted R-squared:  -0.08794 
F-statistic:  0.03 on 1 and 11 DF,  p-value: 0.8656
```

```
Call:
lm(formula = TACC ~ Area.Coverage, data = FCE_CSWP)

Residuals:
   Min     1Q Median     3Q    Max 
-7.938 -5.195  1.106  5.383  7.691 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)    17.5734     2.5729   6.830 2.84e-05 ***
Area.Coverage   0.0302     0.4181   0.072    0.944    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.986 on 11 degrees of freedom
  (18 observations deleted due to missingness)
Multiple R-squared:  0.000474,	Adjusted R-squared:  -0.09039 
F-statistic: 0.005216 on 1 and 11 DF,  p-value: 0.9437
```

```
Call:
glm(formula = Topography ~ TACC, family = binomial(), data = FCE_CSWP$model)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1024  -0.8725  -0.6945   1.3075   1.8635

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -2.39365    2.23901  -1.069    0.285
TACC         0.08684    0.11491   0.756    0.450

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 16.048  on 12  degrees of freedom
Residual deviance: 15.448  on 11  degrees of freedom
  (18 observations deleted due to missingness)
AIC: 19.448

Number of Fisher Scoring iterations: 4
```

```
Call:
lm(formula = TACC ~ Population.Density, data = FCE_CSWP)

Residuals:
   Min     1Q Median     3Q    Max
-6.918 -5.700  1.674  3.795  7.794

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)        20.2198885  2.2975081   8.801 2.61e-06 ***
Population.Density -0.0003228  0.0002220  -1.454    0.174
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.484 on 11 degrees of freedom
  (18 observations deleted due to missingness)
Multiple R-squared:  0.1613,    Adjusted R-squared:  0.08503
F-statistic: 2.115 on 1 and 11 DF,  p-value: 0.1738
```

2. Conventional sewerage without pumping at 100% connection efficiency

```
Call:
lm(formula = TACC ~ Population.Served, data = FCE_CSWOP)

Residuals:
      1       2       3       4       5       6       7 
-4.2874  0.2636 -2.8501  1.7176  0.5779  7.9232 -3.3448 

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)   
(Intercept)       11.7055100  2.7009801   4.334  0.00747 **
Population.Served -0.0001032  0.0001326  -0.779  0.47148   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.557 on 5 degrees of freedom
  (17 observations deleted due to missingness)
Multiple R-squared:  0.1081,	Adjusted R-squared:  -0.07026 
F-statistic: 0.6061 on 1 and 5 DF,  p-value: 0.4715
```

```
Call:
lm(formula = DTACC ~ Distance.to.treatment, data = FCE_CSWOP)

Residuals:
      1       2       3       4       5       6       7 
-6.2862  0.9747 -4.4024  1.5146  0.8289  5.3452  2.0252 

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)             5.6190     4.7342   1.187    0.289
Distance.to.treatment   0.5904     0.5127   1.152    0.302

Residual standard error: 4.37 on 5 degrees of freedom
  (17 observations deleted due to missingness)
Multiple R-squared:  0.2097,	Adjusted R-squared:  0.05158 
F-statistic: 1.326 on 1 and 5 DF,  p-value: 0.3015
```

```
Call:
lm(formula = TACC ~ Area.Coverage, data = FCE_CSWOP)

Residuals:
      1       2       3       4       5       6       7 
-5.3031  1.8071 -5.6864  4.1449  2.5264  3.0437 -0.5326 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)  
(Intercept)     8.1679     2.5310   3.227   0.0233 *
Area.Coverage   0.6410     0.6376   1.005   0.3609  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.401 on 5 degrees of freedom
  (17 observations deleted due to missingness)
Multiple R-squared:  0.1681,	Adjusted R-squared:  0.00177 
F-statistic: 1.011 on 1 and 5 DF,  p-value: 0.3609
```

```
Call:
glm(formula = Topography ~ TACC, family = binomial(), data = FCE_CSWOP$model)

Deviance Residuals:
      1        2        3        4        5        6        7
 1.5117   0.6147  -1.0895   0.4251   0.5248   0.2371  -1.4457

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.1627     2.5616  -0.844    0.399
TACC          0.3425     0.2926   1.171    0.242

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 8.3758  on 6  degrees of freedom
Residual deviance: 6.4523  on 5  degrees of freedom
  (17 observations deleted due to missingness)
AIC: 10.452

Number of Fisher Scoring iterations: 5
```

```
Call:
lm(formula = y ~ x, data = FCE_CSWOP)

Residuals:
      1       2       3       4       5       6       7
 0.4741  1.6560 -4.1885  0.6355 -0.4203  5.1714 -3.3281

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) 13.4874543  2.0135456   6.698  0.00112 **
x           -0.0005913  0.0002676  -2.209  0.07819 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3.433 on 5 degrees of freedom
  (17 observations deleted due to missingness)
Multiple R-squared:  0.4939,	Adjusted R-squared:  0.3927
F-statistic:  4.88 on 1 and 5 DF,  p-value: 0.07819
```

APPENDIX D: Dataset for Chapter 5

D-1. CSDA criteria on current policies, planning issues and budgetary arrangements for sewered services in Lusaka

Sewerage questions on enabling function		Evidence/scoring criteria across the sanitation value chain
Policy and Legislation	**Policy:** Is the provision of sewerage services (including household connections) adequately supported by an appropriate, widely-known, acknowledged and available national or local policy?	**1**: Policy is appropriate, widely-known, acknowledged and available **0.5**: Policy is appropriate, but not widely-known, acknowledged or available; or exists only as a guideline or strategy without legal force **0**: Policy is not available or inappropriate to the context
	Institutional roles: Is responsibility for sewerage service delivery clearly assigned to an entity with well-defined roles, responsibilities, and mandates?	**1**: Responsibility clearly assigned to an entity with well-defined roles, responsibilities, and mandates **0.5**: Responsibility unclear or ambiguous, or roles, responsibilities, and mandates poorly defined **0**: No entity with well-defined roles, responsibilities and mandates for sewerage exists
	Legislation/Regulation: Are there national and/or local legislation and regulatory mechanisms for sewerage services, backed by any necessary complementary codes, specifications, schedules?	**1**: Legislation and regulatory mechanisms are comprehensive, in place and widely publicised **0.5**: Legislation and regulatory mechanisms are comprehensive and in place but not widely publicised **0**: Legislation and regulatory mechanisms are inadequate or do not exist
Planning and budgeting	**Targets:** Are service levels and targets for the accessibility of, and connections to, sewerage specified in current approved plans?	**1**: Service levels and targets are clearly specified and officially adopted **0.5**: Service levels are specified, but targets not stated or not officially adopted **0**: No reference to service levels or targets
	Budget lines: Are there annual and medium-term budget lines for sewerage, including both software, and hardware expansion, operation, and maintenance?	**1**: Annual and medium-term budget lines for sewerage exist **0.5**: Annual and medium-term budget lines are unclear, poorly defined, or lack adequate software components **0**: No budget lines for sewerage exist
Inclusion	**Planning and budgeting:** Is the policy, planning and budgeting process for the provision of sanitation services inclusive?	**1:** Inclusion is explicitly considered in policy and required in the planning and budgeting process **0.5**: Inclusion is mentioned in policy but not explicitly or weakly required in the planning and budgeting process **0**: There are no inclusion criteria in policy, planning and budgeting process

D-2. CSDA criteria on capacity and financing mechanisms to develop improved sewered services in Lusaka

Sewerage questions on delivering function		Evidence/scoring criteria across the sanitation value chain
Funding	**Investment plan:** Is there an investment plan for sewerage hardware and software, including all the components necessary to achieve service level targets over the medium term?	**1**: There is an investment plan, which includes all the components necessary to meet targets over the medium term **0.5**: There is an investment plan, which includes some (~50%) of the components necessary to meet targets over the medium term **0**: There is no investment plan or one that is inadequate to meet targets over the medium term
	Adequate funding: Are annual funding allocations for sewerage sufficient to achieve service level targets, and are they used as planned?	**1**: Funding allocations are sufficient and used as planned **0.5**: Funding allocations are only partially sufficient or partially used as planned **0**: Funding allocations are inadequate or not used as planned
	Coordination: Are there effective mechanisms for coordination of sewerage investments between donors; donors and government; and within government?	**1**: Mechanisms exist, and they are effective at coordinating investments **0.5**: There are some partially functional mechanisms **0**: Mechanisms do not exist or exist on paper only and are completely ineffective
Capacity and outreach	**Institutional capacity:** Is responsibility for delivery of sewerage services mandated to an adequately staffed and structured entity?	**1**: The mandated entity is well structured and adequately staffed **0.5**: The mandated entity is not well structured or adequately staffed **0**: There is no mandated entity, or it is very weak
	Autonomy: Does the entity responsible for sewerage have sufficient autonomy to address identified priorities?	**1**: Entity has adequate autonomy to function according to priorities **0.5**: Partial autonomy from city authorities or national body **0**: Integral part of the city authority or a national ministry
	Outreach: Are there active programmes promoting inclusive sewer connections, behaviour change and community engagement?	**1**: There are systematic programmes promoting sewer connections, behaviour change and community engagement **0.5**: Some outreach activities are being carried out on an ad-hoc basis **0**: No outreach activities are being implemented
Inclusion	**Technology**: Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people, according to the agreed definition?	**1**: There are suitable options available to address the needs of most women and poor and vulnerable people **0.5**: There are options that address the needs of some women and poor and vulnerable people, but they are not sufficient or complete **0**: Options available to meet the sanitation needs of women and poor and vulnerable people are grossly inadequate
	Funding: Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people, according to the agreed definition?	**1**: There are funds, plans and mechanisms to meet the needs of most people, including women and poor and vulnerable people **0.5**: There are funds, plans and mechanisms to meet the needs of some women and poor and vulnerable people **0**: There are few or almost no funds, plans and mechanisms to support women and poor and vulnerable people

D-3. CSDA criteria on operating and sustaining for sewered services in Lusaka

Sewerage questions on sustaining function		Evidence/scoring criteria across the sanitation value chain
Regulation and cost recovery	**Cost recovery**: Are sewerage system O&M costs known and fully covered by cost recovery through user fees and/or local taxes or transfers?	**1**: O&M costs known and revenue adequate to maintain the system well **0.5**: O&M costs known, and revenue covers partial O&M, at less than optimum level **0**: O&M costs not known and/or revenue wholly inadequate
	Monitoring: Are there adequately staffed institutions which monitor performance, health and environmental standards for sewerage services?	**1**: There are adequately staffed institutions which monitor performance, health and environmental standards **0.5**: There are institutions that partially monitor performance, health and environmental standards **0**: There is no institution that monitors performance, health and environmental standards
	Enforcement: Are failures to meet standards for sewerage system performance systematically monitored and sanctions applied where relevant?	**1**: Performance standards exist, are monitored, and sanctions applied **0.5**: Performance standards exist and are monitored, but no sanctions are applied **0**: Performance standards (if they exist) are not monitored
Institutions and service providers	**Staffing**: Does the entity responsible for sewerage have sufficient qualified staff to undertake adaptive planning of sewerage rehabilitation and expansion?	**1**: The entity has sufficient qualified staff for adaptive planning of sewerage rehabilitation and expansion **0.5**: The entity has insufficient staff for adaptive planning of sewerage rehabilitation and expansion **0**: The entity has inadequate staff and is unable to undertake adaptive planning for the sewerage system
	Staff development: Does the entity responsible for sewerage have an active and gender-aware staff development programme and incentives to retain workers?	**1**: The entity has a gender-aware staff development programme and incentives to retain workers **0.5**: The entity has either a staff development programme or incentives to retain workers, but not both **0**: There is no staff development programme or incentives to retain workers
	Health and Safety: Is the health and safety of sewerage workers adequately protected and monitored?	**1**: The health and safety of sewerage workers is adequately protected and monitored **0.5**: The health and safety of sewerage workers is partly protected and monitored **0**: The health and safety of sewerage workers is not protected or monitored
	Capacity-building: Are there ongoing programmes and measures to build the capacity of the sewerage service provider?	**1**: Capacity-building is being implemented according to an agreed plan **0.5**: Limited capacity-building is implemented on an ad-hoc basis **0**: No or very little capacity-building is carried out
Inclusion	**Growth:** Are sanitation services keeping pace with population growth?	**1**: Sanitation services are expanding significantly faster than population, and the number of people with unsafe sanitation is decreasing **0.5**: Sanitation services are keeping pace with population growth **0:** Population is growing significantly faster than sanitation services, and the number of people with unsafe sanitation is increasing
	Planning from evidence: Is sanitation data routinely collected, including from women, poor and vulnerable people, and used for planning services?	**1**: Sanitation data is routinely collected citywide and used for planning services **0.5**: Sanitation data is collected on an ad-hoc basis with incomplete spatial coverage **0**: Sanitation monitoring data is rarely collected
	Outcomes: Do the city's sanitation systems provide safe sanitation services for all users, including women, poor and vulnerable people?	**1**: Safe sanitation services are affordable and available to all users, including women and poor and vulnerable people **0.5**: Safe sanitation services are available to about half of women and poor and vulnerable people **0**: Safe sanitation services are not available to many women and poor and vulnerable people, or this is not known

D-4. CSDA criteria on current policies, planning issues and budgetary arrangements for non-sewered services in Lusaka

Non-sewered questions on enabling function		Evidence/scoring criteria across the sanitation value chain
Policy and Legislation	**Policy:** Is the provision of sewerage services (including household connections) adequately supported by an appropriate, widely-known, acknowledged and available national or local policy?	**1**: Policy is appropriate, widely-known, acknowledged and available **0.5**: Policy is appropriate, but not widely-known, acknowledged or available; or exists only as a guideline or strategy without legal force **0**: Policy is not available or inappropriate to the context
	Institutional roles: Is responsibility for sewerage service delivery clearly assigned to an entity with well-defined roles, responsibilities, and mandates?	**1**: Responsibility clearly assigned to an entity with well-defined roles, responsibilities, and mandates **0.5**: Responsibility unclear or ambiguous, or roles, responsibilities, and mandates poorly defined **0**: No entity with well-defined roles, responsibilities and mandates for sewerage exists
	Legislation/Regulation: Are there national and/or local legislation and regulatory mechanisms for sewerage services, backed by any necessary complementary codes, specifications, schedules?	**1**: Legislation and regulatory mechanisms are comprehensive, in place and widely publicised **0.5**: Legislation and regulatory mechanisms are comprehensive and in place but not widely publicised **0**: Legislation and regulatory mechanisms are inadequate or do not exist
Planning and budgeting	**Targets:** Are service levels and targets for the accessibility of, and connections to, sewerage specified in current approved plans?	**1**: Service levels and targets are clearly specified and officially adopted **0.5**: Service levels are specified, but targets not stated or not officially adopted **0**: No reference to service levels or targets
	Budget lines: Are there annual and medium-term budget lines for sewerage, including both software, and hardware expansion, operation, and maintenance?	**1**: Annual and medium-term budget lines for sewerage exist **0.5**: Annual and medium-term budget lines are unclear, poorly defined, or lack adequate software components **0**: No budget lines for sewerage exist
Inclusion	**Planning and budgeting:** Is the policy, planning and budgeting process for the provision of sanitation services inclusive?	**1:** Inclusion is explicitly considered in policy and required in the planning and budgeting process **0.5**: Inclusion is mentioned in policy but not explicitly or weakly required in the planning and budgeting process **0**: There are no inclusion criteria in policy, planning and budgeting process

D-5. CSDA criteria on capacity and financing mechanisms to develop improved non-sewered services in Lusaka

Non-sewered questions on delivering function		Evidence/scoring criteria across the sanitation value chain
Funding	**Investment plan:** Is there an investment plan for sewerage hardware and software, including all the components necessary to achieve service level targets over the medium term?	**1**: There is an investment plan, which includes all the components necessary to meet targets over the medium term **0.5**: There is an investment plan, which includes some (~50%) of the components necessary to meet targets over the medium term **0**: There is no investment plan or one that is inadequate to meet targets over the medium term
	Adequate funding: Are annual funding allocations for sewerage sufficient to achieve service level targets, and are they used as planned?	**1**: Funding allocations are sufficient and used as planned **0.5**: Funding allocations are only partially sufficient or partially used as planned **0**: Funding allocations are inadequate or not used as planned
	Coordination: Are there effective mechanisms for coordination of sewerage investments between donors; donors and government; and within government?	**1**: Mechanisms exist, and they are effective at coordinating investments **0.5**: There are some partially functional mechanisms **0**: Mechanisms do not exist or exist on paper only and are completely ineffective
Capacity and outreach	**Institutional capacity:** Is responsibility for delivery of sewerage services mandated to an adequately staffed and structured entity?	**1**: The mandated entity is well structured and adequately staffed **0.5**: The mandated entity is not well structured or adequately staffed **0**: There is no mandated entity, or it is very weak
	Autonomy: Does the entity responsible for sewerage have sufficient autonomy to address identified priorities?	**1**: Entity has adequate autonomy to function according to priorities **0.5**: Partial autonomy from city authorities or national body **0**: Integral part of the city authority or a national ministry
	Outreach: Are there active programmes promoting inclusive sewer connections, behaviour change and community engagement?	**1**: There are systematic programmes promoting sewer connections, behaviour change and community engagement **0.5**: Some outreach activities are being carried out on an ad-hoc basis **0**: No outreach activities are being implemented
Inclusion	**Technology**: Are there affordable, appropriate, safe and adaptable technologies available to meet the needs of women, poor and vulnerable people, according to the agreed definition?	**1**: There are suitable options available to address the needs of most women and poor and vulnerable people **0.5**: There are options that address the needs of some women and poor and vulnerable people, but they are not sufficient or complete **0**: Options available to meet the sanitation needs of women and poor and vulnerable people are grossly inadequate
	Funding: Are there specific funding mechanisms to support appropriate, safe and adaptable sanitation services to all users, including women, poor and vulnerable people, according to the agreed definition?	**1**: There are funds, plans and mechanisms to meet the needs of most people, including women and poor and vulnerable people **0.5**: There are funds, plans and mechanisms to meet the needs of some women and poor and vulnerable people **0**: There are few or almost no funds, plans and mechanisms to support women and poor and vulnerable people

D-6. CSDA criteria on operating and sustaining for non-sewered services in Lusaka

Non-sewered questions on sustaining function		Evidence/scoring criteria across the sanitation value chain
Regulation and cost recovery	**Cost recovery**: Are sewerage system O&M costs known and fully covered by cost recovery through user fees and/or local taxes or transfers?	**1**: O&M costs known and revenue adequate to maintain the system well **0.5**: O&M costs known, and revenue covers partial O&M, at less than optimum level **0**: O&M costs not known and/or revenue wholly inadequate
	Monitoring: Are there adequately staffed institutions which monitor performance, health and environmental standards for sewerage services?	**1**: There are adequately staffed institutions which monitor performance, health and environmental standards **0.5**: There are institutions that partially monitor performance, health and environmental standards **0**: There is no institution that monitors performance, health and environmental standards
	Enforcement: Are failures to meet standards for sewerage system performance systematically monitored and sanctions applied where relevant?	**1**: Performance standards exist, are monitored, and sanctions applied **0.5**: Performance standards exist and are monitored, but no sanctions are applied **0**: Performance standards (if they exist) are not monitored
Institutions and service providers	**Staffing**: Does the entity responsible for sewerage have sufficient qualified staff to undertake adaptive planning of sewerage rehabilitation and expansion?	**1**: The entity has sufficient qualified staff for adaptive planning of sewerage rehabilitation and expansion **0.5**: The entity has insufficient staff for adaptive planning of sewerage rehabilitation and expansion **0**: The entity has inadequate staff and is unable to undertake adaptive planning for the sewerage system
	Staff development: Does the entity responsible for sewerage have an active and gender-aware staff development programme and incentives to retain workers?	**1**: The entity has a gender-aware staff development programme and incentives to retain workers **0.5**: The entity has either a staff development programme or incentives to retain workers, but not both **0**: There is no staff development programme or incentives to retain workers
	Health and Safety: Is the health and safety of sewerage workers adequately protected and monitored?	**1**: The health and safety of sewerage workers is adequately protected and monitored **0.5**: The health and safety of sewerage workers is partly protected and monitored **0**: The health and safety of sewerage workers is not protected or monitored
	Capacity-building: Are there ongoing programmes and measures to build the capacity of the sewerage service provider?	**1**: Capacity-building is being implemented according to an agreed plan **0.5**: Limited capacity-building is implemented on an ad-hoc basis **0**: No or very little capacity-building is carried out
Inclusion	**Growth:** Are sanitation services keeping pace with population growth?	**1**: Sanitation services are expanding significantly faster than population, and the number of people with unsafe sanitation is decreasing **0.5**: Sanitation services are keeping pace with population growth **0**: Population is growing significantly faster than sanitation services, and the number of people with unsafe sanitation is increasing
	Planning from evidence: Is sanitation data routinely collected, including from women, poor and vulnerable people, and used for planning services?	**1**: Sanitation data is routinely collected citywide and used for planning services **0.5**: Sanitation data is collected on an ad-hoc basis with incomplete spatial coverage **0**: Sanitation monitoring data is rarely collected
	Outcomes: Do the city's sanitation systems provide safe sanitation services for all users, including women, poor and vulnerable people?	**1**: Safe sanitation services are affordable and available to all users, including women and poor and vulnerable people **0.5**: Safe sanitation services are available to about half of women and poor and vulnerable people **0**: Safe sanitation services are not available to many women and poor and vulnerable people, or this is not known

APPENDIX E: Dataset for Chapter 6

E-1. Bivariate analysis results - Sewered areas

Table E-1. Logistic regression results for factors associated with household connectivity to the sewer network

Explanatory Variable	COR (95% CI)	Explanatory Variable	COR (95% CI)
Income level		**Type of facility access**	
>2,893	1	Private	1
≤2,893	1.29 (0.91 – 1.84) *	Shared	2.26 (1.54 – 3.36) ***
Household living arrangement		**Household size**	
Owned	1	≤5	1
Rented	1.15 (0.80 – 1.66)	≥6	1.53 (0.76 – 3.02) *
Availability of water		Facility ownership	
Yes	1	Yes	1
No	2.73 (1.91 – 3.92) ***	No	0.66 (0.30 – 1.53)
Living on a compound plot		Gender of household head	
No	1	Female	1
Yes	2.44 (1.65 – 3.66) ***	Male	0.87 (0.58 – 1.31)
Length of household stay		**Urban setting**	
Over one year	1	HILD/MIMD	1
Less than one year	0.84 (0.49 – 1.48)	LIHD	10.01 (5.93 – 18.0) ***
Level of education			
Secondary and above	1		
Primary/Basic	1.68 (1.06 – 2.75) **		

*p<0.25; **p<.01; ***p<0.00001.
Factors eligible for backwards stepwise regression in **bold**

E-2. Bivariate analysis output - Sewered areas

1. Sewer connectivity vs Income-level

```
Call:
glm(formula = Sewer.Connection.Status ~ HH.Income.level, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q    Median       3Q      Max
-1.5054  -1.3897   0.8817   0.9791   0.9791

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)       0.4863     0.1277   3.807  0.00014 ***
HH.Income.level   0.2582     0.1784   1.447  0.14796
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 716.26  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 720.26

Number of Fisher Scoring iterations: 4

> coef(fit1)
    (Intercept) HH.Income.level
      0.4862845       0.2581560
> exp(coef(fit1))
    (Intercept) HH.Income.level
       1.626263        1.294541
> exp(confint(fit1))
Waiting for profiling to be done...
                   2.5 %   97.5 %
(Intercept)     1.268866 2.094767
HH.Income.level 0.912652 1.837880
> exp(fit1$coefficients[-1])
HH.Income.level
       1.294541
> (exp(fit1$coefficients[-1])-1)*100
HH.Income.level
       29.45407
```

2. Sewer connectivity vs Household living arrangement

```
Call:
glm(formula = Sewer.Connection.Status ~ Tenure.Status, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.4921  -1.4290   0.8925   0.9451   0.9451

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)     0.5744     0.1118   5.136  2.8e-07 ***
Tenure.Status   0.1406     0.1855   0.758    0.448
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 716.25  on 553  degrees of freedom
Residual deviance: 715.67  on 552  degrees of freedom
  (4 observations deleted due to missingness)
AIC: 719.67

Number of Fisher Scoring iterations: 4

> coef(fit2)
  (Intercept) Tenure.Status
    0.5743636     0.1406026
> exp(coef(fit2))
  (Intercept) Tenure.Status
     1.776000      1.150967
> exp(confint(fit2))
Waiting for profiling to be done...
                  2.5 %   97.5 %
(Intercept)   1.4293384 2.216665
Tenure.Status 0.8016671 1.659957
> exp(fit2$coefficients[-1])
Tenure.Status
     1.150967
> (exp(fit2$coefficients[-1])-1)*100
Tenure.Status
     15.09671
```

3. Sewer connectivity vs Availability of water

```
Call:
glm(formula = Sewer.Connection.Status ~ Reliable.Water.Supply,
    family = binomial(link = "logit"), data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6670  -1.2191   0.7571   0.7571   1.1362

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            0.09764    0.12767   0.765    0.444
Reliable.Water.Supply  1.00529    0.18329   5.485 4.14e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 687.42  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 691.42

Number of Fisher Scoring iterations: 4

> coef(fit3)
          (Intercept) Reliable.Water.Supply
           0.09763847            1.00529348
> exp(coef(fit3))
          (Intercept) Reliable.Water.Supply
             1.102564              2.732709
> exp(confint(fit3))
Waiting for profiling to be done...
                          2.5 %   97.5 %
(Intercept)           0.8586425 1.417225
Reliable.Water.Supply 1.9124031 3.925398
> exp(fit3$coefficients[-1])
Reliable.Water.Supply
             2.732709
> (exp(fit3$coefficients[-1])-1)*100
Reliable.Water.Supply
             173.2709
```

4. Sewer connectivity vs Living on a compound plot

```
Call:
glm(formula = Sewer.Connection.Status ~ Living.on.compound.plot,
    family = binomial(link = "logit"), data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.7269  -1.3265   0.7142   1.0352   1.0352

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)               0.3440     0.1064   3.234  0.00122 **
Living.on.compound.plot   0.8920     0.2033   4.388 1.15e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 697.73  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 701.73

Number of Fisher Scoring iterations: 4

> coef(fit5)
            (Intercept) Living.on.compound.plot
              0.3440123               0.8919998
> exp(coef(fit5))
            (Intercept) Living.on.compound.plot
               1.410596                2.440004
> exp(confint(fit5))
Waiting for profiling to be done...
                           2.5 %   97.5 %
(Intercept)             1.146314 1.740110
Living.on.compound.plot 1.649046 3.664018
> exp(fit5$coefficients[-1])
Living.on.compound.plot
               2.440004
> (exp(fit5$coefficients[-1])-1)*100
Living.on.compound.plot
               144.0004
```

5. Sewer connectivity vs Type of facility of access

```
Call:
glm(formula = Sewer.Connection.Status ~ Access.Type, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6989  -1.3328   0.7341   1.0296   1.0296

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)   0.3581     0.1086   3.296 0.000979 ***
Access.Type   0.8157     0.1991   4.096  4.2e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 709.46  on 548  degrees of freedom
Residual deviance: 691.72  on 547  degrees of freedom
  (9 observations deleted due to missingness)
AIC: 695.72

Number of Fisher Scoring iterations: 4

> coef(fit6)
(Intercept) Access.Type
  0.3580629   0.8156700
> exp(coef(fit6))
(Intercept) Access.Type
   1.430556    2.260690
> exp(confint(fit6))
Waiting for profiling to be done...
               2.5 %   97.5 %
(Intercept) 1.157549 1.772701
Access.Type 1.538788 3.363039
> exp(fit6$coefficients[-1])
Access.Type
    2.26069
> (exp(fit6$coefficients[-1])-1)*100
Access.Type
    126.069
```

6. Sewer connectivity vs Household size

```
Call:
glm(formula = Sewer.Connection.Status ~ Household.Size, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.4630  -1.4630   0.9165   0.9165   1.0842

Coefficients:
               Estimate Std. Error z value Pr(>|z|)
(Intercept)      0.2231     0.3354   0.665    0.506
Household.Size   0.4270     0.3479   1.227    0.220

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 716.88  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 720.88

Number of Fisher Scoring iterations: 4

> coef(fit7)
   (Intercept) Household.Size
     0.2231436      0.4269554
> exp(coef(fit7))
   (Intercept) Household.Size
      1.250000       1.532584
> exp(confint(fit7))
Waiting for profiling to be done...
                   2.5 %   97.5 %
(Intercept)    0.6491227 2.446400
Household.Size 0.7650698 3.024772
> exp(fit7$coefficients[-1])
Household.Size
      1.532584
> (exp(fit7$coefficients[-1])-1)*100
Household.Size
      53.25843
```

7. Sewer connectivity vs Facility ownership

```
Call:
glm(formula = Sewer.Connection.Status ~ Facility.Ownership.Type,
    family = binomial(link = "logit"), data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.4619  -1.4619   0.9174   0.9174   1.0769

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)              0.64768    0.09199   7.041 1.91e-12 ***
Facility.Ownership.Type -0.40652    0.41328  -0.984    0.325
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 709.46  on 548  degrees of freedom
Residual deviance: 708.51  on 547  degrees of freedom
  (9 observations deleted due to missingness)
AIC: 712.51

Number of Fisher Scoring iterations: 4

> coef(fit8)
            (Intercept) Facility.Ownership.Type
              0.6476848              -0.4065227
> exp(coef(fit8))
            (Intercept) Facility.Ownership.Type
              1.9111111               0.6659619
> exp(confint(fit8))
Waiting for profiling to be done...
                            2.5 %   97.5 %
(Intercept)              1.598326 2.292888
Facility.Ownership.Type 0.296946 1.529841
> exp(fit8$coefficients[-1])
Facility.Ownership.Type
              0.6659619
> (exp(fit8$coefficients[-1])-1)*100
Facility.Ownership.Type
              -33.40381
```

8. Sewer connectivity vs Gender

```
Call:
glm(formula = Sewer.Connection.Status ~ Gender, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.4648  -1.4648   0.9150   0.9150   0.9665

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)   0.6542     0.1027   6.368 1.92e-10 ***
Gender       -0.1354     0.2061  -0.657    0.511
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 717.93  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 721.93

Number of Fisher Scoring iterations: 4

> coef(fit9)
(Intercept)      Gender
  0.6542042  -0.1354104
> exp(coef(fit9))
(Intercept)      Gender
  1.9236111   0.8733574
> exp(confint(fit9))
Waiting for profiling to be done...
                2.5 %   97.5 %
(Intercept) 1.5758746 2.358153
Gender      0.5847605 1.313263
> exp(fit9$coefficients[-1])
   Gender
0.8733574
> (exp(fit9$coefficients[-1])-1)*100
   Gender
-12.66426
```

9. Sewer connectivity vs Length of household stay

```
Call:
glm(formula = Sewer.Connection.Status ~ Length.of.HH.Stay, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.4606  -1.4606   0.9185   0.9185   0.9833

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)         0.6450     0.0947   6.810 9.75e-12 ***
Length.of.HH.Stay  -0.1695     0.2819  -0.601    0.548
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 716.25  on 553  degrees of freedom
Residual deviance: 715.89  on 552  degrees of freedom
  (4 observations deleted due to missingness)
AIC: 719.89

Number of Fisher Scoring iterations: 4

> coef(fit10)
      (Intercept) Length.of.HH.Stay
        0.6449451        -0.1695214
> exp(coef(fit10))
      (Intercept) Length.of.HH.Stay
        1.9058824         0.8440687
> exp(confint(fit10))
Waiting for profiling to be done...
                      2.5 %   97.5 %
(Intercept)       1.5856362 2.299044
Length.of.HH.Stay 0.4890016 1.484144
> exp(fit10$coefficients[-1])
Length.of.HH.Stay
        0.8440687
> (exp(fit10$coefficients[-1])-1)*100
Length.of.HH.Stay
        -15.59313
```

10. Sewer connectivity vs Level of education

```
Call:
glm(formula = Sewer.Connection.Status ~ HH.Level.of.Education,
    family = binomial(link = "logit"), data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6651  -1.4309   0.9435   0.9435   0.9435

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)             0.5785     0.0997   5.803 6.53e-09 ***
HH.Level.of.Education   0.5201     0.2436   2.135   0.0327 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 696.99  on 544  degrees of freedom
Residual deviance: 692.18  on 543  degrees of freedom
  (13 observations deleted due to missingness)
AIC: 696.18

Number of Fisher Scoring iterations: 4

> coef(fit11)
          (Intercept) HH.Level.of.Education
            0.5785438             0.5200685
> exp(coef(fit11))
          (Intercept) HH.Level.of.Education
             1.783439              1.682143
> exp(confint(fit11))
Waiting for profiling to be done...
                         2.5 %   97.5 %
(Intercept)           1.469267 2.172581
HH.Level.of.Education 1.055529 2.751174
> exp(fit11$coefficients[-1])
HH.Level.of.Education
             1.682143
> (exp(fit11$coefficients[-1])-1)*100
HH.Level.of.Education
             68.21429
```

11. Sewer connectivity vs Urban setting

```
Call:
glm(formula = Sewer.Connection.Status ~ Urban.Setting, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.2174  -1.2052   0.4229   1.1498   1.1498

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)    0.06524    0.10431   0.625    0.532
Urban.Setting  2.30383    0.28148   8.185 2.73e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 718.36  on 554  degrees of freedom
Residual deviance: 619.03  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 623.03

Number of Fisher Scoring iterations: 5

> coef(fit12)
  (Intercept) Urban.Setting
   0.06524052    2.30383431
> exp(coef(fit12))
  (Intercept) Urban.Setting
     1.067416     10.012500
> exp(confint(fit12))
Waiting for profiling to be done...
                 2.5 %    97.5 %
(Intercept)   0.870089  1.310091
Urban.Setting 5.931774 18.000783
> exp(fit12$coefficients[-1])
Urban.Setting
      10.0125
> (exp(fit12$coefficients[-1])-1)*100
Urban.Setting
       901.25
```

12. Urban setting vs Household income levels

```
Call:
glm(formula = Urban.Setting ~ HH.Income.level, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1066  -1.1066  -0.6752   1.2499   1.7835

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)      -1.3624     0.1539  -8.850  < 2e-16 ***
HH.Income.level   1.1937     0.1930   6.184 6.26e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 713.61  on 556  degrees of freedom
Residual deviance: 672.58  on 555  degrees of freedom
  (1 observation deleted due to missingness)
AIC: 676.58

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit14)
    (Intercept) HH.Income.level
      -1.362427        1.193677
> exp(coef(fit14))
    (Intercept) HH.Income.level
      0.2560386       3.2991914
> exp(confint(fit14))
Waiting for profiling to be done...
                    2.5 %   97.5 %
(Intercept)     0.1875315 0.343325
HH.Income.level 2.2712116 4.845234
> #Odds ratio as a percentage
> exp(fit14$coefficients[-1])
HH.Income.level
       3.299191
> (exp(fit14$coefficients[-1])-1)*100
HH.Income.level
       229.9191
```

13. Urban setting vs Availability of water

```
Call:
glm(formula = Urban.Setting ~ Reliable.Water.Supply, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.153   -1.153   -0.571    1.202    1.946

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            -1.7314     0.1783  -9.709  < 2e-16 ***
Reliable.Water.Supply   1.6731     0.2116   7.908 2.61e-15 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 709.27  on 554  degrees of freedom
Residual deviance: 636.42  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 640.42

Number of Fisher Scoring iterations: 3

> #Odds ratios
> coef(fit15)
          (Intercept) Reliable.Water.Supply
            -1.731416              1.673147
> exp(coef(fit15))
          (Intercept) Reliable.Water.Supply
            0.1770335             5.3289136
> exp(confint(fit15))
Waiting for profiling to be done...
                           2.5 %     97.5 %
(Intercept)            0.1229085 0.2478098
Reliable.Water.Supply 3.5526436 8.1565511
> #Odds ratio as a percentage
> exp(fit15$coefficients[-1])
Reliable.Water.Supply
             5.328914
> (exp(fit15$coefficients[-1])-1)*100
Reliable.Water.Supply
             432.8914
```

14. Type of water source vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ Water.Source.Type, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.3479   0.3623   0.3623   0.3623   1.1774

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)         2.6908     0.1747  15.405  < 2e-16 ***
Water.Source.Type  -2.6908     1.0151  -2.651  0.00803 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 271.87  on 554  degrees of freedom
Residual deviance: 266.22  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 270.22

Number of Fisher Scoring iterations: 5

> #Odds ratios
> coef(fit16)
      (Intercept) Water.Source.Type
         2.690759         -2.690759
> exp(coef(fit16))
      (Intercept) Water.Source.Type
      14.74285714        0.06782946
> exp(confint(fit16))
Waiting for profiling to be done...
                        2.5 %     97.5 %
(Intercept)       10.638317933 21.1418981
Water.Source.Type  0.007943287  0.5788269
> #Odds ratio as a percentage
> exp(fit16$coefficients[-1])
Water.Source.Type
       0.06782946
> (exp(fit16$coefficients[-1])-1)*100
Water.Source.Type
        -93.21705
```

15. Access type vs Urban setting

```
Call:
glm(formula = Access.Type ~ Urban.Setting, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.3478  -0.7488  -0.7488   1.0161   1.6784

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)    -1.1281     0.1220  -9.251  < 2e-16 ***
Urban.Setting   1.5202     0.1929   7.880 3.27e-15 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 721.03  on 549  degrees of freedom
Residual deviance: 655.77  on 548  degrees of freedom
  (8 observations deleted due to missingness)
AIC: 659.77

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit19)
  (Intercept) Urban.Setting
    -1.128135      1.520177
> exp(coef(fit19))
  (Intercept) Urban.Setting
    0.3236364     4.5730337
> exp(confint(fit19))
Waiting for profiling to be done...
                  2.5 %    97.5 %
(Intercept)   0.2535116 0.4091465
Urban.Setting 3.1435728 6.7007625
> #Odds ratio as a percentage
> exp(fit19$coefficients[-1])
Urban.Setting
     4.573034
> (exp(fit19$coefficients[-1])-1)*100
Urban.Setting
     357.3034
```

16. Household living arrangement (landlord or tenant) vs Access type (private or shared)

```
Call:
glm(formula = Tenure.Status ~ Access.Type, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1605  -0.8591  -0.8591   1.1945   1.5335

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -0.8068     0.1157  -6.972 3.13e-12 ***
Access.Type   0.7668     0.1828   4.196 2.72e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 727.46  on 549  degrees of freedom
Residual deviance: 709.75  on 548  degrees of freedom
  (8 observations deleted due to missingness)
AIC: 713.75

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit20)
(Intercept) Access.Type
 -0.8068065   0.7668012
> exp(coef(fit20))
(Intercept) Access.Type
   0.446281    2.152869
> exp(confint(fit20))
Waiting for profiling to be done...
                2.5 %    97.5 %
(Intercept) 0.3544584 0.5582033
Access.Type 1.5060357 3.0846750
> #Odds ratio as a percentage
> exp(fit20$coefficients[-1])
Access.Type
   2.152869
> (exp(fit20$coefficients[-1])-1)*100
Access.Type
   115.2869
```

17. Level of education vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ HH.Level.of.Education,
    family = binomial(link = "logit"), data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.4639   0.3138   0.3138   0.3138   0.5469

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)             2.9862     0.2236  13.352  < 2e-16 ***
HH.Level.of.Education  -1.1616     0.3570  -3.254  0.00114 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 265.21  on 544  degrees of freedom
Residual deviance: 255.50  on 543  degrees of freedom
  (13 observations deleted due to missingness)
AIC: 259.5

Number of Fisher Scoring iterations: 5

> #Odds ratios
> coef(fit21)
          (Intercept) HH.Level.of.Education
             2.986163             -1.161614
> exp(coef(fit21))
          (Intercept) HH.Level.of.Education
           19.8095236             0.3129808
> exp(confint(fit21))
Waiting for profiling to be done...
                           2.5 %     97.5 %
(Intercept)           13.1269698 31.6858921
HH.Level.of.Education  0.1562876  0.6401778
> #Odds ratio as a percentage
> exp(fit21$coefficients[-1])
HH.Level.of.Education
            0.3129808
> (exp(fit21$coefficients[-1])-1)*100
HH.Level.of.Education
            -68.70192
```

18. Income level vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ HH.Income.level, family = binomial(link = "logit"),
    data = Sewerage_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.1201   0.1243   0.1243   0.5026   0.5026

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)       4.8598     0.7098   6.847 7.56e-12 ***
HH.Income.level  -2.8545     0.7323  -3.898 9.70e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 271.87  on 554  degrees of freedom
Residual deviance: 238.34  on 553  degrees of freedom
  (3 observations deleted due to missingness)
AIC: 242.34

Number of Fisher Scoring iterations: 7

> #Odds ratios
> coef(fit22)
    (Intercept) HH.Income.level
       4.859812       -2.854479
> exp(coef(fit22))
    (Intercept) HH.Income.level
   128.99999906      0.05758583
> exp(confint(fit22))
Waiting for profiling to be done...
                       2.5 %      97.5 %
(Intercept)      41.464915501 778.445793
HH.Income.level   0.009290881   0.191401
> #Odds ratio as a percentage
> exp(fit22$coefficients[-1])
HH.Income.level
     0.05758583
> (exp(fit22$coefficients[-1])-1)*100
HH.Income.level
      -94.24142
```

E-3. Backward stepwise selection of predictors - Sewered areas

```
Start:  AIC=605.17
Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Living.on.compound.plot + Access.Type + Household.Size +
    HH.Level.of.Education + Urban.Setting

                          Df Deviance    AIC
- HH.Level.of.Education    1   589.24 603.24
- Living.on.compound.plot  1   589.26 603.26
- Access.Type              1   589.45 603.45
- Household.Size           1   589.95 603.95
<none>                         589.17 605.17
- HH.Income.level          1   592.35 606.35
- Reliable.Water.Supply    1   596.81 610.81
- Urban.Setting            1   653.02 667.02

Step:  AIC=603.24
Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Living.on.compound.plot + Access.Type + Household.Size +
    Urban.Setting

                          Df Deviance    AIC
- Living.on.compound.plot  1   589.31 601.31
- Access.Type              1   589.51 601.51
- Household.Size           1   589.99 601.99
<none>                         589.24 603.24
- HH.Income.level          1   592.39 604.39
- Reliable.Water.Supply    1   597.24 609.24
- Urban.Setting            1   653.14 665.14

Step:  AIC=601.31
Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Access.Type + Household.Size + Urban.Setting

                        Df Deviance    AIC
- Access.Type            1   589.88 599.88
- Household.Size         1   590.08 600.08
<none>                       589.31 601.31
- HH.Income.level        1   592.44 602.44
- Reliable.Water.Supply  1   597.25 607.25
- Urban.Setting          1   653.77 663.77

Step:  AIC=599.88
Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Household.Size + Urban.Setting

                        Df Deviance    AIC
- Household.Size         1   590.62 598.62
<none>                       589.88 599.88
- HH.Income.level        1   592.57 600.57
- Reliable.Water.Supply  1   599.42 607.42
- Urban.Setting          1   659.13 667.13
```

```
Step:  AIC=598.62
Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Urban.Setting

                        Df Deviance    AIC
<none>                       590.62 598.62
- HH.Income.level        1   593.35 599.35
- Reliable.Water.Supply  1   600.64 606.64
- Urban.Setting          1   659.76 665.76

Call:  glm(formula = Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Urban.Setting, family = binomial(link = "logit"), data = Sewerage_AIC_Dataset)

Coefficients:
          (Intercept)        HH.Income.level  Reliable.Water.Supply          Urban.Setting
             -0.01257               -0.35778                0.68591                2.10935

Degrees of Freedom: 540 Total (i.e. Null);  537 Residual
Null Deviance:      692.3
Residual Deviance: 590.6        AIC: 598.6
```

E-4. Final regression model - Sewered areas

```
Call:
glm(formula = Sewer.Connection.Status ~ HH.Income.level + Reliable.Water.Supply +
    Urban.Setting, family = binomial(link = "logit"), data = Sewerage_AIC_Dataset)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.3844  -1.1721   0.4118   1.0467   1.3382

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)           -0.01257    0.14967  -0.084  0.93308
HH.Income.level       -0.35778    0.21831  -1.639  0.10125
Reliable.Water.Supply  0.68591    0.21820   3.144  0.00167 **
Urban.Setting          2.10935    0.29419   7.170 7.49e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 692.35  on 540  degrees of freedom
Residual deviance: 590.62  on 537  degrees of freedom
AIC: 598.62

Number of Fisher Scoring iterations: 5

> coef(full.fit1)
          (Intercept)       HH.Income.level Reliable.Water.Supply         Urban.Setting
          -0.01256861           -0.35777624            0.68591492            2.10935327
> exp(coef(full.fit1))
          (Intercept)       HH.Income.level Reliable.Water.Supply         Urban.Setting
            0.9875100             0.6992295             1.9855877             8.2429086
> exp(confint(full.fit1))
Waiting for profiling to be done...
                          2.5 %    97.5 %
(Intercept)           0.7362731  1.325067
HH.Income.level       0.4537377  1.069017
Reliable.Water.Supply 1.2974338  3.055246
Urban.Setting         4.7528777 15.156184
> exp(full.fit1$coefficients[-1])
      HH.Income.level Reliable.Water.Supply         Urban.Setting
            0.6992295             1.9855877             8.2429086
> (exp(full.fit1$coefficients[-1])-1)*100
      HH.Income.level Reliable.Water.Supply         Urban.Setting
            -30.07705              98.55877             724.29086
```

E-5. Bivariate analysis results – Non-sewered areas

Table E-2. Logistic regression results for factors associated with using a safely managed emptying service

Variable	COR (95% CI)	Variable	COR (95% CI)
Income level		**Type of facility access**	
≤2,893	1	Shared	1
>2,893	2.41 (1.90 – 3.06) ***	Private	1.66 (1.34 – 2.07) ***
Household living arrangement		**Household size**	
Rented	1	≥6	1
Owned	3.61 (2.86 – 4.58) ***	≤5	0.63 (0.37 – 1.04) *
Availability of water		**Type of sanitation facility**	
No	1	Unimproved	1
Yes	3.79 (2.87 – 5.04) ***	Improved	15.83 (7.87 – 37.76) ***
Not living on a compound plot		Gender of household head	
No	1	Female	1
Yes	1.28 (1.03 – 1.59) *	Male	0.97 (0.75 – 1.26)
Length of household stay		**Urban setting**	
Less than one year	1	LIHD	1
Over one year	2.25 (1.63 – 3.12) ***	MIMD/HILD	2.02 (1.53 – 2.68) ***
Level of education		Accessible plot/containment	
Primary/Basic	1	No	1
Secondary and above	1.41 (1.11 – 1.80) ***	Yes	1

*p <0.25; **p<0.01; ***p<0.0001;

Factors eligible for backwards stepwise regression in **bold**

E-6. Bivariate analysis output - Non-sewered areas

1. Use of safely managed emptying service vs Income-level

```
Call:
glm(formula = willingness.to.empty.containment ~ HH.Income.level,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.379   -1.006   -1.006    1.359    1.359

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)     -0.41842    0.06806  -6.148 7.84e-10 ***
HH.Income.level  0.87990    0.12122   7.258 3.92e-13 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1825.0  on 1320  degrees of freedom
Residual deviance: 1770.9  on 1319  degrees of freedom
  (83 observations deleted due to missingness)
AIC: 1774.9

Number of Fisher Scoring iterations: 4

> coef(fit1)
    (Intercept) HH.Income.level
     -0.4184163       0.8798960
> exp(coef(fit1))
    (Intercept) HH.Income.level
      0.6580882       2.4106490
> exp(confint(fit1))
Waiting for profiling to be done...
                    2.5 %    97.5 %
(Intercept)     0.5755292 0.7515688
HH.Income.level 1.9029290 3.0611487
> exp(fit1$coefficients[-1])
HH.Income.level
       2.410649
> (exp(fit1$coefficients[-1])-1)*100
HH.Income.level
       141.0649
```

2. Use of safely managed emptying service vs Household living arrangement

```
Call:
glm(formula = Willingness.to.empty.containment ~ Tenure.Status,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.3327  -0.8167  -0.8167   1.0297   1.5876

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)   -0.92676    0.09583  -9.671   <2e-16 ***
Tenure.Status  1.28467    0.12018  10.689   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1824.7  on 1320  degrees of freedom
Residual deviance: 1702.7  on 1319  degrees of freedom
  (83 observations deleted due to missingness)
AIC: 1706.7

Number of Fisher Scoring iterations: 4

> coef(fit2)
  (Intercept) Tenure.Status
    -0.926762      1.284675
> exp(coef(fit2))
  (Intercept) Tenure.Status
    0.3958333     3.6134919
> exp(confint(fit2))
Waiting for profiling to be done...
                  2.5 %    97.5 %
(Intercept)   0.3271682 0.4764725
Tenure.Status 2.8601315 4.5821186
> exp(fit2$coefficients[-1])
Tenure.Status
     3.613492
> (exp(fit2$coefficients[-1])-1)*100
Tenure.Status
     261.3492
```

3. Use of safely managed emptying service vs Availability of water

```
Call:
glm(formula = Willingness.to.empty.containment ~ Reliable.Water.Supply,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.578   -1.002   -1.002    1.363    1.363

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)           -0.42744    0.06387  -6.692  2.2e-11 ***
Reliable.Water.Supply  1.33190    0.14355   9.278  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1825.0  on 1320  degrees of freedom
Residual deviance: 1730.8  on 1319  degrees of freedom
  (83 observations deleted due to missingness)
AIC: 1734.8

Number of Fisher Scoring iterations: 4

> coef(fit3)
          (Intercept) Reliable.Water.Supply
            -0.427444              1.331900
> exp(coef(fit3))
          (Intercept) Reliable.Water.Supply
            0.6521739             3.7882353
> exp(confint(fit3))
Waiting for profiling to be done...
                          2.5 %    97.5 %
(Intercept)           0.5750947 0.7387694
Reliable.Water.Supply 2.8690868 5.0391842
> exp(fit3$coefficients[-1])
Reliable.Water.Supply
             3.788235
> (exp(fit3$coefficients[-1])-1)*100
Reliable.Water.Supply
             278.8235
```

4. Use of safely managed emptying service vs Non-compound plot

```
Call:
glm(formula = Willingness.to.empty.containment ~ Not.living.on.compound.plot,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.170   -1.170   -1.068    1.185    1.291

Coefficients:
                            Estimate Std. Error z value Pr(>|z|)
(Intercept)                 -0.26290    0.07864  -3.343 0.000829 ***
Not.living.on.compound.plot  0.24483    0.11049   2.216 0.026708 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1826.3  on 1321  degrees of freedom
Residual deviance: 1821.4  on 1320  degrees of freedom
  (82 observations deleted due to missingness)
AIC: 1825.4

Number of Fisher Scoring iterations: 3

> coef(fit5)
                (Intercept) Not.living.on.compound.plot
                 -0.2629020                   0.2448293
> exp(coef(fit5))
                (Intercept) Not.living.on.compound.plot
                  0.7688172                   1.2774032
> exp(confint(fit5))
Waiting for profiling to be done...
                                2.5 %    97.5 %
(Intercept)                 0.6586028 0.8965451
Not.living.on.compound.plot 1.0288620 1.5867629
> exp(fit5$coefficients[-1])
Not.living.on.compound.plot
                   1.277403
> (exp(fit5$coefficients[-1])-1)*100
Not.living.on.compound.plot
                   27.74032
```

5. Use of safely managed emptying service vs Type of facility access

```
Call:
glm(formula = willingness.to.empty.containment ~ Access.Type,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-1.240  -1.027  -1.027   1.116   1.335

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -0.36391    0.07479  -4.866 1.14e-06 ***
Access.Type  0.50949    0.11203   4.548 5.42e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1819.5  on 1316  degrees of freedom
Residual deviance: 1798.6  on 1315  degrees of freedom
  (87 observations deleted due to missingness)
AIC: 1802.6

Number of Fisher Scoring iterations: 4

> coef(fit6)
(Intercept) Access.Type
 -0.3639094   0.5094948
> exp(coef(fit6))
(Intercept) Access.Type
  0.6949541   1.6644500
> exp(confint(fit6))
Waiting for profiling to be done...
                2.5 %    97.5 %
(Intercept) 0.5997679 0.8042073
Access.Type 1.3368641 2.0742463
> exp(fit6$coefficients[-1])
Access.Type
    1.66445
> (exp(fit6$coefficients[-1])-1)*100
Access.Type
     66.445
```

6. Use of safely managed emptying service vs Household size

```
Call:
glm(formula = Willingness.to.empty.containment ~ Household.Size,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.128   -1.128   -1.128    1.227    1.433

Coefficients:
               Estimate Std. Error z value Pr(>|z|)
(Intercept)    -0.11647    0.05655  -2.059   0.0394 *
Household.Size -0.46668    0.26100  -1.788   0.0738 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1826.3  on 1321  degrees of freedom
Residual deviance: 1823.0  on 1320  degrees of freedom
  (82 observations deleted due to missingness)
AIC: 1827

Number of Fisher Scoring iterations: 4

> coef(fit7)
   (Intercept) Household.Size
    -0.1164661     -0.4666802
> exp(coef(fit7))
   (Intercept) Household.Size
     0.8900602      0.6270806
> exp(confint(fit7))
Waiting for profiling to be done...
                   2.5 %    97.5 %
(Intercept)    0.7965600 0.9942983
Household.Size 0.3708082 1.0367209
> exp(fit7$coefficients[-1])
Household.Size
     0.6270806
> (exp(fit7$coefficients[-1])-1)*100
Household.Size
     -37.29194
```

7. Use of safely managed emptying service vs Gender

```
Call:
glm(formula = Willingness.to.empty.containment ~ Gender, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-1.121  -1.121  -1.112   1.235   1.244

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -0.13459    0.06301  -2.136   0.0327 *
Gender      -0.02056    0.13020  -0.158   0.8745
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1826.3  on 1321  degrees of freedom
Residual deviance: 1826.2  on 1320  degrees of freedom
  (82 observations deleted due to missingness)
AIC: 1830.2

Number of Fisher Scoring iterations: 3

> coef(fit9)
(Intercept)      Gender
-0.13459015 -0.02055903
> exp(coef(fit9))
(Intercept)      Gender
  0.8740741   0.9796509
> exp(confint(fit9))
Waiting for profiling to be done...
                2.5 %    97.5 %
(Intercept) 0.7723621 0.9888419
Gender      0.7585405 1.2640640
> exp(fit9$coefficients[-1])
   Gender
0.9796509
> (exp(fit9$coefficients[-1])-1)*100
   Gender
-2.034913
```

8. Use of safely managed emptying service vs Length of household stay

```
Call:
glm(formula = Willingness.to.empty.containment ~ Length.of.HH.Stay,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1676  -1.1676  -0.8497   1.1873   1.5453

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)        -0.8329     0.1546  -5.386 7.20e-08 ***
Length.of.HH.Stay   0.8098     0.1658   4.885 1.03e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1825.0  on 1320  degrees of freedom
Residual deviance: 1799.6  on 1319  degrees of freedom
  (83 observations deleted due to missingness)
AIC: 1803.6

Number of Fisher Scoring iterations: 4

> coef(fit10)
      (Intercept) Length.of.HH.Stay
       -0.8329091         0.8097558
> exp(coef(fit10))
      (Intercept) Length.of.HH.Stay
        0.4347826         2.2473592
> exp(confint(fit10))
Waiting for profiling to be done...
                      2.5 %    97.5 %
(Intercept)       0.3189693 0.5855144
Length.of.HH.Stay 1.6317017 3.1281101
> exp(fit10$coefficients[-1])
Length.of.HH.Stay
         2.247359
> (exp(fit10$coefficients[-1])-1)*100
Length.of.HH.Stay
         124.7359
```

9. Use of safely managed emptying service vs Level of education

```
Call:
glm(formula = Willingness.to.empty.containment ~ HH.Level.of.Education,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.162   -1.162   -1.019    1.193    1.344

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)            -0.3836     0.1045  -3.671 0.000242 ***
HH.Level.of.Education   0.3466     0.1236   2.804 0.005040 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1794.7  on 1298  degrees of freedom
Residual deviance: 1786.8  on 1297  degrees of freedom
  (105 observations deleted due to missingness)
AIC: 1790.8

Number of Fisher Scoring iterations: 4

> coef(fit11)
          (Intercept) HH.Level.of.Education
           -0.3835824             0.3465814
> exp(coef(fit11))
          (Intercept) HH.Level.of.Education
            0.6814159             1.4142247
> exp(confint(fit11))
Waiting for profiling to be done...
                          2.5 %    97.5 %
(Intercept)           0.5543882 0.8353282
HH.Level.of.Education 1.1109124 1.8037209
> exp(fit11$coefficients[-1])
HH.Level.of.Education
             1.414225
> (exp(fit11$coefficients[-1])-1)*100
HH.Level.of.Education
             41.42247
```

10. Use of safely managed emptying service vs Urban setting

```
Call:
glm(formula = Willingness.to.empty.containment ~ Urban.Setting,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.364   -1.063   -1.063    1.296    1.296

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)   -0.27565    0.06184  -4.458 8.29e-06 ***
Urban.Setting  0.70396    0.14204   4.956 7.20e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1826.3  on 1321  degrees of freedom
Residual deviance: 1801.1  on 1320  degrees of freedom
  (82 observations deleted due to missingness)
AIC: 1805.1

Number of Fisher Scoring iterations: 4

> coef(fit12)
  (Intercept) Urban.Setting
   -0.2756535     0.7039581
> exp(coef(fit12))
  (Intercept) Urban.Setting
    0.7590759     2.0217391
> exp(confint(fit12))
Waiting for profiling to be done...
                  2.5 %    97.5 %
(Intercept)   0.6721798 0.8566297
Urban.Setting 1.5329054 2.6763987
> exp(fit12$coefficients[-1])
Urban.Setting
     2.021739
> (exp(fit12$coefficients[-1])-1)*100
Urban.Setting
     102.1739
```

11. Use of safely managed emptying service vs Accessibility of plot and or containment

```
Call:
glm(formula = Willingness.to.empty.containment ~ Accessible,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
      Min          1Q      Median          3Q         Max
2.409e-06  2.409e-06  2.409e-06  2.409e-06  2.409e-06

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) 2.657e+01  2.518e+05       0        1
Accessible  2.000e-07  2.552e+05       0        1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 0.0000e+00  on 74  degrees of freedom
Residual deviance: 4.3512e-10  on 73  degrees of freedom
  (1329 observations deleted due to missingness)
AIC: 4

Number of Fisher Scoring iterations: 25

> coef(fit13)
 (Intercept)   Accessible
2.656607e+01 2.000362e-07
> exp(coef(fit13))
 (Intercept)   Accessible
344744301652            1
```

12. Use of safely managed emptying service vs Type of sanitation facility

```
Call:
glm(formula = Willingness.to.empty.containment ~ Sanitation.Facility.Type,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.1845  -1.1845  -0.3528   1.1704   2.3697

Coefficients:
                         Estimate Std. Error z value Pr(>|z|)
(Intercept)               -2.7454     0.3899  -7.041 1.91e-12 ***
Sanitation.Facility.Type   2.7621     0.3942   7.008 2.42e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1820.7  on 1317  degrees of freedom
Residual deviance: 1719.1  on 1316  degrees of freedom
  (86 observations deleted due to missingness)
AIC: 1723.1

Number of Fisher Scoring iterations: 5

> coef(fit14)
             (Intercept) Sanitation.Facility.Type
               -2.745438                 2.762077
> exp(coef(fit14))
             (Intercept) Sanitation.Facility.Type
              0.06422018              15.83269415
> exp(confint(fit14))
Waiting for profiling to be done...
                             2.5 %     97.5 %
(Intercept)              0.0271028  0.1279232
Sanitation.Facility.Type 7.8680970 37.7625136
> exp(fit14$coefficients[-1])
Sanitation.Facility.Type
                15.83269
> (exp(fit14$coefficients[-1])-1)*100
Sanitation.Facility.Type
                1483.269
```

13. Type of water source vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ Water.Source.Type, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.1506   0.4566   0.4566   0.4566   0.6765

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)         1.3581     0.3737   3.634 0.000279 ***
Water.Source.Type   0.8502     0.3850   2.208 0.027228 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 896.69  on 1356  degrees of freedom
Residual deviance: 892.53  on 1355  degrees of freedom
  (47 observations deleted due to missingness)
AIC: 896.53

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit15)
      (Intercept) Water.Source.Type
        1.3581235         0.8501509
> exp(coef(fit15))
      (Intercept) Water.Source.Type
         3.888889          2.340000
> exp(confint(fit15))
Waiting for profiling to be done...
                     2.5 %   97.5 %
(Intercept)       1.954214 8.614403
Water.Source.Type 1.036976 4.774432
> #Odds ratio as a percentage
> exp(fit15$coefficients[-1])
Water.Source.Type
             2.34
> (exp(fit15$coefficients[-1])-1)*100
Water.Source.Type
              134
```

14. Access type vs Urban setting

```
Call:
glm(formula = Access.Type ~ Urban.Setting, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.5744  -0.9625  -0.9625   1.4088   1.4088

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)   -0.52916    0.06303  -8.395   <2e-16 ***
Urban.Setting  1.42660    0.15080   9.460   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1833.2  on 1337  degrees of freedom
Residual deviance: 1734.6  on 1336  degrees of freedom
  (66 observations deleted due to missingness)
AIC: 1738.6

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit18)
  (Intercept) Urban.Setting
   -0.5291566     1.4266042
> exp(coef(fit18))
  (Intercept) Urban.Setting
    0.5891016     4.1645333
> exp(confint(fit18))
Waiting for profiling to be done...
                 2.5 %    97.5 %
(Intercept)   0.520278 0.6661509
Urban.Setting 3.111180 5.6227314
> #Odds ratio as a percentage
> exp(fit18$coefficients[-1])
Urban.Setting
     4.164533
> (exp(fit18$coefficients[-1])-1)*100
Urban.Setting
     316.4533
```

15. Household living arrangement vs Access type

```
Call:
glm(formula = Tenure.Status ~ Access.Type, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.5259  -1.2114   0.8651   1.1438   1.1438

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  0.07962    0.07289   1.092    0.275
Access.Type  0.71034    0.11533   6.159 7.32e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1806.8  on 1336  degrees of freedom
Residual deviance: 1768.0  on 1335  degrees of freedom
  (67 observations deleted due to missingness)
AIC: 1772

Number of Fisher Scoring iterations: 4

> #Odds ratios
> coef(fit19)
(Intercept) Access.Type
 0.07961763  0.71033711
> exp(coef(fit19))
(Intercept) Access.Type
   1.082873    2.034677
> exp(confint(fit19))
Waiting for profiling to be done...
               2.5 %   97.5 %
(Intercept) 0.938778 1.249424
Access.Type 1.624681 2.553762
> #Odds ratio as a percentage
> exp(fit19$coefficients[-1])
Access.Type
   2.034677
> (exp(fit19$coefficients[-1])-1)*100
Access.Type
   103.4677
```

16. Level of Education vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ HH.Level.of.Education,
    family = binomial(link = "logit"), data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.3007   0.3835   0.3835   0.3835   0.6137

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)             1.5740     0.1323  11.900  < 2e-16 ***
HH.Level.of.Education   0.9990     0.1839   5.434 5.52e-08 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 874.12  on 1332  degrees of freedom
Residual deviance: 845.18  on 1331  degrees of freedom
  (71 observations deleted due to missingness)
AIC: 849.18

Number of Fisher Scoring iterations: 5

> #Odds ratios
> coef(fit20)
          (Intercept) HH.Level.of.Education
            1.5740360             0.9990388
> exp(coef(fit20))
          (Intercept) HH.Level.of.Education
             4.826087              2.715670
> exp(confint(fit20))
Waiting for profiling to be done...
                         2.5 %   97.5 %
(Intercept)           3.749975 6.303314
HH.Level.of.Education 1.893710 3.898422
> #Odds ratio as a percentage
> exp(fit20$coefficients[-1])
HH.Level.of.Education
              2.71567
> (exp(fit20$coefficients[-1])-1)*100
HH.Level.of.Education
              171.567
```

17. Income level vs Type of sanitation facility

```
Call:
glm(formula = Sanitation.Facility.Type ~ HH.Income.level, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.8632   0.1829   0.5517   0.5517   0.5517

Coefficients:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)      1.80555    0.09392  19.224  < 2e-16 ***
HH.Income.level  2.27682    0.39246   5.801 6.58e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 896.69  on 1356  degrees of freedom
Residual deviance: 832.54  on 1355  degrees of freedom
  (47 observations deleted due to missingness)
AIC: 836.54

Number of Fisher Scoring iterations: 6

> #Odds ratios
> coef(fit21)
    (Intercept) HH.Income.level
       1.805553        2.276815
> exp(coef(fit21))
    (Intercept) HH.Income.level
       6.083333        9.745596
> exp(confint(fit21))
Waiting for profiling to be done...
                   2.5 %   97.5 %
(Intercept)     5.080355  7.34374
HH.Income.level 4.862514 23.18736
> #Odds ratio as a percentage
> exp(fit21$coefficients[-1])
HH.Income.level
       9.745596
> (exp(fit21$coefficients[-1])-1)*100
HH.Income.level
       874.5596
```

18. Not living in a compound vs Access type

```
Call:
glm(formula = Not.living.on.compound.plot ~ Access.Type, family = binomial(link = "logit"),
    data = FSM_Dataset1)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-1.300   -1.095   1.060    1.262    1.262

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -0.19692    0.07319  -2.691  0.00713 **
Access.Type  0.47961    0.11110   4.317 1.58e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1854.8  on 1337  degrees of freedom
Residual deviance: 1836.0  on 1336  degrees of freedom
  (66 observations deleted due to missingness)
AIC: 1840

Number of Fisher Scoring iterations: 3

> #Odds ratios
> coef(fit22)
(Intercept) Access.Type
 -0.1969204   0.4796099
> exp(coef(fit22))
(Intercept) Access.Type
   0.821256    1.615444
> exp(confint(fit22))
Waiting for profiling to be done...
                2.5 %    97.5 %
(Intercept) 0.7112242 0.9476711
Access.Type 1.2999149 2.0095810
> #Odds ratio as a percentage
> exp(fit22$coefficients[-1])
Access.Type
   1.615444
> (exp(fit22$coefficients[-1])-1)*100
Access.Type
   61.54441
```

E-7. Backward stepwise selection of predictors - Non-sewered areas

```
Start:  AIC=1482.96
Willingness.to.empty.containment ~ HH.Income.level + Tenure.Status +
    Reliable.Water.Supply + Not.living.on.compound.plot + Access.Type +
    Household.Size + Length.of.HH.Stay + HH.Level.of.Education +
    Urban.Setting + Sanitation.Facility.Type

                              Df Deviance    AIC
- Access.Type                  1   1461.0 1481.0
- HH.Level.of.Education        1   1461.2 1481.2
- Household.Size               1   1462.9 1482.9
<none>                             1461.0 1483.0
- Length.of.HH.Stay            1   1463.6 1483.6
- Not.living.on.compound.plot  1   1465.0 1485.0
- Urban.Setting                1   1466.0 1486.0
- HH.Income.level              1   1466.4 1486.4
- Reliable.Water.Supply        1   1490.6 1510.6
- Sanitation.Facility.Type     1   1540.7 1560.7
- Tenure.Status                1   1558.3 1578.3

Step:  AIC=1480.97
Willingness.to.empty.containment ~ HH.Income.level + Tenure.Status +
    Reliable.Water.Supply + Not.living.on.compound.plot + Household.Size +
    Length.of.HH.Stay + HH.Level.of.Education + Urban.Setting +
    Sanitation.Facility.Type

                              Df Deviance    AIC
- HH.Level.of.Education        1   1461.2 1479.2
- Household.Size               1   1462.9 1480.9
<none>                             1461.0 1481.0
- Length.of.HH.Stay            1   1463.6 1481.6
- Not.living.on.compound.plot  1   1465.1 1483.1
- Urban.Setting                1   1466.3 1484.3
- HH.Income.level              1   1466.4 1484.4
- Reliable.Water.Supply        1   1491.8 1509.8
- Sanitation.Facility.Type     1   1541.1 1559.1
- Tenure.Status                1   1560.8 1578.8

Step:  AIC=1479.16
Willingness.to.empty.containment ~ HH.Income.level + Tenure.Status +
    Reliable.Water.Supply + Not.living.on.compound.plot + Household.Size +
    Length.of.HH.Stay + Urban.Setting + Sanitation.Facility.Type

                              Df Deviance    AIC
<none>                             1461.2 1479.2
- Household.Size               1   1463.2 1479.2
- Length.of.HH.Stay            1   1463.7 1479.7
- Not.living.on.compound.plot  1   1465.3 1481.3
- Urban.Setting                1   1466.5 1482.5
- HH.Income.level              1   1467.5 1483.5
- Reliable.Water.Supply        1   1492.7 1508.7
- Sanitation.Facility.Type     1   1542.0 1558.0
- Tenure.Status                1   1560.9 1576.9
```

```
Call:  glm(formula = Willingness.to.empty.containment ~ HH.Income.level +
    Tenure.Status + Reliable.Water.Supply + Not.living.on.compound.plot +
    Household.Size + Length.of.HH.Stay + Urban.Setting + Sanitation.Facility.Type,
    family = binomial(link = "logit"), data = FSM_All_AIC_Dataset$model)

Coefficients:
                (Intercept)            HH.Income.level>2893           Tenure.StatusOwned
                    -4.3361                          0.3549                       1.3282
      Reliable.Water.SupplyYes     Not.living.on.compound.plotYes           Household.Size<=5
                     0.9252                          0.2593                      -0.4340
Length.of.HH.StayMore than 1 year          Urban.SettingMDMI/LDHI   Sanitation.Facility.TypeImproved
                     0.3083                          0.4044                       2.7731

Degrees of Freedom: 1287 Total (i.e. Null);  1279 Residual
Null Deviance:      1780
Residual Deviance: 1461        AIC: 1479
```

E-8. Final regression model - Non-sewered areas

```
Call:
glm(formula = willingness.to.empty.containment ~ HH.Income.level +
    Tenure.Status + Reliable.Water.Supply + Not.living.on.compound.plot +
    Household.Size + Length.of.HH.Stay + Urban.Setting + Sanitation.Facility.Type,
    family = binomial(link = "logit"), data = FSM_All_AIC_Dataset)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.0699  -0.9201  -0.2920   1.0017   2.8444

Coefficients:
                            Estimate Std. Error z value Pr(>|z|)
(Intercept)                  -4.3361     0.4689  -9.247  < 2e-16 ***
HH.Income.level               0.3549     0.1415   2.508   0.0121 *
Tenure.Status                 1.3282     0.1370   9.693  < 2e-16 ***
Reliable.Water.Supply         0.9252     0.1682   5.502 3.76e-08 ***
Not.living.on.compound.plot   0.2593     0.1273   2.037   0.0417 *
Household.Size               -0.4340     0.3078  -1.410   0.1586
Length.of.HH.Stay             0.3083     0.1940   1.589   0.1120
Urban.Setting                 0.4044     0.1747   2.314   0.0206 *
Sanitation.Facility.Type      2.7731     0.4320   6.419 1.37e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1779.5  on 1287  degrees of freedom
Residual deviance: 1461.2  on 1279  degrees of freedom
AIC: 1479.2

Number of Fisher Scoring iterations: 5

> coef(full.fit1)
                (Intercept)             HH.Income.level               Tenure.Status       Reliable.Water.Supply
                 -4.3360758                   0.3548540                   1.3282328                   0.9252148
Not.living.on.compound.plot              Household.Size           Length.of.HH.Stay               Urban.Setting
                  0.2593182                  -0.4339586                   0.3083481                   0.4043650
   Sanitation.Facility.Type
                  2.7730775
> exp(coef(full.fit1))
                (Intercept)             HH.Income.level               Tenure.Status       Reliable.Water.Supply
                 0.01308779                  1.42597243                  3.77436756                  2.52241000
Not.living.on.compound.plot              Household.Size           Length.of.HH.Stay               Urban.Setting
                 1.29604614                  0.64793910                  1.36117469                  1.49835070
   Sanitation.Facility.Type
                16.00782250
```

```
> exp(confint(full.fit1))
Waiting for profiling to be done...
                                  2.5 %      97.5 %
(Intercept)                 0.004730022  0.03054048
HH.Income.level             1.080563808  1.88214615
Tenure.Status               2.891538962  4.94940322
Reliable.Water.Supply       1.819415412  3.51979496
Not.living.on.compound.plot 1.010076345  1.66416719
Household.Size              0.350525284  1.17718638
Length.of.HH.Stay           0.932827885  1.99811282
Urban.Setting               1.064886881  2.11384347
Sanitation.Facility.Type    7.450616318 41.73880673
> exp(full.fit1$coefficients[-1])
            HH.Income.level               Tenure.Status       Reliable.Water.Supply Not.living.on.compound.plot
                  1.4259724                   3.7743676                   2.5224100                   1.2960461
             Household.Size           Length.of.HH.Stay               Urban.Setting    Sanitation.Facility.Type
                  0.6479391                   1.3611747                   1.4983507                  16.0078225
> (exp(full.fit1$coefficients[-1])-1)*100
            HH.Income.level               Tenure.Status       Reliable.Water.Supply Not.living.on.compound.plot
                   42.59724                   277.43676                   152.24100                    29.60461
             Household.Size           Length.of.HH.Stay               Urban.Setting    Sanitation.Facility.Type
                  -35.20609                    36.11747                    49.83507                  1500.78225
```

APPENDIX F: Dataset for Chapter 8

F-1. Water supply and sanitation status, spatial organisation, and population of LIHD areas in Lusaka

PU	LIHD Area	Water supply status	Sanitation status	Spatial Organisation	2020 Estimated Population		
					Sewered	Non-sewered	Area Total
1	Bauleni	Public taps and yard/house connections	100% non-sewered; mostly traditional latrines	Haphazardly arranged		32,000	32,000
2	Chainda	Public taps and yard/house connections	100% non-sewered; mostly traditional latrines	Haphazardly arranged		27,000	27,000
3	Chaisa	Public taps and yard/house connections	100% non-sewered; mostly latrines with some septic tanks	Haphazardly arranged		27,170	27,170
4	Chawama	Public taps and yard/house connections	100% non-sewered; mostly latrines with some septic tanks	Mixed		89,502	89,502
5	Chibolya	Mainly public taps	100% non-sewered; mostly latrines	Haphazardly arranged		39,000	39,000
6	Chipata	Mainly public taps with yard connections	100% non-sewered; mostly traditional latrines with septic tanks	Mixed		46,158	46,158
7	Chunga	Public taps and 80% yard/house connections	40% sewered; septic tanks and traditional latrines	Mixed	1,602	2,404	4,006
8	Garden	Public taps and yard connections	15% sewered; mostly traditional latrines and some septic tanks	Mixed	13,184	74,707	87,891
9	George	Mainly public taps with yard connections	100% non-sewered; mostly traditional latrines and septic tanks	Haphazardly arranged		158,252	158,252
10	Industries	Public taps and yard/house connections	24% sewered; septic tanks and traditional latrines	Mixed	36,332	115,050	151,382
11	Jack	Public taps and yard connections	100% non-sewered; pit latrines and some septic tanks	Haphazardly arranged		16,124	16,124
12	John Howard	Public taps and yard connections	100% non-sewered; pit latrines and some septic tanks	Haphazardly arranged		61,333	61,333
13	John Laing	Public taps and yard connections	100% non-sewered; pit latrines and some septic tanks	Haphazardly arranged		100,000	100,000
14	Kabanana	Public taps and yard/house connections	100% non-sewered; pit latrines and some septic tanks	Mixed		29,000	29,000
15	Kalingalinga	Public taps and yard/house connections	9% sewered; pit latrines and some septic tanks	Mixed	1,029	10,406	11,435
16	Kamanga	Public taps with yard/house connections	100% non-sewered; mostly latrines with limited septic tanks	Mixed		4,759	4,759
17	Kanyama	Mainly public taps with yard connections	100% non-sewered, mostly traditional latrines with septic tanks	Mixed		50,940	50,940
18	Kaunda Square I & II	100% house connections	100% sewered but experiences many sewage overflows	Organised	4,574		4,574
19	Marapodi	Public taps and yard connections	100% non-sewered; mostly traditional latrines with septic tanks	Mixed		53,501	53,501
20	Matero	Mostly yard and some house connections	53% sewered; latrines and septic tanks	Organised	17,347	15,178	32,525
21	Misisi	Public taps and yard connections	100% non-sewered; mostly traditional latrines with septic tanks	Haphazardly arranged		25,959	25,959
22	Mtendere/Mtendere East	Public taps and yard/house connections	40% sewered; traditional pit latrines and some septic tanks	Mixed	41,782	62,672	104,454
23	Ng'ombe	Public taps and yard connections	100% non-sewered; traditional pit latrines and some septic tanks	Haphazardly arranged		52,918	52,918
24	Kalikiliki	Public taps and yard connections	100% non-sewered; mostly traditional latrines with septic tanks	Haphazardly arranged		26,000	26,000
25	Linda	Public taps and yard connections	100% non-sewered; traditional pit latrines	Haphazardly arranged		23,000	23,000
26	Freedom/Lilayi	Public taps and yard connections	100% non-sewered; traditional pit latrines	Haphazardly arranged		13,000	13,000
27	Chunga – Madimba	Public taps and yard connections	100% non-sewered; traditional pit latrines	Haphazardly arranged		17,000	17,000
28	SOS & Tiyende Pamodzi	Public taps and yard/house connections	100% non-sewered; traditional pit latrines and some septic tanks	Mixed		15,000	15,000
29	Mazyopa	Public taps and yard/house connections	100% non-sewered; mostly traditional pit latrines	Haphazardly arranged		18,000	18,000
30	Chazanga	Public taps and yard/house connections	100% non-sewered; traditional pit latrines and some septic tanks	Mixed		73,285	73,285
31	Zingalume/Twikatane	Public taps and yard/house connections	7% sewered; traditional latrines and some septic tanks	Mixed	5,660	75,202	80,862
32	Kuku	Public taps and yard connections	100% non-sewered; mostly traditional latrines with septic tanks	Haphazardly arranged		24,041	24,041
33	Kuomboka	Public taps and yard/house connections	100% non-sewered; mostly latrines with some septic tanks	Mixed		40,405	40,405
34	Matero East	Mostly yard and some house connections	48% sewered; latrines and septic tanks	Organised	10,841	11,564	22,405
35	Matero North	Mostly yard and some house connections	100% non-sewered; latrines and septic tanks	Organised		17,346	17,346
			Total LIHD population by sewered and non-sewered status		**132,155**	**1,448,072**	**1,580,227**

F-2. Water supply and sanitation status, spatial organisation, and population of MIMD areas in Lusaka

PU	MIMD Area	Water supply status	Sanitation status	Spatial Organisation	2020 Estimated Population		
					Sewered	Non-sewered	Area Total
36	Avondale	100% house connections	100% non-sewered; septic tanks	Organised		40,740	40,740
37	Chamba Valley	100% house connections	100% non-sewered; septic tanks	Organised		17,735	17,735
38	Chelstone	100% house connections	46% sewered; septic tanks	Organised	22,263	26,135	48,398
39	Chilenje/Chilenje South	100% house connections	57% sewered; septic tanks	Organised	13,712	10,344	24,056
40	Emmasdale	100% house connections	35% sewered; septic tanks	Organised	11,077	20,572	31,649
41	Fairview	100% house connections	57% sewered; septic tanks	Organised	1,029	777	1,806
42	Helen Kaunda	100% house connections	100% sewered	Organised	10,463		10,463
43	Kabwata Estates	100% house connections	100% sewered	Organised	4,264		4,264
44	Libala/Libala South	100% house connections	30% sewered; septic tanks	Organised	10,229	23,867	34,096
45	Lilanda	100% yard/house connections	20% sewered; septic tanks	Organised	1,276	5,105	6,381
46	New Kabwata	100% house connections	54% sewred; septic tanks	Organised	6,490	5,528	12,018
47	Kamwala	100% house connections	36% sewered; septic tanks	Organised	3,451	6,135	9,586
48	Nyumba Yanga	100% house connections	100% sewered	Organised	5,182		5,182
49	Shakespear	100% house connections	68% sewered; septic tanks	Organised	3,541	1,666	5,207
50	Sikanze	100% yard/house connections	20% sewered; septic tanks	Organised	508	2,030	2,538
51	Thorn Park	100% house connections	100% sewered	Organised	1,452		1,452
52	PHI	100% house connections	18% sewered; septic tanks	Organised	3,820	17,402	21,222
53	Farm 1080	100% house connections	100% non-sewered;	Organised		20,545	20,545
54	Farm 917	100% house connections	100% non-sewered; septic tanks	Organised		18,106	18,106
55	Chalala/Shantumbu	100% house connections	100% non-sewered; septic tanks	Organised		52,526	52,526
56	Meanwood (Ndeke I,II, III & Vorna Valley)	100% house connections	100% non-sewered; septic tanks	Organised		27,000	27,000
57	Foxdale/Ngwerere	100% house connections	100% non-sewered; septic tanks	Organised		4,800	4,800
58	North Gate Gardens	100% house connections	30% sewered; septic tanks	Organised	812	1,894	2,706
59	Chipwenupwenu	100% yard/house connections	100% non-sewered; septic tanks	Organised		3,642	3,642
60	Statunga	100% house connections	100% sewered	Organised	3,396		3,396
61	Chandamali	100% house connections	100% non-sewered; septic tanks	Organised		23,866	23,866
	Total MIMD population by sewered and non-sewered status				**102,946**	**330,880**	**433,380**

F-3. Water supply and sanitation status, spatial organisation, and population of HILD areas in Lusaka

PU	HILD Area	Water supply status	Sanitation status	Spatial Organisation	2020 Estimated Population		
					Sewered	Non-sewered	Area Total
62	Chainama/Munali	100% house connections	31% sewered; septic tanks	Organised	5,978	13,306	19,284
63	Chudleigh	100% house connections	100% non-sewered; septic tanks	Organised		5,623	5,623
64	Government	100% house connections	31% sewered; septic tanks	Organised	1,396	3,108	4,504
65	Handsworth	100% house connections	100% non-sewered; septic tanks	Organised		2,120	2,120
66	Kabulonga	100% house connections	18% sewered; septic tanks	Organised	2,405	10,958	13,363
67	Kalundu	100% house connections	100% non-sewered; septic tanks	Organised		9,700	9,700
68	Luburma	100% house connections	73% sewered; septic tanks	Organised	10,347	3,827	14,174
69	Mwambula	100% house connections	100% non-sewered; septic tanks	Organised		2,535	2,535
70	Ibex Hill	100% house connections	18% sewered; septic tanks	Organised	588	2,676	3,264
71	Northmead	100% house connections	26% sewered; septic tanks	Organised	2,160	6,148	8,308
72	Olympia Park/Extension	100% house connections	100% non-sewered; septic tanks	Organised		10,040	10,040
73	Prospect Hill	100% house connections	14% sewered; septic tanks	Organised	773	4,746	5,519
74	Rhodes Park	100% house connections	35% sewered; septic tanks	Organised	11,131	20,671	31,802
75	Roma	100% house connections	100% non-sewered; septic tanks	Organised		22,587	22,587
76	State House	100% house connections	3% sewered; septic tanks	Organised	442	14,296	14,738
77	Town/Kabelenga	100% house connections	60% sewered; septic tanks	Organised	44,267	29,512	73,779
78	University of Zambia	100% house connections	70% sewered; septic tanks	Organised	9,682	4,149	13,831
79	Villa Elizabertha	100% house connections	13% sewered; septic tanks	Organised	1,498	10,022	11,520
80	Woodlands/Extension	100% house connections	66% sewered; septic tanks	Organised	8,426	4,340	12,766
81	Lilayi/Eureka	100% house connections	100% non-sewered; septic tanks	Organised		6,900	6,900
82	Leopards Hill/New Kasama	100% house connections	100% non-sewered; septic tanks	Organised		5,400	5,400
83	Makeni/St. Bonaventure/Buckley	100% house connections	100% non-sewered; septic tanks	Organised		18,564	18,564
84	Roma Park	100% house connections	100% non-sewered; septic tanks	Organised		3,220	3,220
	Total HILD population by sewered and non-sewered status				**100,096**	**213,445**	**313,541**

F-4(a). Pairwise comparison and weighted matrix of sub-criteria when costs have the highest priority with the enabling environment having a higher priority than community-level factors

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	9	9	9	9	9	9	9	9	
OpEx	1	1	9	9	9	9	9	9	9	9	
Policy & legislation	1/9	1/9	1	1	1	1	1	4	4	4	
Institutional roles & capacity	1/9	1/9	1	1	1	1	1	4	4	4	
Monitoring & enforcement	1/9	1/9	1	1	1	1	1	4	4	4	
Institutions & service providers	1/9	1/9	1	1	1	1	1	4	4	4	
Cost recovery	1/9	1/9	1	1	1	1	1	4	4	4	
Population density	1/9	1/9	1/4	1/4	1/4	1/4	1/4	1	1	1	
WAP	1/9	1/9	1/4	1/4	1/4	1/4	1/4	1	1	1	
Water supply access	1/9	1/9	1/4	1/4	1/4	1/4	1/4	1	1	1	
Sum	**2.89**	**2.89**	**23.75**	**23.75**	**23.75**	**23.75**	**23.75**	**41**	**41**	**41**	
Weighted Matrix											**Priority**
CapEx	0.34	0.34	0.38	0.38	0.38	0.38	0.38	0.22	0.22	0.22	**0.32**
OpEx	0.34	0.34	0.38	0.38	0.38	0.38	0.38	0.22	0.22	0.22	**0.32**
Policy & legislation	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	**0.06**
Institutional roles & capacity	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	**0.06**
Monitoring & enforcement	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	**0.06**
Institutions & service providers	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	**0.06**
Cost recovery	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.10	0.10	0.10	**0.06**
Population density	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	**0.02**
WAP	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	**0.02**
Water supply access	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	**0.02**

F-4(b). Pairwise comparison and weighted matrix of sub-criteria when costs have the highest priority with community-level factors having a higher priority than the enabling environment

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	9	9	9	9	9	9	9	9	
OpEx	1	1	9	9	9	9	9	9	9	9	
Policy & legislation	1/9	1/9	1	1	1	1	1	1/4	1/4	1/4	
Institutional roles and capacity	1/9	1/9	1	1	1	1	1	1/4	1/4	1/4	
Monitoring & enforcement	1/9	1/9	1	1	1	1	1	1/4	1/4	1/4	
Institutions & service providers	1/9	1/9	1	1	1	1	1	1/4	1/4	1/4	
Cost recovery	1/9	1/9	1	1	1	1	1	1/4	1/4	1/4	
Population density	1/9	1/9	4	4	4	4	4	1	1	1	
WAP	1/9	1/9	4	4	4	4	4	1	1	1	
Water supply access	1/9	1/9	4	4	4	4	4	1	1	1	
Sum	**2.89**	**2.89**	**35**	**35**	**35**	**35**	**35**	**22.25**	**22.25**	**22.25**	
Weighted Matrix											**Priority**
CapEx	0.34	0.34	0.26	0.26	0.26	0.26	0.26	0.40	0.40	0.40	**0.32**
OpEx	0.34	0.34	0.26	0.26	0.26	0.26	0.26	0.40	0.40	0.40	**0.32**
Policy & legislation	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	**0.03**
Institutional roles & capacity	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	**0.03**
Monitoring & enforcement	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	**0.03**
Institutions & service providers	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	**0.03**
Cost recovery	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	**0.03**
Population density	0.04	0.04	0.11	0.11	0.11	0.11	0.11	0.04	0.04	0.04	**0.07**
WAP	0.04	0.04	0.11	0.11	0.11	0.11	0.11	0.04	0.04	0.04	**0.07**
Water supply access	0.04	0.04	0.11	0.11	0.11	0.11	0.11	0.04	0.04	0.04	**0.07**

F-4(c). Pairwise comparison and weighted matrix of sub-criteria when the enabling environment is the highest priority with cost and community-level factors having equal priorities

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	1/9	1/9	1/9	1/9	1/9	1	1	1	
OpEx	1	1	1/9	1/9	1/9	1/9	1/9	1	1	1	
Policy & legislation	9	9	1	1	1	1	1	9	9	9	
Institutional roles & capacity	9	9	1	1	1	1	1	9	9	9	
Monitoring & enforcement	9	9	1	1	1	1	1	9	9	9	
Institutions & service providers	9	9	1	1	1	1	1	9	9	9	
Cost recovery	9	9	1	1	1	1	1	9	9	9	
Population density	1	1	1/9	1/9	1/9	1/9	1/9	1	1	1	
WAP	1	1	1/9	1/9	1/9	1/9	1/9	1	1	1	
Water supply access	1	1	1/9	1/9	1/9	1/9	1/9	1	1	1	
Sum	**50**	**50**	**5.55**	**5.55**	**5.55**	**5.55**	**5.55**	**50**	**50**	**50**	
Weighted Matrix											**Priority**
CapEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
OpEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
Policy & legislation	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	**0.18**
Institutional roles & capacity	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	**0.18**
Monitoring & enforcement	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	**0.18**
Institutions & service providers	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	**0.18**
Cost recovery	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	**0.18**
Population density	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
WAP	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
Water supply access	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**

F-4(d). Pairwise comparison and weighted matrix of sub-criteria when the enabling environment is the highest priority with cost having a higher priority than community-level factors

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	1/9	1/9	1/9	1/9	1/9	4	4	4	
OpEx	1	1	1/9	1/9	1/9	1/9	1/9	4	4	4	
Policy & legislation	9	9	1	1	1	1	1	9	9	9	
Institutional roles & capacity	9	9	1	1	1	1	1	9	9	9	
Monitoring & enforcement	9	9	1	1	1	1	1	9	9	9	
Institutions & service providers	9	9	1	1	1	1	1	9	9	9	
Cost recovery	9	9	1	1	1	1	1	9	9	9	
Population density	1/4	1/4	1/9	1/9	1/9	1/9	1/9	1	1	1	
WAP	1/4	1/4	1/9	1/9	1/9	1/9	1/9	1	1	1	
Water supply access	1/4	1/4	1/9	1/9	1/9	1/9	1/9	1	1	1	
Sum	**47.75**	**47.75**	**5.55**	**5.55**	**5.55**	**5.55**	**5.55**	**56**	**56**	**56**	
Weighted Matrix											**Priority**
CapEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.07	0.07	**0.04**
OpEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.07	0.07	**0.04**
Policy & legislation	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	**0.17**
Institutional roles & capacity	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	**0.17**
Monitoring & enforcement	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	**0.17**
Institutions & service providers	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	**0.17**
Cost recovery	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.16	0.16	0.16	**0.17**
Population density	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
WAP	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**
Water supply access	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.02**

F-4(e). Pairwise comparison and weighted matrix of sub-criteria when the enabling environment is the highest priority with community-level factors having a higher priority than cost

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	1/9	1/9	1/9	1/9	1/9	1/4	1/4	1/4	
OpEx	1	1	1/9	1/9	1/9	1/9	1/9	1/4	1/4	1/4	
Policy & legislation	9	9	1	1	1	1	1	9	9	9	
Institutional roles & capacity	9	9	1	1	1	1	1	9	9	9	
Monitoring & enforcement	9	9	1	1	1	1	1	9	9	9	
Institutions & service providers	9	9	1	1	1	1	1	9	9	9	
Cost recovery	9	9	1	1	1	1	1	9	9	9	
Population density	4	4	1/9	1/9	1/9	1/9	1/9	1	1	1	
WAP	4	4	1/9	1/9	1/9	1/9	1/9	1	1	1	
Water supply access	4	4	1/9	1/9	1/9	1/9	1/9	1	1	1	
Sum	**59**	**59**	**5.55**	**5.55**	**5.55**	**5.55**	**5.55**	**48.5**	**48.5**	**48.5**	
Weighted Matrix											**Priority**
CapEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	**0.01**
OpEx	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	**0.01**
Policy & legislation	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	**0.18**
Institutional roles & capacity	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	**0.18**
Monitoring & enforcement	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	**0.18**
Institutions & service providers	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	**0.18**
Cost recovery	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	**0.18**
Population density	0.07	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.03**
WAP	0.07	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.03**
Water supply access	0.07	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	**0.03**

F-4(f). Pairwise **c**omparison and weighted matrix of sub-criteria when community-level factors have the highest priority with cost and enabling environment with equal priorities

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	1	1	1	1	1	1/9	1/9	1/9	
OpEx	1	1	1	1	1	1	1	1/9	1/9	1/9	
Policy & legislation	1	1	1	1	1	1	1	1/9	1/9	1/9	
Institutional roles & capacity	1	1	1	1	1	1	1	1/9	1/9	1/9	
Monitoring & enforcement	1	1	1	1	1	1	1	1/9	1/9	1/9	
Institutions & service providers	1	1	1	1	1	1	1	1/9	1/9	1/9	
Cost recovery	1	1	1	1	1	1	1	1/9	1/9	1/9	
Population density	9	9	9	9	9	9	9	1	1	1	
WAP	9	9	9	9	9	9	9	1	1	1	
Water supply access	9	9	9	9	9	9	9	1	1	1	
Sum	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**3.77**	**3.77**	**3.77**	
Weighted Matrix											**Priority**
CapEx	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
OpEx	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Policy & legislation	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Institutional roles & capacity	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Monitoring & enforcement	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Institutions & service providers	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Cost recovery	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**
Population density	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	**0.26**
WAP	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	**0.26**
Water supply access	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	**0.26**

F-4(g). Pairwise **c**omparison and weighted matrix of sub-criteria when community-level factors have the highest priority with cost having a higher priority than the enabling environment

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	4	4	4	4	4	1/9	1/9	1/9	
OpEx	1	1	4	4	4	4	4	1/9	1/9	1/9	
Policy & legislation	1/4	1/4	1	1	1	1	1	1/9	1/9	1/9	
Institutional roles & capacity	1/4	1/4	1	1	1	1	1	1/9	1/9	1/9	
Monitoring & enforcement	1/4	1/4	1	1	1	1	1	1/9	1/9	1/9	
Institutions & service providers	1/4	1/4	1	1	1	1	1	1/9	1/9	1/9	
Cost recovery	1/4	1/4	1	1	1	1	1	1/9	1/9	1/9	
Population density	9	9	9	9	9	9	9	1	1	1	
WAP	9	9	9	9	9	9	9	1	1	1	
Water supply access	9	9	9	9	9	9	9	1	1	1	
Sum	**30.25**	**30.25**	**40**	**40**	**40**	**40**	**40**	**3.77**	**3.77**	**3.77**	
Weighted Matrix											**Priority**
CapEx	0.03	0.03	0.10	0.10	0.10	0.10	0.10	0.03	0.03	0.03	**0.07**
OpEx	0.03	0.03	0.10	0.10	0.10	0.10	0.10	0.03	0.03	0.03	**0.07**
Policy & legislation	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.02**
Institutional roles & capacity	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.02**
Monitoring & enforcement	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.02**
Institutions & service providers	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.02**
Cost recovery	0.01	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.02**
Population density	0.30	0.30	0.23	0.23	0.23	0.23	0.23	0.27	0.27	0.27	**0.25**
WAP	0.30	0.30	0.23	0.23	0.23	0.23	0.23	0.27	0.27	0.27	**0.25**
Water supply access	0.30	0.30	0.23	0.23	0.23	0.23	0.23	0.27	0.27	0.27	**0.25**

F-4(h). Pairwise comparison and weighted matrix of sub-criteria when community-level factors have the highest priority with the enabling environment having a higher priority than cost

Sanitation option selection	CapEx	OpEx	Policy & legislation	Institutional roles & capacity	Monitoring & enforcement	Institutions & service providers	Cost recovery	Population density	WAP	Water supply access	
CapEx	1	1	1/4	1/4	1/4	1/4	1/4	1/9	1/9	1/9	
OpEx	1	1	1/4	1/4	1/4	1/4	1/4	1/9	1/9	1/9	
Policy & legislation	4	4	1	1	1	1	1	1/9	1/9	1/9	
Institutional roles & capacity	4	4	1	1	1	1	1	1/9	1/9	1/9	
Monitoring & enforcement	4	4	1	1	1	1	1	1/9	1/9	1/9	
Institutions & service providers	4	4	1	1	1	1	1	1/9	1/9	1/9	
Cost recovery	4	4	1	1	1	1	1	1/9	1/9	1/9	
Population density	9	9	9	9	9	9	9	1	1	1	
WAP	9	9	9	9	9	9	9	1	1	1	
Water supply access	9	9	9	9	9	9	9	1	1	1	
Sum	**49**	**49**	**32.5**	**32.5**	**32.5**	**32.5**	**32.5**	**3.77**	**3.77**	**3.77**	
Weighted Matrix											**Priority**
CapEx	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	**0.02**
OpEx	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	**0.02**
Policy & legislation	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.04**
Institutional roles & capacity	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.04**
Monitoring & enforcement	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.04**
Institutions & service providers	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.04**
Cost recovery	0.08	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.04**
Population density	0.18	0.18	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27	**0.25**
WAP	0.18	0.18	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27	**0.25**
Water supply access	0.18	0.18	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27	**0.25**

F-5. Pairwise comparison and weighted matrix for alternatives with respect to cost, enabling environment and community-level criteria

Criteria	**Cost**		**Enabling Environment**															**Community-level factors**								
Sub-criteria	**CapEx**	**OpEx**	**Policy & legislation**			**Institutional roles & capacity**			**Monitoring & enforcement**			**Institutions & service providers**			**Cost recovery**			**Population density**			**WAP**			**Water supply access**		
Alternatives	1/Cost		BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3	BC-1	BC-2	BC-3
BC-1	0.0072	0.0180	1	1	5	1	7	5	1	1	1/2	1	4	3	1	1	1/7	1	1	7	1	1	4	1	1	1/5
BC-2	0.0073	0.0175	1	1	4	1/7	1	2	1	1	1/2	1/4	1	2	1	1	1/7	1	1	7	1	1	4	1	1	1/5
BC-3	0.0131	0.0229	1/5	1/4	1	1/5	1/2	1	2	2	1	1/3	1/2	1	7	7	1	1/7	1/7	1	1/4	1/4	1	5	5	1
Sum	**0.0276**	**0.0584**	**2.20**	**2.25**	**10**	**1.34**	**8.5**	**8**	**4**	**4**	**2**	**1.58**	**5.50**	**6**	**9**	**9**	**1.28**	**2.14**	**2.14**	**15**	**2.25**	**2.25**	**9**	**7**	**7**	**1.4**
Weighted Matrix																										
BC-1	0.26	0.31	0.45	0.45	0.50	0.75	0.82	0.63	0.25	0.25	0.25	0.63	0.73	0.50	0.11	0.11	0.11	0.47	0.47	0.47	0.44	0.44	0.44	0.14	0.14	0.14
BC-2	0.27	0.30	0.45	0.45	0.40	0.10	0.12	0.25	0.25	0.25	0.25	0.16	0.19	0.33	0.11	0.11	0.11	0.47	0.47	0.47	0.44	0.44	0.44	0.14	0.14	0.14
BC-3	0.47	0.39	0.09	0.11	0.10	0.15	0.06	0.13	0.50	0.50	0.50	0.21	0.09	0.17	0.78	0.78	0.78	0.06	0.06	0.07	0.12	0.12	0.12	0.72	0.72	0.72

Cost inputs (CapEx and OpEx): BC-1 (138.8 and 55.4); BC-2 (137.3 and 57.0); BC-3 (76.0 and 43.7)

F-6. Local priorities of the alternatives with respect to cost, the enabling environment, and community-level criteria

Criteria	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	**CapEx**	**OpEx**	**Policy & legislation**	**Institutional roles & capacity**	**Monitoring & enforcement**	**Institutions & service providers**	**Cost recovery**	**Population density**	**WAP**	**Water supply access**
All Conventional Sewers (BC-1)	0.26	0.31	0.47	0.73	0.25	0.62	0.11	0.47	0.44	0.14
Conventional and Simplified Sewers (BC-2)	0.27	0.30	0.43	0.16	0.25	0.22	0.11	0.47	0.44	0.14
All Enhanced FSM (BC-3)	0.47	0.39	0.10	0.11	0.50	0.16	0.78	0.06	0.12	0.72

F-7(a). Global and local weights, priorities, and overall priorities when the cost criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Costs have a higher priority with enabling environment and community-level factors having equal priorities	**(0.68)**		**(0.20)**					**(0.12)**		
	(0.34)	(0.34)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	**(0.64)**		**(0.30)**					**(0.06)**		
	(0.32)	(0.32)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.02)	(0.02)	(0.02)
Costs have a higher priority, with community-level factors having a higher priority than the enabling environment	**(0.64)**		**(0.15)**					**(0.21)**		
	(0.32)	(0.32)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)	(0.07)	(0.07)
All Conventional Sewers	0.26	0.31	0.47	0.73	0.25	0.62	0.11	0.47	0.44	0.14
Conventional and Simplified Sewers	0.27	0.30	0.43	0.16	0.25	0.22	0.11	0.47	0.44	0.14
All Enhanced FSM	0.47	0.39	0.10	0.11	0.50	0.16	0.78	0.06	0.12	0.72

Overall Priorities

Sanitation Alternatives	Costs have a higher priority with the enabling environment and community-level factors having equal priorities	Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	Costs have a higher priority, with community-level factors having a higher priority than the enabling environment
All Conventional Sewers	**0.34**	**0.35**	**0.33**
Conventional and Simplified Sewers	**0.27**	**0.26**	**0.28**
All Enhanced FSM	**0.39**	**0.39**	**0.38**

Notes: The global (**bold**) and local weights are within brackets for each criterion and sub-criteria; in the cells are the priorities of the sanitation options (alternatives).

F-7(b). Global and local weights, priorities, and overall priorities when the enabling environment criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Enabling environment has a higher priority with costs and community-level factors having equal priorities	**(0.04)**		**(0.90)**					**(0.06)**		
	(0.02)	(0.02)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.02)	(0.02)	(0.02)
Enabling environment has a higher priority with costs having a higher priority than community-level factors	**(0.08)**		**(0.85)**					**(0.06)**		
	(0.04)	(0.04)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.02)	(0.02)	(0.02)
Enabling environment has a higher priority, with community-level factors having a higher priority than costs	**(0.02)**		**(0.90)**					**(0.09)**		
	(0.01)	(0.01)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.03)	(0.03)	(0.03)
All Conventional Sewers	0.26	0.31	0.47	0.73	0.25	0.62	0.11	0.47	0.44	0.14
Conventional and Simplified Sewers	0.27	0.30	0.43	0.16	0.25	0.22	0.11	0.47	0.44	0.14
All Enhanced FSM	0.47	0.39	0.10	0.11	0.50	0.16	0.78	0.06	0.12	0.72

Overall Priorities

Sanitation Alternatives	Enabling environment has a higher priority with costs and community-level factors having equal priorities	Enabling environment has a higher priority with costs having a higher priority than community-level factors	Enabling environment has a higher priority, with community-level factors having a higher priority than costs
All Conventional Sewers	**0.43**	**0.42**	**0.43**
Conventional and Simplified Sewers	**0.24**	**0.24**	**0.25**
All Enhanced FSM	**0.33**	**0.33**	**0.33**

F-7(c). Global and local weights, priorities, and overall priorities when community-level criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Community-level factors have a higher priority with costs and the enabling environment having equal priorities	**(0.06)**		**(0.15)**					**(0.78)**		
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.26)	(0.26)	(0.26)
Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	**(0.14)**		**(0.10)**					**(0.75)**		
	(0.07)	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.25)	(0.25)	(0.25)
Community-level factors have a higher priority, with the enabling environment having a higher priority than costs	**(0.04)**		**(0.20)**					**(0.75)**		
	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.25)	(0.25)	(0.25)
All Conventional Sewers	0.26	0.31	0.47	0.73	0.25	0.62	0.11	0.47	0.44	0.14
Conventional and Simplified Sewers	0.27	0.30	0.43	0.16	0.25	0.22	0.11	0.47	0.44	0.14
All Enhanced FSM	0.47	0.39	0.10	0.11	0.50	0.16	0.78	0.06	0.12	0.72

Overall Priorities

Sanitation Alternatives	Community-level factors have a higher priority with costs and the enabling environment having equal priorities	Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	Community-level factors have a higher priority, with the enabling environment having a higher priority than costs
All Conventional Sewers	**0.36**	**0.35**	**0.36**
Conventional and Simplified Sewers	**0.32**	**0.32**	**0.32**
All Enhanced FSM	**0.31**	**0.32**	**0.31**

F-8(a). Pairwise comparison and weighted matrix for alternatives with respect to cost and community-level criteria

Criteria	**Cost**		**Community-level factors**																	
Sub-criteria	**CapEx**	**OpEx**	**Population density**						**Willingness & Ability to Pay**						**Water supply access**					
Options	1/Cost		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
BVO-1	0.0342	0.0215	1	1/3	1/4	1/5	1/5	1/5	1	1/4	1/4	1/4	1/4	1/4	1	4	5	6	6	6
BVO-2	0.0200	0.0209	3	1	1/2	1/3	1/3	1/3	4	1	1/3	1/3	1/3	1/3	1/4	1	3	4	4	4
BVO-3	0.0145	0.0215	1/4	2	1	1/2	1/2	1/2	4	3	1	1/3	1/3	1/3	1/5	1/3	1	3	3	3
BVO-4	0.0122	0.0198	5	3	2	1	1	1	4	3	3	1	1	1	1/6	1/4	1/3	1	1	1
BVO-5	0.0122	0.0199	5	3	2	1	1	1	4	3	3	1	1	1	1/6	1/4	1/3	1	1	1
BVO-6	0.0130	0.0201	5	3	2	1	1	1	4	3	3	1	1	1	1/6	1/4	1/3	1	1	1
Sum	**0.1061**	**0.1237**	**19.3**	**12.3**	**7.8**	**4**	**4**	**4**	**21**	**13.3**	**10.6**	**3.9**	**3.9**	**3.9**	**2.0**	**6.1**	**10**	**16**	**16**	**16**
Weighted Matrix																				
BVO-1	0.32	0.174	0.05	0.03	0.03	0.05	0.05	0.05	0.05	0.02	0.02	0.06	0.06	0.06	0.51	0.66	0.50	0.38	0.38	0.38
BVO-2	0.19	0.169	0.16	0.08	0.06	0.08	0.08	0.08	0.19	0.08	0.03	0.09	0.09	0.09	0.13	0.16	0.30	0.25	0.25	0.25
BVO-3	0.14	0.174	0.01	0.16	0.13	0.12	0.12	0.12	0.19	0.23	0.09	0.09	0.09	0.09	0.10	0.05	0.10	0.19	0.19	0.19
BVO-4	0.11	0.160	0.26	0.24	0.26	0.25	0.25	0.25	0.19	0.23	0.28	0.26	0.26	0.26	0.09	0.04	0.03	0.06	0.06	0.06
BVO-5	0.11	0.161	0.26	0.24	0.26	0.25	0.25	0.25	0.19	0.23	0.28	0.26	0.26	0.26	0.09	0.04	0.03	0.06	0.06	0.06
BVO-6	0.12	0.162	0.26	0.24	0.26	0.25	0.25	0.25	0.19	0.23	0.28	0.26	0.26	0.26	0.09	0.04	0.03	0.06	0.06	0.06

Cost inputs (CapEx and OpEx): BVO-1 (29.2 and 46.4); BVO-2 (49.9 and 47.8); BVO-3 (69.1 and 46.5); BVO-4 (81.8 and 50.4); BVO-5 (81.7 and 50.3); and BVO-6 (77.0 and 49.7)

F-8(b). Pairwise comparison and weighted matrix for alternatives with respect to the enabling environment criteria

Criteria	**Enabling Environment**																													
Sub-criteria	**Policy & legislation**						**Institutional roles and capacity**						**Monitoring & enforcement**						**Institutions and service providers**						**Cost recovery**					
Options	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
BVO-1	1	1/3	1/4	1/5	1/5	1/5	1	3	3	5	6	7	1	3	4	5	5	5	1	1/3	1/4	1/5	1/5	1/5	1	3	4	5	5	5
BVO-2	3	1	1/3	4	4	4	1/3	1	3	4	5	6	1/3	1	3	5	5	5	3	1	1/3	1/4	1/4	1/4	1/3	1	3	4	4	4
BVO-3	4	3	1	1/3	1/3	1/3	1/3	1/3	1	4	4	5	1/4	1/3	1	4	4	4	4	3	1	1/3	1/3	1/3	1/4	1/3	1	3	3	3
BVO-4	5	1/4	3	1	1	1	1/5	1/4	1/4	1	4	5	1/5	1/5	1/4	1	1	1	5	4	3	1	1	1	1/5	1/4	1/3	1	1	1
BVO-5	5	1/4	3	1	1	1	1/6	1/5	1/4	1/4	1	4	1/5	1/5	1/4	1	1	1	5	4	3	1	1	1	1/5	1/4	1/3	1	1	1
BVO-6	5	1/4	3	1	1	1	1/7	1/6	1/5	1/5	1/4	1	1/5	1/5	1/4	1	1	1	5	4	3	1	1	1	1/5	1/4	1/3	1	1	1
Sum	**23**	**5.1**	**10.6**	**7.5**	**7.5**	**7.5**	**2.2**	**5.0**	**7.7**	**14.5**	**20.3**	**28**	**2.2**	**4.9**	**8.8**	**17**	**17**	**17**	**23**	**16.3**	**10.6**	**3.8**	**3.8**	**3.8**	**2.2**	**5.1**	**9**	**15**	**15**	**15**
Weighted Matrix																														
BVO-1	0.04	0.07	0.02	0.03	0.03	0.03	0.46	0.61	0.39	0.35	0.30	0.25	0.46	0.61	0.46	0.29	0.29	0.29	0.04	0.02	0.02	0.05	0.05	0.05	0.46	0.59	0.44	0.33	0.33	0.33
BVO-2	0.13	0.20	0.03	0.53	0.53	0.53	0.15	0.20	0.39	0.28	0.25	0.21	0.15	0.20	0.34	0.29	0.29	0.29	0.13	0.06	0.03	0.07	0.07	0.07	0.15	0.20	0.33	0.27	0.27	0.27
BVO-3	0.17	0.59	0.09	0.04	0.04	0.04	0.15	0.07	0.13	0.28	0.20	0.18	0.11	0.07	0.11	0.24	0.24	0.24	0.17	0.18	0.09	0.09	0.09	0.09	0.11	0.07	0.11	0.20	0.20	0.20
BVO-4	0.22	0.05	0.28	0.13	0.13	0.13	0.09	0.05	0.03	0.07	0.20	0.18	0.09	0.04	0.03	0.06	0.06	0.06	0.22	0.24	0.28	0.26	0.26	0.26	0.09	0.05	0.04	0.07	0.07	0.07
BVO-5	0.22	0.05	0.28	0.13	0.13	0.13	0.08	0.04	0.03	0.02	0.05	0.14	0.09	0.04	0.03	0.06	0.06	0.06	0.22	0.24	0.28	0.26	0.26	0.26	0.09	0.05	0.04	0.07	0.07	0.07
BVO-6	0.22	0.05	0.28	0.13	0.13	0.13	0.07	0.03	0.03	0.01	0.01	0.04	0.09	0.04	0.03	0.06	0.06	0.06	0.22	0.24	0.28	0.26	0.26	0.26	0.09	0.05	0.04	0.07	0.07	0.07

F-9. Local priorities of the alternatives with respect to cost, the enabling environment, and community-level criteria

Criteria	Cost		Enabling Environment					Community-level factors		
Sub-criteria	CapEx	OpEx	Policy & legislation	Institutional roles and capacity	Monitoring & enforcement	Institutions and service providers	Cost recovery	Population density	WAP	Water supply access
BVO-1	0.32	0.174	0.04	0.39	0.40	0.04	0.42	0.04	0.05	0.47
BVO-2	0.19	0.169	0.33	0.25	0.26	0.07	0.25	0.09	0.09	0.22
BVO-3	0.14	0.174	0.17	0.17	0.17	0.12	0.15	0.11	0.13	0.14
BVO-4	0.11	0.160	0.16	0.10	0.06	0.26	0.06	0.25	0.24	0.06
BVO-5	0.11	0.161	0.16	0.06	0.06	0.26	0.06	0.25	0.24	0.06
BVO-6	0.12	0.162	0.16	0.03	0.06	0.26	0.06	0.25	0.24	0.06

F-10(a). Global and local weights, priorities, and overall priorities when the cost criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Costs have a higher priority with enabling environment and community-level factors having equal priorities	**(0.68)**		**(0.20)**					**(0.12)**		
	(0.34)	(0.34)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	**(0.64)**		**(0.30)**					**(0.06)**		
	(0.32)	(0.32)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.02)	(0.02)	(0.02)
Costs have a higher priority, with community-level factors having a higher priority than the enabling environment	**(0.64)**		**(0.15)**					**(0.21)**		
	(0.32)	(0.32)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)	(0.07)	(0.07)
BVO-1	0.32	0.174	0.04	0.39	0.40	0.04	0.42	0.04	0.05	0.47
BVO-2	0.19	0.169	0.33	0.25	0.26	0.07	0.25	0.09	0.09	0.22
BVO-3	0.14	0.174	0.17	0.17	0.17	0.12	0.15	0.11	0.13	0.14
BVO-4	0.11	0.160	0.16	0.10	0.06	0.26	0.06	0.25	0.24	0.06
BVO-5	0.11	0.161	0.16	0.06	0.06	0.26	0.06	0.25	0.24	0.06
BVO-6	0.12	0.162	0.16	0.03	0.06	0.26	0.06	0.25	0.24	0.06

Overall Priorities

Sanitation Alternatives	Costs have a higher priority with the enabling environment and community-level factors having equal priorities	Costs have a higher priority, with the enabling environment having a higher priority than community-level factors	Costs have a higher priority, with community-level factors having a higher priority than the enabling environment
BVO-1	**0.24**	**0.25**	**0.24**
BVO-2	**0.18**	**0.19**	**0.18**
BVO-3	**0.15**	**0.15**	**0.15**
BVO-4	**0.14**	**0.14**	**0.15**
BVO-5	**0.14**	**0.13**	**0.14**
BVO-6	**0.14**	**0.14**	**0.15**

F-10(b). Global and local weights, priorities, and overall priorities when the enabling environment criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Enabling environment has a higher priority with costs and community-level factors having equal priorities	**(0.04)**		**(0.90)**					**(0.06)**		
	(0.02)	(0.02)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.02)	(0.02)	(0.02)
Enabling environment has a higher priority with costs having a higher priority than community-level factors	**(0.08)**		**(0.85)**					**(0.06)**		
	(0.04)	(0.04)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.02)	(0.02)	(0.02)
Enabling environment has a higher priority, with community-level factors having a higher priority than costs	**(0.02)**		**(0.90)**					**(0.09)**		
	(0.01)	(0.01)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.03)	(0.03)	(0.03)
BVO-1	0.32	0.174	0.04	0.39	0.40	0.04	0.42	0.04	0.05	0.47
BVO-2	0.19	0.169	0.33	0.25	0.26	0.07	0.25	0.09	0.09	0.22
BVO-3	0.14	0.174	0.17	0.17	0.17	0.12	0.15	0.11	0.13	0.14
BVO-4	0.11	0.160	0.16	0.10	0.06	0.26	0.06	0.25	0.24	0.06
BVO-5	0.11	0.161	0.16	0.06	0.06	0.26	0.06	0.25	0.24	0.06
BVO-6	0.12	0.162	0.16	0.03	0.06	0.26	0.06	0.25	0.24	0.06

Overall Priorities

Sanitation Alternatives	Enabling environment has a higher priority with costs and community-level factors having equal priorities	Enabling environment has a higher priority with costs having a higher priority than community-level factors	Enabling environment has a higher priority, with community-level factors having a higher priority than costs
BVO-1	**0.25**	**0.25**	**0.25**
BVO-2	**0.22**	**0.22**	**0.22**
BVO-3	**0.15**	**0.15**	**0.15**
BVO-4	**0.13**	**0.13**	**0.13**
BVO-5	**0.12**	**0.12**	**0.13**
BVO-6	**0.12**	**0.12**	**0.12**

F-10(c). Global and local weights, priorities, and overall priorities when community-level criterion has the highest priority

Criterion	**Cost**		**Enabling Environment**					**Community-level factors**		
Sub-criteria	Capital Costs	O&M Costs	Policy & legislation	Institutional Roles & Capacity	Monitoring & Enforcement	Institutions & Service Providers	Cost Recovery	Pop. Density	WAP	Water Supply Access
Community-level factors have a higher priority with costs and the enabling environment having equal priorities	**(0.06)**		**(0.15)**					**(0.78)**		
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.26)	(0.26)	(0.26)
Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	**(0.14)**		**(0.10)**					**(0.75)**		
	(0.07)	(0.07)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.25)	(0.25)	(0.25)
Community-level factors have a higher priority, with the enabling environment having a higher priority than costs	**(0.04)**		**(0.20)**					**(0.75)**		
	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.25)	(0.25)	(0.25)
BVO-1	0.32	0.174	0.04	0.39	0.40	0.04	0.42	0.04	0.05	0.47
BVO-2	0.19	0.169	0.33	0.25	0.26	0.07	0.25	0.09	0.09	0.22
BVO-3	0.14	0.174	0.17	0.17	0.17	0.12	0.15	0.11	0.13	0.14
BVO-4	0.11	0.160	0.16	0.10	0.06	0.26	0.06	0.25	0.24	0.06
BVO-5	0.11	0.161	0.16	0.06	0.06	0.26	0.06	0.25	0.24	0.06
BVO-6	0.12	0.162	0.16	0.03	0.06	0.26	0.06	0.25	0.24	0.06

Overall Priorities

Sanitation Alternatives	Community-level factors have a higher priority with costs and the enabling environment having equal priorities	Community-level factors have a higher priority, with costs having a higher priority than the enabling environment	Community-level factors have a higher priority, with the enabling environment having a higher priority than costs
BVO-1	**0.20**	**0.20**	**0.20**
BVO-2	**0.15**	**0.15**	**0.16**
BVO-3	**0.13**	**0.13**	**0.13**
BVO-4	**0.17**	**0.17**	**0.17**
BVO-5	**0.17**	**0.17**	**0.17**
BVO-6	**0.17**	**0.17**	**0.17**