Planning for Faecal Sludge Management in informal urban settlements of low-income countries: A study of Lusaka, Republic of Zambia

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Abstract

Faecal Sludge Management is regarded as an affordable and viable option for providing sanitation services in complex informal urban settlements. This thesis examines to what extent current urban sanitation planning approaches and practices are suitable frameworks for achieving sustainable Faecal Sludge Management in informal settlements. The findings are based on a mixed methodology approach where primary data was collected from household level questionnaires (N=169) and a series of key informant interviews (N=35 at city and country level, N=14 at community level) during 2013 in Lusaka, Zambia. The development of a decision support tool that allows for the modelling, costing and comparison of various Faecal Sludge Management infrastructure and technology scenarios was also completed.

The findings conclude that whilst many urban sanitation planning approaches exist, adaptation is required so that sustainable Faecal Sludge Management systems can be achieved in complex informal environments. Firstly, a more in depth understanding of social structures, dominant influences and their effect on service provision is required. In particular, an understanding of the role of politics, power, trust and history was shown to be vital. Insights from various decision-making domains including household, community, city and country level representatives was shown to be essential. Application of the developed decision support tool highlighted that obtaining accurate spatio-topological information on the existing sanitation and transport infrastructure networks and on the status and capacity of the containment, removal and transportation components of the Sanitation Value Chain is critical. These are required to ensure accurate long-term cost projections can be developed for various modelled scenarios, that comparisons can be made against other sanitation technologies and where appropriate, sustainable services can be implemented.

This research bridges a gap in the sanitation sector by highlighting key socio-technical factors that need to be addressed in order to achieve sustainable sanitation provision for informal settlements in Zambia and beyond.

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In loving memory of my Grandad Paddy and my dad, Roger Walker

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List of Abbreviations

AIC	Average Incremental Cost
BORDA	Bremen Overseas Research Development Agency
CBE	Community Based Enterprise
CBO	Community Based Organisation
CLTS	Community Led Total Sanitation
CLUES	Community-Led Urban Environmental Sanitation
DDMC	Lusaka District Disaster Management Committee
DEWATS	Decentralised Wastewater Treatment
DTF	Devolution Trust Fund
DWA	Department of Water Affairs
ECF	Excreta Containing Facility
ECZ	Environmental Council of Zambia
EPSRC	Engineering and Physical Science Research Council
FS	Faecal Sludge
FSM	Faecal Sludge Management
GIS	Geographic Information System
GPS	Global Positioning System
GTZ	German Agency for Technical Cooperation
HCES	Household Centred Environmental Sanitation
JIF	JMP Improved Facility
JMP	Joint Monitoring Program
KAP	Knowledge, Attitude and Practice
KII	Key Informant Interview
LA	Local Authority
LCC	Lusaka City Council
LWSC	Lusaka Water and Sewerage Company

MDG	Millennium Development Goal
MOH	Ministry of Health
MOLGH	Ministry of Local Government and Housing
MSW	Municipal Solid Waste
NGO	Non-Governmental Organisation
NPV	Net Present Value
NUWSSP	National Urban Water Supply and Sanitation Programme
NWASCO	National Water Supply and Sanitation Council
PHA	Public Health Act
PUD	Peri Urban Department
PV	Present Value
SDS	Sewer Discharge Station
SSA	Strategic Sanitation Approach
SVC	Sanitation Value Chain
SWM	Solid Waste Management
TS	Transfer Station
WASH	Water, Sanitation and Hygiene
WDC	Ward Development Committees
WSP	Water and Sanitation Program
WSS	Water Supply and Sanitation
WSSCC	Water Supply and Sanitation Collaborative Council
WSUP	Water and Sanitation for the Urban Poor
WT	Water Trust
WwTP	Wastewater Treatment Plant
ZEMA	Zambian Environment Management Agency
ZMK	Zambian Kwacha (currency until 2013)
ZMW	Zambian Kwacha (rebased)

List of Publications

The following papers are outputs of this thesis and are discussed within the text (referred to by letters). My contribution to each paper is given in italics below each title.

A) Kennedy-Walker, R., Evans, B., Amezaga, J.M. and Paterson, C.A. (2014) 'Challenges for the future of urban sanitation planning: critical analysis of John Kalbermatten's influence', *Journal of Water, Sanitation and Hygiene for Development*, 4(1), pp. 1-14.

   I was responsible for the review of urban planning approaches and took a lead role in writing the paper.

B) Kennedy-Walker, R., Holderness, T., Alderson, D., Evans, B. and Barr, S. (2014) 'Network modelling for road-based faecal sludge management', *Proceedings of the ICE - Municipal Engineer*, 167(3), pp. 157-165.

   I was responsible for identifying the benefits of adapting previously developed network modelling tool for the FSM context. I worked in collaboration with the other authors to develop the concepts of this paper, to adapt the modelling tool and had a main role in writing the paper with Tomas Holderness.

Chapter 1. Introduction

1.1 Introduction

This chapter provides a background to the global urban sanitation situation and highlights where this research fits into the overall picture of urban sanitation provision. The chapter introduces the concepts of urban sanitation planning and Faecal Sludge Management and highlights possible research gaps. The chapter concludes by introducing the rationale for the research conducted.

1.2 Background

In the early 2000s, many world leaders pledged their agreement to targets which vowed to free people from extreme poverty and uphold the principles of human dignity, equality and equity (United Nations, 2014a). From here eight Millennium Development Goals (MDGs) were created which set measurable time bound targets to tackle key development issues across the globe (ibid). The 7th MDG, target c, focused on water supply and sanitation access and called on countries to *"halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation"* (WHO/UNICEF JMP, 2012). To monitor progress the World Health Organisation and UNICEF's Joint Monitoring Programme for Water Supply and Sanitation (JMP) reports every two years on progress towards achieving this target (WHO/UNICEF JMP, 2012). Since 2008, the JMP has defined sanitation access using a sanitation ladder which goes from open defecation to improved facilities via unimproved and shared facilities (WHO/UNICEF JMP, 2014a). An improved sanitation facility is defined as one that *"hygienically separates human excreta from human contact"* (WHO/UNICEF JMP, 2014a). The definition is based on two main indicators; access to an improved technology type and the number of households sharing the facility (WHO & UNICEF, 2008).

Although huge progress has been made globally since the creation of the MDGs to improve the sanitation situation for the world's poorest, there is still an estimated 2.5 billion people who lack access to improved sanitation (WHO/UNICEF JMP, 2014b). Figure 1-1 below highlights the global distribution of improved sanitation access. Sub-Saharan Africa continues to have some of the lowest levels of coverage worldwide where only 30% of the population have access to improved sanitation and progress has been slow (5% point increase since 1990) (WHO/UNICEF JMP, 2014b). In urban environments globally, progress made has been outpaced by population growth and in 2012, 756 million lacked access to improved sanitation up from 215 million in 1990 (ibid).

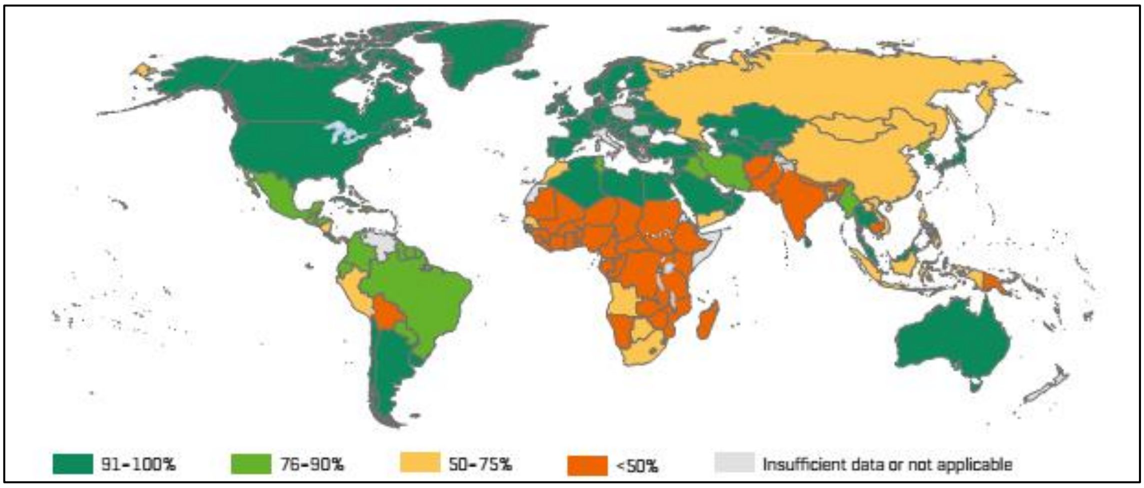


Figure 1-1: Proportion of population using improved sanitation in 2012 (WHO/UNICEF JMP, 2014b)

One of the most complex environments for urban planners to achieve sanitation access is in informal settlements. These have become commonplace in growing cities and towns within developing countries and are caused by rural-urban migration and natural urban growth which leads to rapid urbanisation. Rapid urbanisation is set to continue with a predicted 67% of the global population set to live in urban areas by 2050 (United Nations, 2011). In sub-Saharan Africa, urbanisation (at high levels and rates) is set to continue for some time and occur in the poorest regions, where planning systems and public institutions are less equipped to deal with the resulting challenges (UNHABITAT, 2009).

These informal settlements are often characterised by poor site conditions, low income, high population density, lack of legal land tenure, heterogeneous nature of the population, lack of planning, poor infrastructure and poor access to formal water, sanitation and waste management services (Hogrewe *et al.*, 1993; The STEPS Centre and Sarai, 2011). Beyond technical constraints these areas have tremendous social, political and institutional complexities inherent to them which cause barriers for the provision of basic services and require specific approaches for planning for interventions in such environments (Norström *et al.*, 2007; Lüthi *et al.*, 2010).

Within this thesis these types of settlements will be defined as informal settlements. Informal settlements are often seen as temporary entities which have administrative and jurisdictional ambiguity due to the lack of formal tenure or illegal status (Lüthi *et al.*, 2010). This causes a lack of commitment on the part of the authorities to take responsibility for the provision of basic services within such environments. There is often a lack of data on these settlements and in particular spatial maps, critical for the development of such areas (Netzband and Rahman, 2009; Hagen, 2010; Patel and Baptist, 2012). Authorities are often focused on the provision of high cost conventional sewerage (large scale sewerage infrastructure connecting individual households to an offsite centralised treatment facility) that serves a small minority of the population and is not cost effective for informal settlements (Mara, 1996; Lüthi *et al.*, 2010; Peal *et al.*, 2014a). In Africa for example, studies have shown that only half of the largest cities have sewerage networks and these serve only a fraction of the total population in each city (Banerjee et al, 2011) and that onsite technologies are used by 65-100% of populations in urban areas (Strauss *et al.*, 2000).

This neglect by city authorities causes households to become responsible for managing their own sanitation needs which often results in low-quality un-standardised sanitation facilities (i.e. pit latrine or septic tanks) being built (Scott *et al.*, 2013). These onsite facilities often only collect or contain the Faecal Sludge (FS) (the contents of septic tanks or pit latrines) and once full there are no systems in place to safely manage or exploit its potential value (through the removal, transportation, treatment and reuse or disposal- see Figure 1-2). In informal settlements these facilities are often shared by many households causing them to fill up frequently. However, due to the dense nature of such environments the safe abandonment and construction of new onsite facilities is difficult or in some cases impossible (Hawkins *et al.*, 2013). Therefore, there is a need to hygienically manage FS so that the onsite facility can continue to be used. The safe management of FS forms a key component of the proposed Water, Sanitation and Hygiene (WASH) post 2015 targets and indicators that will replace the JMP indicators discussed earlier. These have been a result of a large-scale consultative process involving leading organisations in the sector (WSSCC, 2014). Specifically in relation to sanitation the proposed indicators go beyond a sole focus on the containment facility and prescribes that the safe transportation of FS to a designated disposal/treatment site or treatment in situ will be required for households to be deemed to have access to a 'safely managed' sanitation service (WSSCC, 2014).

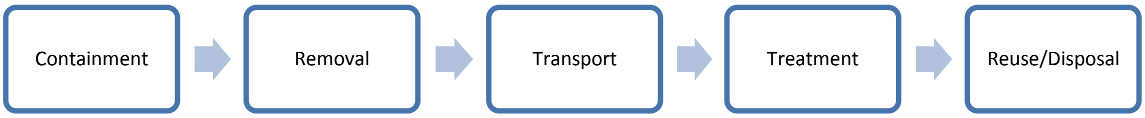


Figure 1-2: Sanitation Value Chain (Hawkins *et al.*, 2013)

Faecal Sludge Management (FSM) is one of the technical solutions available to provide a safely managed sanitation service. It involves the manual or mechanical emptying of FS from onsite sanitation systems to treatment facilities using road based transportation equipment (O'Riordan, 2009a). The role of FSM as a sustainable and affordable option for unsewered urban areas in low and middle income countries has achieved traction in recent years with many scholars emphasising its potential for meeting the global sanitation challenge (AECOM *et al.*, 2010; Chowdry and Kone, 2012; Peal *et al.*, 2014b; Strande, 2014).

Within the sanitation planning sector there are many different approaches that have been developed which attempt to address the shortfall in sanitation provision by providing guidelines of how improved sanitation provision can be achieved (Murray and Ray, 2010; Peal *et al.*, 2010). However, the lack of progress in the sector to date raises questions over whether such planning approaches are really working in achieving sustainable sanitation access for the millions that require it (McConville, 2010; Murray and Ray, 2010). One study concluded that more attention is needed to look at how the planning process is designed and conducted as there are major differences seen between what is set out in planning guidelines and what is implemented in reality (McConville, 2010). Other studies indicate that existing planning approaches provide inadequate information and recognition of complex dynamics inherent to informal environments and as such inhibit intervention success (Marshall *et al.*, 2009; Institute of Development Studies, 2012a). This situation creates questions around whether existing planning approaches and available tools provide suitable frameworks to support the planning and implementation of sanitation services in informal settlements and in particular FSM.

Recent work related to FSM indicates that more tools and approaches need to be developed which support decision makers on the ground (AECOM *et al.*, 2010; Peal *et al.*, 2014b). There are limited examples of implemented FSM schemes which are replicable for varying contexts (Opel and Bashar, 2013). In particular, there is limited financial information available to support the development of detailed cost analysis for FSM to establish its potential as a business and its profitability (Chowdry and Kone, 2012; Dodane *et al.*, 2012; Opel and Bashar, 2013). At the planning stage, decisions over possible technological solutions to improve sanitation access will predominantly be based on cost (Mara, 1996; Morella *et al.*, 2008). Investments in sanitation should reinforce rather than undermine the communities and government's current facilities and financial resources, in order to ensure success (Eales *et al.*, 2006). This is particularly relevant in informal settlements where users' ability to pay is limited. Scholars argue that funding from charities fail to cover anything beyond initial capital costs (Struss and Montanegero, 2002), that public subsidies fail to increase access and poor targeting of subsidies means the poor often do not actually benefit (Caincross, 2004). Therefore, where possible user fees should be used to achieve financial sustainability and ensure maintenance so that the extension and improvement of services can occur (ADB Group, 2010).

Despite being perceived as an affordable alternative to other technical solutions, such as conventional sewerage, there are a number of documents in literature that highlight that FSM projects have not been able to achieve full cost recovery (Parkinson and Quader, 2008; Yousuf and Mahmud, 2011). A lack of consideration for the long term operational, maintenance and capital costs, could be one cause for this problem which if not considered has shown to cause project failure or long term reliance on external subsidies (Koné, 2010). Therefore to ensure that a sustainable and affordable solution is implemented, and to ensure decision making frameworks for sanitation options are effective, the long term costs associated with each option are required at the planning stages (Palaniappan *et al.*, 2008; Thye *et al.*, 2011). Existing cost methodologies used typically only consider the first year of operation or the initial stages of the Sanitation Value Chain (SVC) and therefore do not achieve the above objective (Von Münch and Mayumbelo, 2007; Dodane *et al.*, 2012; Hutton and Haller, 2012).

A major barrier to the success of FSM solutions is reported to be the costs associated with the operation and maintenance of FS transportation vehicles and specialists indicate that more consideration is required of this component (Von Münch and Mayumbelo, 2007; O'Riordan, 2009b; Thye *et al.*, 2009; Chowdhry and Koné, 2012). The transportation component of the SVC is directly affected by the previous components of containment and removal. In particular, transportation requirements and therefore costs are directly influenced by the location of the containment facility, the accumulation rate and volume of FS and its emptying frequency (AECOM *et al.*, 2010). The accumulation rate of containment facilities are affected by factors such as the number of users, their behaviours and the overall design of the facility (Buckley *et al.*, 2008). In informal settlements the unregulated and unrecorded development of onsite containment facilities means it is difficult to make estimates related to FS accumulation rates. Some of this uncertainty can be reduced and containment facilities can be optimised through education, system design and service delivery (Still and Foxon, 2012).

This uncertainty causes the downstream FSM service requirements (removal, transportation, treatment and reuse) to be unpredictable. A better understanding of how to assess the status of a containment facility, how this effects the FS accumulation rate, how the accumulation rate impacts upon the subsequent components of the SVC and how all these factors impact the long term cost of FSM systems would be a useful contribution for the sector. This would support the planning and delivery of FSM systems and allow for accurate costing, billing and desludging schedules to be developed, thus moving away from unpredictable and ad hoc emptying service delivery which is inherent to such informal environments (Coulter and Coulter, 2002; AECOM *et al.*, 2010). Making steps to formalise and optimise FSM service delivery may also help to raise awareness about FSM and support its recognition as a 'proper' solution rather than a temporary or informal solution to the problem (AECOM *et al.*, 2010; Peal *et al.*, 2014a).

This thesis looks to support the status of FSM within the sector by addressing some of the gaps identified from within the literature. The research reviews the current urban sanitation planning sector and reports upon whether existing approaches are appropriate for the requirements of FSM technologies being implemented in informal settlements. To do so the thesis draws on primary data collected from household level questionnaires and Key Informant Interviews (KIIs) in the city of Lusaka, The Republic of Zambia. Lusaka was selected as the case study for this research because it provided a good example of a city in sub-Saharan Africa which is experiencing rapid urbanisation and where informal settlements have developed and associated problems of poor planning and basic service provision has ensued. Using the findings from Lusaka the research aims to identify practical improvements to existing approaches and develop decision support tools that could be used to support the planning and implementation of FSM within Lusaka and the wider sanitation sector.

1.3 Conclusion

This chapter draws upon literature and provides a background to the current global urban sanitation crisis. In particular the chapter highlights the problem of urbanisation for the sanitation sector, current urban sanitation planning methods available and how FSM may provide a plausible technical solution to achieving improved sanitation provision for the world’s poorest communities. The chapter indicates where there are gaps within the sector that this research hopes to address. The next chapter provides an overview of the research aims and objectives and the research strategy used.

Chapter 2. Aim, objectives and research strategy

2.1 Introduction

This chapter identifies how this research will fill the gap identified in Chapter 1. This chapter introduces the wider research consortium that this project was guided by and introduces the aim and objectives that were developed to fill the research gap. The research strategy and the data collection and analysis methods selected are outlined and rationales for each are provided. A schematic overview of the structure of the overall thesis concludes this chapter.

2.2 Wider EPSRC Consortium

This PhD is part of an Engineering and Physical Science Research Council (EPSRC) funded project entitled, 'A Global Solution to Protect Water by Transforming Waste' which was formed in 2011. The project is in collaboration with the Universities of Glasgow, Sheffield, Cranfield and Ulster, and the Institute of Development Studies, Brighton. The wider project centres on the development of a high-rate, eco-engineered, anaerobic digester for high-solids, domestic wastewater conversion to clean water and valuable products for implementation in informal settlements of developing countries. The role of this research within the consortium was to focus on the physical planning of collection, treatment and reuse solutions for FS and consider socio cultural, gender and economic factors which may affect the implementation of this developed decentralised treatment technology. Delays in the development and implementation of the technology meant that this research could no longer focus on collecting information solely for the planning and implementation of the project's digester because at the time when the fieldwork was conducted the design of the technology had not been clearly defined. Instead the research moved to focus more widely on understanding existing sanitation planning approaches, identifying critical social and technical factors required to make FSM systems work in complex informal settlements and identifying any gaps between them.

2.3 Research Aim and Objectives

The main aim of this research is to identify to what extent current urban sanitation planning approaches and practices are suitable frameworks for achieving sustainable

Faecal Sludge Management in complex informal settlements in Lusaka, The Republic of Zambia. Where required, suggestions will be provided to how improved planning and implementation of Faecal Sludge Management service delivery for informal settlements in Lusaka and for the wider urban sanitation planning sector could be achieved. The objectives developed to achieve this aim are as follows:

1. Review current approaches to planning for improvements in urban sanitation and highlight dominant processes and foci within the sector.
2. Present a situational analysis of current sanitation provision within informal settlements in Lusaka.
3. Examine the current FSM situation in informal settlements of Lusaka and identify key factors which may prevent access to improved FSM.
4. Investigate factors at the city and country level domains which may prevent access to improved FSM for informal settlements in Lusaka.
5. Develop a tool that aims to improve planners' ability to model FSM infrastructural network scenarios and provide long term cost projections for implementing FSM solutions for informal settlements in Lusaka.
6. Identify how an improvement in an understanding of each component of the SVC may promote sustainable FSM implementation and resource recovery from FS.
7. Evaluate how the findings gathered have implications for current urban sanitation planning approaches and practices and present adaptations that need to be made for the implementation of FSM service delivery in informal settlements of Lusaka.

2.4 Research Strategy

Section 2.3 presented the aim and key objectives of the research that drove the research strategy which will be presented and rationalised within this section.

A research strategy provides a framework for the collection and analysis of data and ultimately aims to provide useful conclusions (Bryman, 2008; Yin, 2009). Appropriate research design and associated methods selection depend on a number of factors; such as, resources available, the purpose of the research and the type of data required (Cohen *et al.*, 2007). Bryman (2008) classifies social research design into five different types: experimental; cross sectional; longitudinal; case study and comparative research design. Yin (2009) recommends the use of three guiding notions to aid in the selection of the most appropriate research design type, which are: a) the type of research question posed; b) the extent of control the investigator has on behavioural events; and c) focus on contemporary events rather than historical. The selection of the chosen research strategy was based on these conditions.

This research focuses on the sanitation situation at various decision making domains (section 2.6.2) and at different stages of SVC and therefore it is essential that the selected strategy is inclusive of the whole sanitation service delivery system with specific relation to FSM. Due to the nature and complexities of the research location (informal settlements) internal validity could not be assured and so a method where control was not required was deemed the most suitable. The research looked to focus on contemporary events and therefore those strategies which relate to historic events were not appropriate for this research. Based on these principals the shortlisted research design strategies were cross sectional design and case study analysis.

The research aims to establish if current urban sanitation approaches are suitable frameworks for achieveing sustainable FSM in informal settlements. The research looked to do this by collecting primary and secondary information from a range of domains. Therefore, a mixed methodology approach was identified as the most appropriate for this study, drawing upon the benefits of both cross sectional design and case study analysis. The use of a mixed methodology approach has many positive attributes. It can allow for the collection of large amounts of data within a limited timeframe; it can allow for triangulation of findings and increase the validity of the results gained; it can be used to provide completeness to the study; and can help to provide credibility for results and enhance findings (Bryman, 2008). One potential flaw with the use of these two methodologies is that the data collected is taken as a 'snapshot' and does not incorporate time (ibid). To overcome this the primary data collection methods used provided an opportunity for respondents and interviewees to discuss a historical perspective which may have led to the current sanitation situation and secondary data was reviewed to develop an understanding of how the sector or city had developed over time.

To be able to obtain the data required from the various domains and stakeholders (household, community, city and country level) it was identified that different data collection methods would be required that are based upon both quantitative and qualitative approaches. These will be discussed in more detail within the relevant chapters.

It is of important to note that the ontological position of Critical Realism was taken within the analysis. The realist position takes the view that there is a reality beyond our perceptions of it (Cohen *et al.*, 2007; Bryman, 2008). Critical Realism is a form of realism and acknowledges the need to identify the structures of society and generative mechanisms (events and discourses) in order to understand ‘reality’ (Bhaskar, 1989). The ontological position of Critical Realism fits well with the methodological approach used in this thesis as it recognises that knowledge is socially constructed and encourages the exploration of realist and constructivist perspectives as part of the research design.

2.5 Rationale for Research Location

At the beginning of the project two case study locations (cities in Africa and India) were selected for the project. During exploratory field visits to one of the proposed case study sites it became clear that this case could no longer be used. As a result the research focused on a single case study city due to the limited time and available resources for the research at that stage (one year into the research project). It was decided that due to the exploratory nature of the research, focusing on complexities around planning and providing FSM in such informal settlements, a single case study was suitable.

The pre-selection criteria for the research location were major cities that had low levels of current sanitation access, the existence of informal settlements and had an absence of recent conflict or political instability. Through contacts from the research consortium, links were made with two Non-Governmental Organisations (NGOs) working in the area of Water Supply and Sanitation (WSS) in low income countries. In October 2011, a colleague from the consortium and I undertook a scoping study to establish whether the city of Nanded, Maharashtra, India would provide a suitable case study location. Shortly after the site visit local elections were held which resulted in the gatekeeping NGO being asked to stop their work within the city. It was therefore felt that it would be too difficult to work in Nanded and use it as a case study location without their support.

Discussions with a second NGO, Water and Sanitation for the Urban Poor (WSUP), indicated Lusaka in the Republic of Zambia as a possible location to conduct this research. WSUP currently have a team based in Lusaka and in late 2012 embarked on a FSM project in one of the informal settlements in Lusaka. Due to available contacts on the ground (gatekeepers) and the new and novel work taking place in the field of sanitation provision in informal settlements, Lusaka was selected. The specific informal settlements studied were selected due to their current WSS activities, which will be discussed in more detail in Chapter 4.

2.6 Research Data

Once the research methodology had been defined the next stage was to identify which data would provide the best answers the aim and objectives. This section will provide information on the research framework, data sources used and a background to the methods of data collection and analysis. However, detailed methodologies are provided within each of the main chapters.

2.6.1 Decision making domains

Based on methods used in existing sanitation planning frameworks (Eawag, 2005; Parkinson and Luthi, 2013) the research was conducted at various decision making domains within the urban environment. The first decision making domain was the households, who manage and make decision related to their own sanitation situation. The second domain encapsulates the next level of the sanitation system being the community as a whole. All community based level institutions and stakeholders were grouped at this level. The final decision making domain captures those stakeholders and institutions that were involved with wider city and country planning and sanitation management or service delivery.

2.6.2 Data sources and variables

There were two different types of data sources used within this research: Primary data that was collected first hand and secondary data that was collected and presented by another person or organisation, both of which are defined below in the following section.

A number of primary sources and stakeholders were identified as good sources of information related to the current sanitation situation in Lusaka. These data sources were identified early on in the research through a stakeholder mapping exercise which looked to identify individuals, groups or organisations with an interest in, relevance to, or influence over the sanitation sector (Lüthi *et al.*, 2011). Table 2-1 highlights the various primary data sources and stakeholders selected within each decision making domain.

Table 2-1: Primary data sources from each decision making domain

Domain	Data sources
Households	1. Informal settlement with community based water providers and FSM service 2. Informal settlement with community based water providers 3. Informal settlement with water delivered directly by Commercial Utility
Community level stakeholders	1. Community based water providers 2. Ward Development Committees 3. Ward Water Committees 4. Pit Emptiers 5. Community Based Enterprises
City and Country level stakeholders	1. Water Regulator 2. Commercial Utility 3. City Council 4. University lecturers involved in WASH research 5. Ministries related to sanitation 6. NGOs working in sanitation

At the household level domain the aim was to gather data from a cross section of WSS typologies within informal settlements. At the community level, data was sought from locally based organisations that work or were involved in the WASH sector. Finally, the city and country level stakeholders included those that were involved in, planning for, or in charge of, the provision of sanitation in informal settlements in some way. Further details related to these stakeholders are discussed in Chapter 5 and 6.

In addition to the primary sources there was a large amount of secondary data collected from several departments and interviewees, mainly at the city and country level, whilst in Lusaka. The sources are referenced directly within the text. The aim of collecting and using this data was to strengthen the findings of the primary data and explore different perceptions where possible through triangulation (Roger, 2008; Borrego *et al.*, 2009).

2.6.3 Data collection and analysis methods

There was a range of data collection methods used within this research study, with Figure 2-1 providing a diagrammatic overview.

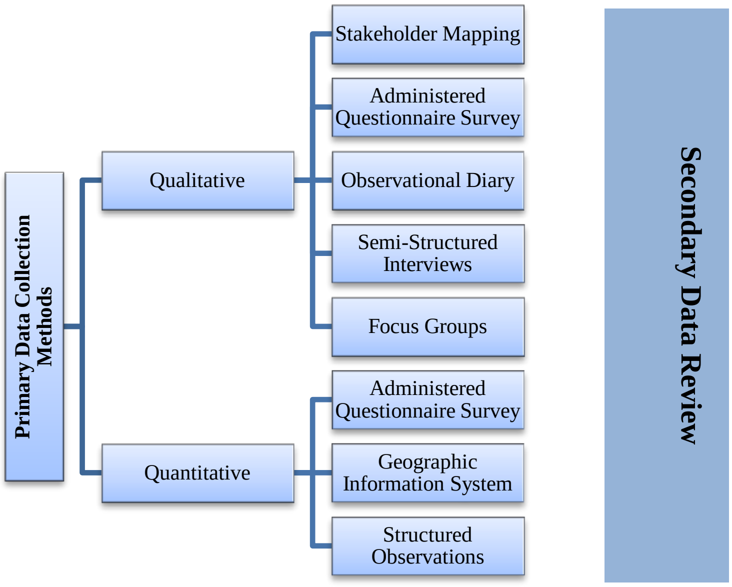


Figure 2-1: Data collection methods used in this research

Varying data analysis methodologies were used within this research to analyse both the qualitative and quantitative data that was collected. Detailed descriptions of the methods used and rationale for their use is provided within the related chapters of the thesis.

2.7 Timing of Project and Fieldwork

The EPSRC research consortium and this PhD research began in June 2011. Exploratory fieldwork was undertaken in Nanded, India in February and October 2012. However, the results of this fieldwork are not discussed in this thesis as the location was not deemed suitable. Fieldwork and data collection was done in Lusaka, Zambia from January-April 2013 and in December 2013. A summary of the primary data collected during this time is provided in Appendix A.

2.8 Structure of the Thesis

The chapters of the thesis are set out so that each chapter addresses one of the research objectives. This is depicted in Figure 2-2 which states which objective will be met by each chapter and includes the methodologies used within each chapter. Each of the remaining chapters includes its own introduction, in-depth methodology, results and discussion sections.

Chapters | **Research Objectives *(& Collection Methods)***

3
- **1. Review current approaches to planning for improvements in urban sanitation and highlight dominant processes and foci within the sector.**

4
- **2. Present a situational analysis of current sanitation provision within informal settlements in Lusaka.**
  - *Secondary Data Review*
  - *Stakeholder Map*

5
- **3. Examine the current FSM situation in informal settlements of Lusaka and identify key factors which may prevent access to improved FSM.**
  - *Administered Questionnaire Survey*
  - *Structured Observations*
  - *Focus Groups*
  - *Geographic Information System (GIS)*
  - *Semi-Structured Interviews*
  - *Observational Diary*

6
- **4. Investigate factors at the city and country level domains which may prevent access to improved FSM for informal settlements in Lusaka.**
  - *Semi-Structured Interviews*

7
- **5. Develop a tool that aims to improve planners' ability to model FSM infrastructural network scenarios and provide long term cost projections for implementing FSM solutions for informal settlements in Lusaka.**
  - *Geographic Information System*
  - *Secondary Data Review*
  - *Structured Observations*
  - *Adminstered Questionnaire Survey*

8
- **6. Identify how an improvement in an understanding of each component of the Sanitation Value Chain may promote sustainable FSM implementation and resource recovery from FS.**

9
- **7. Evaluate how the findings gathered have implications for current urban sanitation planning approaches and practices and present adaptations that need to be made for the implementation of FSM service delivery in informal settlements of Lusaka.**

Figure 2-2: Flow diagram of chapters, objectives and data collection methods used

2.9 Conclusion

This chapter describes the research aim and objectives and provides an overview of the methodologies used to achieve them. The chapter introduces the wider EPSRC ‘Transforming Waste’ consortium within which this PhD research was conducted and guided, and provides a rationale for the selected research location. The structure of the thesis and how each objective is addressed is depicted in the final section. The following chapter looks to answer the first objective of the research by reviewing current urban sanitation planning approaches.

Chapter 3. Review of Urban Sanitation Planning Approaches

This chapter is based on paper A, entitled 'Challenges for the future of urban sanitation planning: critical analysis of John Kalbermatten's influence.'

3.1 Introduction

This chapter aims to achieve the first research objective by providing a review of the current urban sanitation planning approaches that exist. The review aims to highlight dominant processes and foci which have developed in the sector since the late 1970s. In parts the chapter also draws on wider planning theory and the development of the planning sector in general.

In the late 1970s John Kalbermatten and colleagues at the World Bank led a shift in the approach to planning and implementation of urban sanitation in less developed countries. They were responding to the repeated failures of conventional sanitation solutions which were increasingly found to be inappropriate for the contexts in which they were being implemented. Kalbermatten was concerned that this would have disastrous consequences for the planned International Drinking Water and Sanitation Decade running throughout the 1980s. The new approach first formulated in the World Bank publication, 'A Planning and Design Manual' addressed not only inadequacies in the technology being recommended but also the planning failures that had caused so many inappropriate solutions to be selected in the first place (Kalbermatten *et al.*, 1982a; Kalbermatten *et al.*, 1982b). Since then a large number of urban sanitation planning approaches have been developed, each with unique ideas and methodologies but mostly stemming from those original conceptual foundations brought to the sector by Kalbermatten. This chapter looks to provide an overview of the main urban sanitation approaches developed in the last 30 years, to identify how John Kalbermatten impacted the sector and establish if recent planning tools are achieving in practice what Kalbermatten first set out to do. It also explores how understanding those initial concepts can guide the future of urban sanitation planning.

3.2 The World Bank Planning Paradigm

Before turning to more recent developments it is useful to consider how urban sanitation was developing in the late 1970s and John Kalbermatten's influence upon it. For industrialised countries, conventional sewerage (waterborne sewerage) had long been the technology of choice for the disposal of human excreta (Kalbermatten *et al.*, 1982b). This preference was also evident in less developed countries, with conventional sewerage being considered by engineers and planners as the only sanitation technology option for their cities (Mara, 1996). In reality, the high cost of installation, operation and maintenance of conventional sewerage systems and the need for an in house (onsite) water supply meant that conventional sewerage proved to be an inappropriate option for many developing country cities which lacked the regular fund flow to pay for proper operations. For these reasons it proved wholly inappropriate in rapidly growing low income and unplanned urban communities which were often excluded from the planning and implementation process (Mara, 1996). High expectations for sewerage continued despite limited capacity, inadequate financing and weak institutions in most cities and towns. Given the high costs of the solutions being recommended, investment was concentrated on capital and major cities and often resulted in systems which were only partially usable and rapidly fell into disrepair as funds dried up. The result was decades of slow progress within the sanitation sector (Kalbermatten *et al.*, 1982b). Proof of this remains with us today – a recent study estimated that even among water utilities serving Sub Saharan Africa's largest cities, only 50% offer sanitation services and of those with sewer networks only 50% of their service area has sewer coverage (Morella *et al.*, 2008).

3.2.1 Kalbermatten's big ideas

Kalbermatten and the World Bank proposed an alternative model of sanitation planning (Figure 1). The model refocused the attention of the engineers who were still largely leading planning efforts. The four underlying principles were:

1. To identify sanitation interventions that would provide maximum health benefits as Kalbermatten asserted that conventional sewerage was unsuitable because its aim was to maximise convenience,
2. To consider the whole range of potential sanitation technologies, selecting those that would provide as many people as possible with the required facilities,
3. To move away from a top-down technology-centred approach to planning and encourage the inclusion of additional professional disciplines,
4. To include the community in a more iterative planning process. The rationale of which was that an interdisciplinary project team would more successfully interact

with the community to identify a wider range of technically feasible, economically and financially affordable, and socioculturally acceptable sanitation options (Kalbermatten *et al.*, 1982b; Mara, 1996).

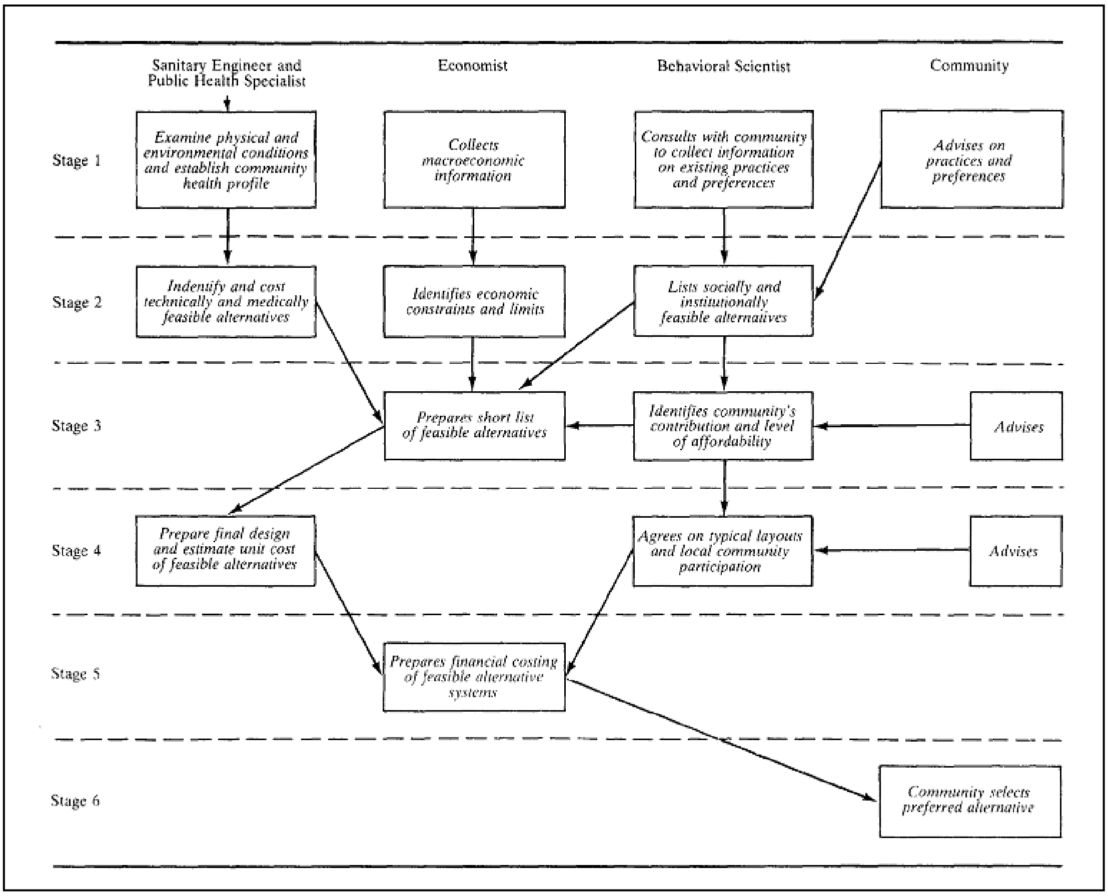


Figure 3-1: The World Bank model for sanitation programme planning (Kalbermatten et al., 1982b).

Principle 3 and 4 are in line with collaborative planning theory which has become a key approach within the planning sector since the late 1980s. This theory focuses away from centralised top down planning to one based on achieving collective rationality through open dialogue which then leads to consensus and action (Healey, 1997; Allmendinger, 2009).

3.3 The Evolution of Planning Approaches

3.3.1 The global landscape

Since the development of the World Bank model, events such as the International Decade for Drinking WSS along with numerous conferences and declarations have resulted in sanitation becoming more prominent in the global agenda for development. Consequently over the last 30 years a number of sanitation planning models have been developed which have shaped this sector. Figure 2 below presents a timeline of events which have been instrumental in shaping the urban sanitation planning sector and illustrates the contemporaneous planning approaches.

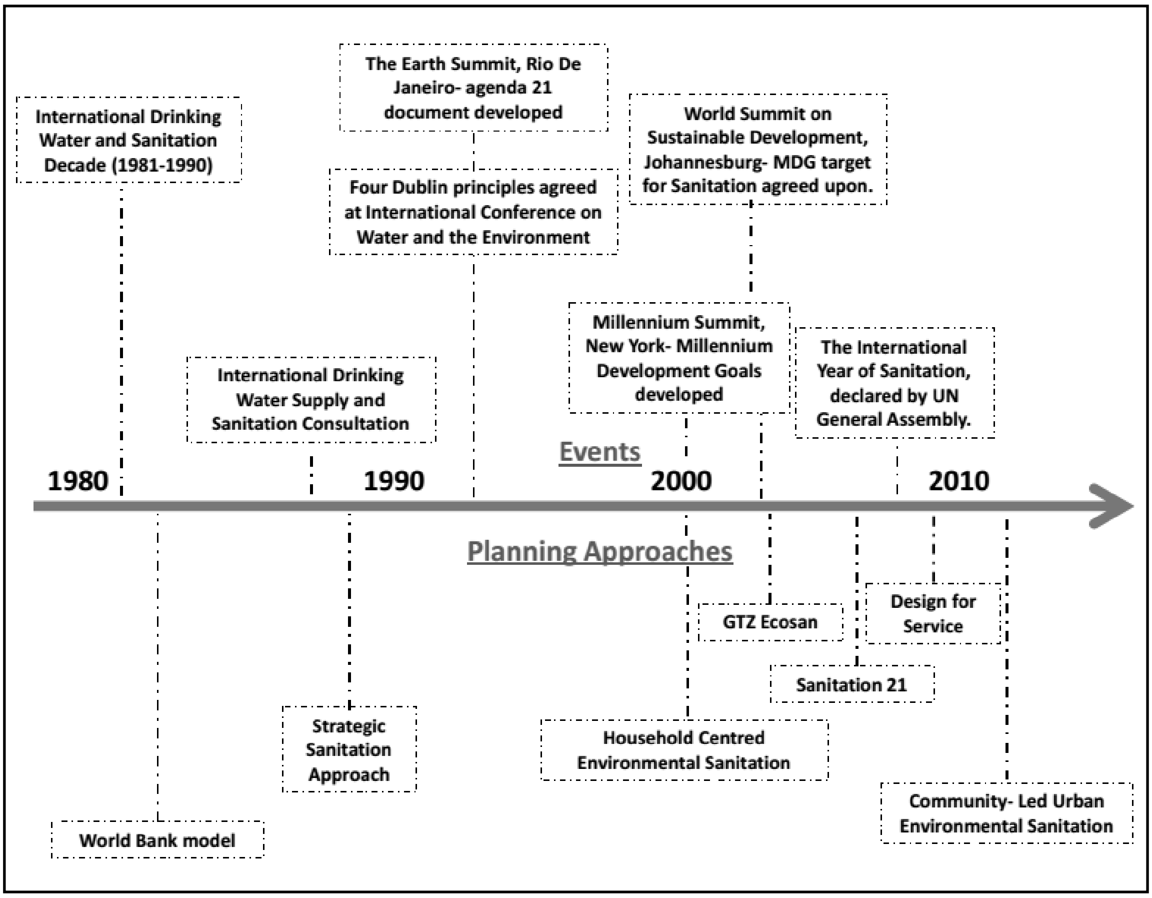


Figure 3-2: Timeline of development of selected urban sanitation planning approaches and significant events in sanitation sector

3.3.2 Kalbermatten's influence on evolving urban planning approaches

In the following sections urban sanitation planning approaches which have been influenced by Kalbermatten's concepts will be considered. An overview of their implementation in practice and their ability in achieving sanitation at scale based on the rationale set out by Kalbermatten is highlighted.

Strategic Sanitation Approach (1989)

The Strategic Sanitation Approach (SSA) also known as the Strategic Sanitation Planning approach, first described in 1989 by the UNDP-World Bank 'Water and Sanitation Program' (WSP), was strongly influenced by Kalbermatten, who was responsible for establishing WSP (Black, 1998). WSP developed the approach and used it to guide significant World Bank supported urban sanitation investment, pilot projects in Kumasi, Ghana and Ouagadougou, Burkina Faso. Since then it has formed the basis for a number of projects in India, Indonesia, Thailand, Brazil and Pakistan (Peal *et al.*, 2010).

Drawing on Kalbermatten's ideas the multidisciplinary team codified a planning approach which recognised that there was a pivotal point of action at the neighbourhood level. The key new idea was to respond to demand at the community level (an idea which drew strongly from recent developments in the rural water supply sector) where demand would be demonstrated both by the participation of communities in planning and management and by their willingness to pay for elements of the system.

The approach also considered incentives at each level, seeking to understand what motivated communities, local government and other actors along the SVC. An outcome of that approach was the idea that sanitation services could be 'unbundled' –different solutions could be used in different parts of the city (horizontal unbundling) and different management arrangements could be used along the value chain (vertical unbundling) (Tayler *et al.*, 2000; Peal *et al.*, 2010). The SSA also specifically encouraged a consideration of sanitation across the entire SVC (i.e. including collection, transport and treatment of waste as well as household level services). In relation to the four underlying principles of the World Bank model, SSA reiterates the importance of household level participation, the need for an inclusion of a multi-disciplinary planning team whilst introducing the idea that different technical solutions and services can be used for different situations/environments within one city.

While SSA worked well in Kumasi and Ouagadougou where there was significant technical and financial support, it presented challenges in cities with less planning capacity (WSP, 2000 ; Vezina, 2002; Colin *et al.*, 2009). Reports have noted that for such an approach to work (as with any planning approach) an 'enabling environment' needs to be created on the ground to specifically deal with such an incentive and demand based focus (Colin *et al.*, 2009; Murray, 2009; Peal *et al.*, 2010).

Household Centred Environmental Sanitation (HCES) (2000)

In 2000 the environmental sanitation working group of the Water Supply and Sanitation Collaborative Council (WSSCC) developed the so called 'Bellagio Principles', a set of principles for good urban environmental sanitation (Eawag, 2005). They state that human dignity, quality of life and environmental security should be at the centre of urban sanitation planning; decision making should involve participation of all stakeholders; waste should be considered as a resource and should form part of an integrated water resources and waste management process; and that environmental sanitation problems should be resolved at as low a level as possible (Peal *et al.*, 2010). Kalbermatten was part of the working group and was key in the conceptualisation of the Bellagio Principles; the underlying principles of World Bank model can clearly be seen within these (Kalbermatten *et al.*, 1999; Sandec and WSSCC, 2000).

Household Centred Environmental Sanitation (HCES) was developed to operationalise the Bellagio Principles. It was conceived by the WSSCC working group and further developed by the Swiss Federal Institute of Aquatic Science and Technology (known as EAWAG) and identified that for any plan to be successfully implemented an enabling environment needed to be established within which the hygiene or sanitation intervention operates (Peal *et al.*, 2010). To achieve an enabling environment certain requisites were to be met.

- An adequate level of **government support** for the project in terms of political support and favourable national policies and strategies
- A **legal framework**, with appropriate standards and codes at national and municipal levels
- **Institutional arrangements** that suit and support the approach of the project,
- Effective **training and communication** ensuring that all participants understand and accept the concepts
- **Credit and other financial arrangements** that facilitate the required level of participation and community involvement
- **Information and knowledge management** providing access to relevant information sharing experiences, training and resource materials, the development of new approaches and the dissemination of findings.

(Eawag, 2005).

This enabling environment framework goes beyond the multidisciplinary approach in Kalbermatten's original model and recognised that the entire institutional context influences whether appropriate planning can be achieved. This was highlighted in the experiences of WSP with SSA pilots in India. The HCES approach also formalised the value placed on the ecological effects of sanitation by the Bellagio Principles; particularly the idea of resources from sanitation being used as close to the point of production as possible and the link to integrated water resources planning – both of which were important ideas in the wider water sector of the time. This focus on ecological concepts may also have encouraged a consideration of technologies with stronger ‘ecological’ credentials when compared to conventional sewerage and pit latrines - although this is not particularly evident from case study literature. Like the World Bank approach, HCES aims to respond to the users’ needs and demands by ensuring they are placed at the core of the planning and implementation process (Peal *et al.*, 2010).

This approach has been extensively implemented in a number of locations. Evaluative literature is limited but available reports state that an ‘enabling environment’ was critical to success as; capacity and access to requisite professional skills was noted alongside local knowledge of existing sanitation solutions (particularly non-conventional ones), enabling institutional arrangements, government/authority skills and support, a suitable legal framework and access to the necessary financial arrangements (Peal *et al.*, 2010; Rohrer, 2010).

Sanitation 21 Framework (2007)

In 2007 the International Water Association attempted to ‘take stock’ of the state of knowledge around urban sanitation especially planning, and interpret this for the use of professional engineers working in less developed countries. The resultant framework, known as Sanitation 21, encourages technical professionals to think beyond ‘business as usual’ by reiterating key ideas from models such as those outlined by Kalbermatten, SSA and the HCES approach (International Water Association, 2006). The framework defines domains within which sanitation exists (from household, via neighbourhood and ward, to the wider city and beyond). These domains are defined by different social and political norms and structures and provide a framework, within which the approach can identify aspects such as stakeholder interests, stakeholder capacities, external factors and existing systems and their functionality and success (ibid). These domains can then map fairly accurately onto the technical elements of the SVC (collection, transport, treatment, disposal, reuse etc.). This allows for a more realistic assessment of the feasibility of a range of sanitation solutions by considering whether management capacity to operate it exists in the places where it is needed. Solutions to local problems are thus linked to feasible systems of collection, transport and disposal/ reuse of waste (International Water Association, 2006; Murray, 2009; Peal *et al.*, 2010). The outcome of this approach is predominately a masterplan or action plan and the approach draws upon rational planning theories. In particular, rational-comprehensive planning theory focuses on achieving an objective through expert led, quantitative analysis with often limited participation (Allmendinger, 2009).

Relating back to those four concepts defined by Kalbermatten this approach looks to go beyond the engineer by ensuring a wide range of stakeholders (including households) are included within the process. One could argue that the focus on influencing professional engineers may make Sanitation 21 less accessible for non-technical stakeholders. Another interpretation is that International Water Association considered that the professional engineers were the ones who had most to gain from a deeper understanding of the non-technical, institutional aspects of effective sanitation service delivery. In terms of technology selection Sanitation 21 once again highlights the importance of understanding the entire SVC and opens the door to technologies which optimise ecological value. This approach seems to focus less on health specifically but instead on how effective and efficient the chosen technology will be within the defined environment. There is currently no documented evidence of this approach having being tested on the ground so it is difficult to establish its success in implementation. A new document redefining the Sanitation 21 approach was released in September 2013 and draws on other tools such as the Community-Led Urban Environmental Sanitation (CLUES) approach (see below) to ensure a more participatory and collaborative focus within this planning framework (Parkinson and Luthi, 2013).

Community-Led Urban Environmental Sanitation (CLUES) (2011)

The implementation of the HCES approach highlighted the importance and the challenge in achieving community participation (including the household level and beyond) in the planning and decision making processes and prompted the development of the new hybrid planning framework, CLUES (Lüthi *et al.*, 2011). CLUES provides a seven step approach to planning for environmental sanitation (water supply, sanitation, solid waste management and storm drainage) which emphasises the importance of broad community involvement as well as encouraging a multi sector and multi actor approach (Lüthi *et al.*, 2011). As with the HCES approach, CLUES calls for an enabling environment to be established that provides the required conditions for sustainable environmental sanitation intervention (identical to HCES approach). This approach addresses some of the pitfalls seen in the earlier HCES and identifies the importance of the processes of Awareness Raising and Communication, Capacity Development throughout the planning process and also returns to the theme of SSA by highlighting the importance of monitoring and evaluation, ensuring accountability and tracking success of the intervention throughout. This approach expands upon some of Kalbermatten's original concepts especially the importance of household level inclusion in the planning process. It further develops the idea of the enabling environment and refers to the need to include expertise from different sectors and roles. Building on Bellagio it highlights the importance of viewing waste as a resource and as integral to a sustainable solution. This is a new approach with little evidence of its successful implementation on the ground. Notwithstanding this the Centre for Urban and Regional Excellence, in partnership with Eawag-Sandec, with the financial support of the German government, has utilised this approach for preparing slum upgrading plans (which include ward strategy papers and detailed project reports) in Raipur, India, as part of the Slum Free Cities in India programme (Eawag, 2012; Eawag, 2013).

3.3.3 Other urban sanitation planning approaches

While it is possible to draw a direct conceptual link between Kalbermatten's original model and the subsequent development of SSA, HCES, Sanitation 21 and CLUES there are other urban sanitation planning approaches which have emerged from parallel traditions or developments. Despite their alternative provenance many show conceptual consistency with some of Kalbermatten's principles and are discussed below.

GTZ Ecosan Approach (2003)

In 2003, the German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit), GTZ (now known as GIZ) developed a set of tools which encourage the use of ecological sanitation solutions. It is linked to the Bellagio principles but it strongly places ecological considerations at the heart of any sanitation intervention, with other objectives being secondary. Consequently a toolbox was developed to provide planning guidelines for so called Ecosan technologies (Werner *et al.*, 2003b). The toolbox emphasises that ecological sanitation is not synonymous with a particular technology but rather an idea that encourages recycling oriented resource management (UNESCO and GTZ, 2006). However, many observers conflate the use of the term Ecosan to the specific use of urine diverting dry toilets.

It incorporates a ten step model, adapted from the HCES model containing the stringent requirement to recognise human excreta and water as a resource to be exploited rather than a waste (Werner *et al.*, 2003b). It also acknowledges the need for an enabling environment to be in place but also highlights how elements of the environment may need to be refined to incorporate the Ecosan philosophy. This approach encourages a move away from conventional technology options to consider the use of a variety of technologies for the whole SVC. Although there are a number of schemes which have used this approach there is little evaluative data available (UNESCO and GTZ, 2006). Observations indicate that elements such as awareness raising and planning for reuse are more demanding as Ecosan is still a fairly unknown concept in many places (Panse *et al.*, 2007).

Design for Service Approach (2009)

Recently the 'ecological' view of sanitation has prompted a serious reconsideration of the products of sanitation (specifically nutrients and water). The Design for Service is a five step planning approach developed by Ashley Murray as part of her doctorate (Murray, 2009). It presents a radical change of approach and highlights the importance of identifying sanitation solutions and participating with stakeholders at the downstream (reuse) elements of the SVC as a starting point. This planning approach emphasises the importance of health but also highlights the importance of the end use functionality of the sanitation system to ensure the success of any system implemented. This may result in a reduction of conventional sanitation solutions as those solutions which provide the best downstream solution (i.e. for reuse) will be prioritised. The model has withstood some initial testing during its development in China and Ghana, however further evaluation of its implementation and usefulness is required.

City Sanitation Plans

City Sanitation Plans are a recent development in Urban Planning Departments in a number of countries. Taking a holistic approach to city planning enables City Sanitation Plans to be embedded in city budgets and to relate constructively to other service provisions thereby addressing many of the implementation challenges faced by sanitation planners who would otherwise be working with technical departments alone. In a number of developing countries production of these plans by local government have been linked to financial incentives with the preparation of City Sanitation Plans being required by state or central government. These plans take both technical and non-technical aspects associated with delivering sanitation at citywide level into consideration and many draw upon the fundamentals of the planning models and approaches identified in the earlier sections. Frameworks and in depth guidelines for City Sanitation Plans have been developed by a number of supporting organisation in a variety of cities. In India a number of organisations have supported the National Urban Sanitation Policy for India. These include the WSP and Centre for Environmental Planning and Technology University, GIZ, Bremen Overseas Research and Development Association (BORDA) and the consortium for DEWATS (Decentralized Wastewater Treatment) dissemination society; and the Indian local governments departments for sustainability (Government of India, 2008; CEPT, 2010; WSP, 2010; BORDA, 2012; GIZ, 2012). WSP have also supported sanitation planning in Indonesia (WSP, 2010) and beyond Asia, Programme Solidarite Eau have supported local authority led planning in various cities in West Africa (Programme Solidarité Eau, 2012) and a number of experiences can be seen from Brazil (Aroeira *et al.*, 2010; Wartchow and Daronco, 2013). Shortcomings have however been identified with the City Sanitation Plan approach and these, once again, primarily relate to the funding challenges first identified by Kalbermatten and the capacity/enabling environment gaps first identified in SSA (Government of India, 2008; WSP, 2010).

3.4 Emerging Characteristics and Concepts

3.4.1 Linear and parallel developments

Over the last 30 years a succession of multidisciplinary teams have produced a series of credible planning frameworks which could be usefully deployed by local governments motivated to prepare serious urban sanitation plans. Within this review approaches to urban sanitation planning can be seen to be broadly linear (with a few diversions along the way) and there is an encouraging consistency throughout indicating that the underlying planning process is well understood and will continue to be relevant into the future. There are other concepts which have emerged from within the sanitation sector and wider developmental arena which have had varying levels of impact on the approaches taken to urban sanitation planning. The following section briefly explores some of those concepts, to assess how they relate to the World Bank’s paradigm and identify how they are being implemented in practice.

3.4.2 Focus on health

The World Bank model proposed that any technology intervention should be implemented to maximise health benefits. This analysis has highlighted that some of the approaches developed have moved away from focusing on health, reverting instead to a focus on technological functionality, particularly ecological functionality. There is no evidence currently available to suggest that demoting health improves sanitation service delivery. For approaches such as the GTZ Ecosan Approach, the focus on ecological functionality may result in prescribed technologies being promoted at the expense of others which may offer greater health benefits. In practice the enforcement of ecologically based technologies in urban areas has shown to be a difficult one due to the complexities of the environment itself and the requirements needed for such a system to function properly (e.g. enabling environment). On a more general level, connection between improving sanitation conditions having a positive impact on health is taken as a given. A shift away from health objectives may not be critical provided that there remains a focus on improving access to services which work for as many people as possible. Perhaps Kalbermatten's main contribution was to prompt a consideration of objectives in the first place which had rarely been the case up to that point.

3.4.3 Sanitation Value Chain

Since Bellagio the idea of sanitation as a resource has been widely acknowledged and has become a key concept in urban sanitation. To be successful, it has to link management of wastes (at the household level) via collection, transport and treatment to ultimate reuse or disposal of by products. The early World Bank teams had a solid understanding of the technical SVC, however this understanding was so strongly embedded in the conventional approaches to sanitation that Kalbermatten challenged that it was never explicitly referred to in the World Bank approach.

The term 'Sanitation Value Chain' has uncertain provenance but has been used increasingly in recent years by organisations including the Gates Foundation. It neatly illustrates the real technical and institutional challenges of urban sanitation which has to function at both the private household level and the public network level. SSA made this dimension of urban sanitation more explicit through the introduction of institutional and technical unbundling along the value chain.

Despite the perceived benefits of viewing waste as a resource there is little evidence that cities are moving towards viewing sanitation as a resource generating sector. There is little evidence that any urban sanitation planning approaches have successfully stimulated reuse of the products of treated domestic wastewater. This is not surprising since it is not holistically incorporated into all stages of any of the planning processes discussed (Murray, 2009). It also suggests a genuine challenge for the sector, namely that those people who currently control sanitation investments themselves do not value the resources of sanitation. There are numerous technical and cultural reasons for this with lack of knowledge and capacity playing a part. In countries with high capacity and severe resource constraints, a much more progressive approach has been evident for many years (Kfouri *et al.*, 2009). For such approaches to become more widespread knowledge about appropriate treatment and post treatment, interventions are needed. To achieve this in practice, a stronger focus on the downstream elements of the value chain (similar to that presented by Design for Service tool) would be needed, although gaining acceptance of this idea at community and city level remains challenging.

3.4.4 Sanitation ladder

The 'Sanitation Ladder' is a term widely used to describe a stepwise process by which communities or households may progressively experience improved sanitation. The idea recognises that sanitation imparts benefits of varying magnitude and differing nature depending on both the type of facility available to the user and the extent to which waste is subsequently well managed in the value chain. Often the focus of sanitation ladder analysis is on the household experience. Thus for example, since 2008, the JMP has reported global access to sanitation using a step scale from open defecation, via unimproved facilities to improved facilities, where 'improved' is a technology based indicator used as a proxy for sanitation which is more likely to deliver health benefits (WHO/UNICEF JMP, 2012). Many commentators feel that access to 'improved sanitation' is a poor indicator towards progress (Shordt *et al.*, 2004; Sutton, 2008). Others note that the reporting in JMP creates incentives for countries to take a technology based approach to regulation and policy which can hamper innovation (Kvarnström *et al.*, 2011). This in turn reduces investment in the SVC as a whole.

To address these concerns Kvarnström *et al.* (2011) developed the 'function approach' ladder which moves away from describing predefined technologies and focuses on assessing the outcomes or effects of any given sanitation system. This approach assesses how excreta is managed throughout the whole SVC rather than just at the collection point and a resource orientated focus is integral to the ladder. A clear focus of this approach is to put the health functions of the sanitation system at the earlier rungs of the ladder which once achieved then concentrates on the environmental functioning of the system. This is in line with Kalbermatten's focus where health should be of primary importance. The ladder also highlights that sanitation provision is often a dynamic process where incentives may change as progress is made. In this sense it also brings forward the idea that the enabling environment can develop progressively as the ambition of sanitation interventions grows over time i.e. higher or later rungs on the ladder have higher costs and management and logistical requirements associated with them.

3.4.5 Enabling environment

Since Kalbermatten an almost universal theme within urban sanitation planning has been the need for a conducive enabling environment. This is said to define aspects of the political, economic, educational, sociocultural, organisational, technological, and legal framework (or sometimes, captured in the term 'institutional' in its broadest sense) within which the sanitation intervention operates (Peal *et al.*, 2010). The concept indicates what needs to be in place for planning to be successful in practice (Eawag, 2005). Another key factor sometimes noted is how the built environment can impact on the potential and outcome of sanitation interventions (Peal *et al.*, 2010). The concept of the 'enabling environment is far broader than the need for inclusion of an interdisciplinary project team first noted by Kalbermatten, but the latter is clearly predicated on the former. Unfortunately, a common theme throughout the literature of urban sanitation planning, and in particular the small canon of case studies and evaluations, is the almost universal failure or absence of the required enabling environment. CLUES practitioners try to address this problem in part by highlighting that it is not only vital to ensure that the correct stakeholders and sectors are included in the planning process but that those individuals and institutional bodies are aware of the importance of sanitation, have the capacity to deal with planning for and implementing sanitation interventions, that knowledge and understanding can be transferred between people and they can monitor and be held accountable for failings in providing acceptable outcomes. Nonetheless it is clear that in most cases the absence of the appropriate institutions and capacities severely constrains both willingness to prioritise sanitation in general and sanitation planning in particular, and the ability to handle the complex process of planning once it begins. Once low income and informal settlements are included these failures only appear to become more marked.

3.4.6 Household participation

Household participation has become integral to all urban sanitation planning approaches. Participation has the potential to overcome any lack of effective demand for sanitation experienced on the ground and to help develop long term project sustainability. Ensuring upstream users (households or communities) are included in the planning process helps develop a sense of ‘ownership’ (Mara, 2005). This post-Kalbermatten shift in promoting the use of participatory approaches has not only been seen in the sanitation sector but also in water, health and hygiene. However, few studies have been completed which show how participation has been undertaken or which explore the relationship between participation and achieving long term project success. Overall, studies which are available conclude that participation is often undertaken with a ‘tick box ‘approach and that pre-defined objectives and expert led solutions are actually implemented with little understanding of what users really want (Jones, 2003; Nance and Ortolano, 2007; McConville, 2010).

Commentators note that for participation to truly work it must be deeply institutionalised in order for both the process to be properly facilitated and for the ‘state’ to be responsive to the demands of the community. Evidence shows that those interventions which work best do so because of their ability to be sensitive and adaptable to variations in context (Reed, 2008; Mansuri and Rao, 2013). It is noted that the institutional structure within urban sector institutions could have an impact on how successful participation/demand driven approaches are as they are typically set up with a supply orientated focus and therefore may not be adequately staffed or trained to undertake participation in reality (Cotton and Saywell, 1998). Literature, also suggests that participation should emphasise iterative and two way learning between participants and stakeholders from very different knowledge and perspective backgrounds (Reed, 2008) but in reality this cyclical process is rarely seen; there is usually limited honest informative feedback that helps to facilitate learning between the inner and outer circles of stakeholder groups (Mansuri and Rao, 2013). This disconnect may be due to the nature of institutions and the incentives that drive individual action or it may be closely related to issues around trust (Wright, 1997). Once again it is the ‘enabling environment’ that appears to be critical – since participation needs to be underpinned by ‘a philosophy that emphasises empowerment, equity, trust and learning for it to be successful’ (Reed, 2008). This takes two forms by ensuring the participants have the power to influence the decision and by ensuring participants have the technical capability to engage effectively with the decision making (Reason and Bradbury, 2008).

3.5 Challenges for the Future

3.5.1 Planning in practice

Although sanitation has become more prominent on the global agenda, progress has not been made at the required scale and speed. In urban and peripheral urban areas in particular progress often fails to keep up with the pace of population growth and coverage rates are actually falling (WHO/UNICEF JMP, 2012). In urban areas, improved planning is likely to be a part of the solution although not the entire solution. What is perhaps most striking about urban sanitation over the past thirty years is the lack of evaluation of implementation experiences of approaches discussed in this chapter. This is not surprising as in reality, sanitation in urban areas is said to be delivered in an ad hoc fashion, if at all, and few cities identify it as an investment priority or are prepared to invest time and resources in planning for efficient and effective service delivery (Tayler and Parkinson, 2005). Even where sanitation planning is undertaken, experience suggests that capacity and skills gaps persist. Numerous commentators have noted how lack of knowledge of new developments results in the propagation of old fashioned approaches and solutions which do not meet the needs of people (Nance and Ortolano, 2007; McConville, 2010; Lüthi and Kraemer, 2012). In particular, 'participation' does not appear to be yielding the results expected in terms of improved tailored and effective local solutions. Wright (1997) identifies that the challenge for governments and donor agencies is to motivate and build the capacity of the different stakeholders to participate in appropriate and productive ways. This coincides with others who note that adequate sanitation knowledge is required at the local level to achieve universal sanitation access (Mara, 2013). Large capacity deficits exist at all levels in key water and sanitation agencies in most low income countries caused by adverse institutional structures and systems of incentives, as well as insufficient funds (Cavill and Saywell, 2009; DFID and IWA, 2010).

3.5.2 Learning from the past

There is a lack of case study evidence regarding the implementation of urban sanitation planning approaches and where there is evidence this is mainly based on short run reporting rather than ongoing monitoring or repeat evaluations of success. The SSA for example, was identified as a success based on several case studies which were published during the planning phase and shortly after but since then little continuous monitoring and reporting of its ongoing success has taken place. This lack of long term monitoring creates gaps in knowledge about real impact of interventions and reduces potential learning for the future as most evaluations and reporting take place immediately after the project is implemented (FAO, 2010; Jones *et al.*, 2013; Mansuri and Rao, 2013). Few urban sanitation planning approaches place much emphasis on accountability– which would require both an explicit definition of outcomes and the development of associated monitoring and evaluation processes. Accountability is implicitly assumed to arise through processes of participation but there is no evidence that this actually happens in practice.

Knowledge gain through experience seems to be implicit in the successive and cumulative development of increasingly sophisticated planning approaches outlined here but there is almost no record of the basis upon which those developments were made. Conclusive evidence regarding the relative importance of the various planning principles underpinning these approaches could potentially be generated if case studies could be revisited; the cohort of well documented planning approaches described here provides a potentially fascinating basis for a historical review of the impact of planning on sanitation service delivery. For future interventions, greater attention to long term monitoring would also be highly valuable and enable lessons to be learnt and shared more openly.

3.5.3 Inherent problems for urban sanitation planning

Across all the approaches covered in this paper there appears to be recognition of some common constraints to effective sanitation planning and associated sanitation investments. Lack of political will is cited on numerous occasions, evidenced by the low priority given to sanitation via government policies and budgets (Tayler and Parkinson, 2005; Cairncross *et al.*, 2010). Although more market based and participatory planning models can achieve some traction at the local level, the physical nature of the urban environment and the need to manage some aspects of sanitation collectively, means that public support (and successful participation) will always be needed to ensure that the entire SVC functions. Local demand for improved environmental conditions will rarely be sufficient to support the costs and institutional challenges of coordinated sanitation in the urban space. Thus urban sanitation always requires an explicit institutional commitment to planning and service delivery (Evans, 2005; Tayler and Parkinson, 2005). However there is an inherent problem in those public institutions who are mandated to deliver such services as they generally appear to have low capacity and to be severely under-resourced (Evans, 2005; Cairncross *et al.*, 2010). They also tend to lack a planning culture being more commonly focused on addressing crises in an ad hoc and non-systematic way (Tayler and Parkinson, 2005). Their ability to plan for and engage with communities and households in order to understand and influence household behaviours and the role of community action as a means to creating an 'enabling environment', thereby achieving increased demand for sanitation, is also usually weak (Evans, 2005). Finally, these institutions are inherently unable to hold themselves accountable through the collection of credible evidence for monitoring purposes and evaluation of their progress (ibid).

3.5.4 Going forward

It is evident that the challenges of delivering urban sanitation go beyond the need for better planning. The institutional constraints that hold back planning and investment in such an essential service generally constrain all aspects of urban governance; provision of most critical services, from housing to education, remains ad hoc and chaotic in many rapidly growing poor cities. Nonetheless, sanitation can be seen as a touchstone for urban governance; a city which can provide its' citizens with a functioning, articulated urban sanitation system is well placed to deliver much more. But similarly, the delivery of urban sanitation cannot surmount structural failings in the city at large; a rational sanitation plan is no match for politically motivated land developers' intent on withholding basic services from informal settlements. Perhaps the critical point here is this; just as Kalbermatten called for an iterative planning process based on the understanding of what is on the ground already, sanitation planners need to invest more time in understanding the nature of the problem to be solved and the capacity of the existing systems to address those problems. Despite many of the planning approaches referred to in this chapter prescribing some form of situational analysis as part of the planning process there it still a need to understand and engage with the realities more. We may wring our hands at the failure of the enabling environment, but perhaps we could achieve more by working with what exists and doing at least part of the job in the right way in the short term. The recent focus on the SVC and ecological objectives tends to push decision makers towards achieving the perfect complete system in one leap, but the functional sanitation ladder should remind us that even sanitation system development can be progressive, with progressive marginal gains keeping step with progressively strengthening institutional capacity.

3.6 Limitations

There are other sanitation planning approaches and perspectives to be seen in the literature but there has been an attempt to bring focus to this analysis by taking the four principles articulated by the World Bank team in the 1970s as a starting point. The limited empirical data that exists means that such a review must be highly speculative. Furthermore, the conclusions drawn here are generalised rather than specific to any given case. Despite these limitations is possible to trace the influence and linkages of successive attempts to articulate effective urban sanitation planning tools and to use this as a pointer towards more effective interventions in the future.

3.7 Conclusion

This chapter has established how John Kalbermatten and the World Bank model impacted upon urban sanitation planning and how subsequent planning approaches have evolved. The chapter sought to demonstrate conceptual links and tensions between the differing perspectives of optimising health gains, increasing the repertoire of potential technical solutions; multi-disciplinariasm, the SVC, the functional sanitation ladder, the enabling environment and participation.

The trajectory of change is complex; firstly the focus on health has increasingly been challenged by a move towards a focus on achieving ecological outputs within sanitation and the need to holistically achieve access along the whole SVC. The introduction of ‘enabling environment’ is more sophisticated than the call for multidisciplinary. As identified by Kalbermatten, household participation is still inherent to every planning approach, despite the lack of evidence about how best to do it, or indeed the relationship between participation and long term success of the approaches on the ground. However, beyond this it is argued that real progress in the sector cannot occur without better evidence of what really works and a better understanding of where we are now and a realistic notion of how to get to where we need to be. We need a commitment to better long term monitoring and evaluation of the effects of urban sanitation planning and its connection to investment and improved service delivery. If in the process we can also contribute to building a stronger enabling environment, greater capacity, more effective participation and more accountability this will all be to the good; John Kalbermatten would have asked for nothing less.

Chapter 4. Analysis of the Sanitation Situation in Lusaka

4.1 Introduction

This chapter aims to meet the second objective of the research by presenting a situational analysis of the current sanitation provision within informal settlements in Lusaka, The Republic of Zambia. The majority of the information presented is from secondary data sources (explicitly highlighted where it is not). Each source was critically analysed to gain an in depth understanding of the factors that may affect the sanitation situation in Lusaka.

4.2 Background to Lusaka

The Republic of Zambia is a landlocked country in Southern Africa and forms part of the sub-Saharan African region (Figure 4-1). It was formerly Northern Rhodesia, a British protectectorate and gained independence in 1964 (WHO, 2011). Historically, its main economic activity was based around the copper mining industry. Since the 1970s it has faced economic difficulties, however it has seen continuous economic growth in recent times and has achieved ongoing political stability (The World Bank, 2014b). It is now defined by the World Bank as a 'lower-middle income' level country meaning it has an average gross national income per capita of $1,026-$4,035 (The World Bank, 2012). Table 4-1 highlights basic demographic and economic statistics for the country. Prior to 1991, a one-party political system based on socialism was in place. Constitutional change occurred after 1991 (caused by pressure from the population) and a multi-party government was implemented (Burnell, 2001). Policies introduced by this government included the liberalisation of the economy and reforms to the entire public service management system (NWASCO, 2004).

Table 4-1: Demographic and economic statistics for Zambia (United Nations, 2014b)

Demographic and Economic Indicators	Results
Population (2012)	14,075,000
Population density / km^2 (2012)	18.7
Urban Population (%) (2013)	40
Gross national income per capita (US$) (2012)	1402.6
Life expectancy at birth (females and males, year) (2010-2015)	59.5/55.9
Infant mortality rate (per 1000 births) (2010-2015)	65.5
Education: Female third- level students (% of total) (2006-2012)	31.6%

Lusaka is the capital city and is located in the south-central part of the country (Figure 4-1). The majority of the country's population reside here along with the Copper Belt province to the North West. The population of Lusaka province was recorded in the 2010 census at approx. 2.2 million with an annual growth rate of 4.7% (Central Statistics Office, 2012). Results from the Demographic and Health Survey (2007) show that Lusaka is the most urbanised province and has the highest proportion of people in the highest quintiles of wealth compared to other provinces (Central Statistical Office *et al.*, 2009). These wealth quintiles are based on data related to a household's ownership of goods, dwelling characteristics, types of drinking water sources, toilet facilities and other characteristics related to a household's socio-economic status. The United Nations Habitat report (2007) stated that only an estimated 9% of city's population is engaged in formal employment with the majority of the city's economy coming from wholesale and retail trade, government employment as well as urban agriculture and hunting.

Figure 4-1: Map of Zambia (Ezilon Maps, 1999)

4.2.1 Urbanisation in Lusaka

Lusaka is noted as experiencing problems associated with urbanisation such as population growth, high levels of unemployment, lack of services and inadequate waste management (UN Habitat 2007). Zambia has historically experienced problems with housing and a large increase in the development of unauthorised houses was seen in urban areas after independence as a result of the minimal spending and provision of low-cost housing by government (Todd, 1987). In Lusaka, the majority of the urbanisation has shown to have occurred in peri-urban areas where over 60% of the city's population are reported to reside (Government of The Republic of Zambia, 2011). In Zambia, peri-urban areas can be defined as *"settlements which grow out of the periphery of formal or planned municipal areas without being subjected to any form of planning control and also lack basic services such as water supply, sanitation and solid waste collection"* (NWASCO, 2011), definied in this study as informal settlements.

PhD research conducted by Banda (2013), which focused on identifying suitable institutional mechanisms to improve water supply in informal settlements of Lusaka, indicated that having an understanding of how informal settlements have developed is important in understanding the current service provision situation.

In Zambia, the **Local Government Act of Zambia Cap 281** (GRZ, 1991b) stipulates that the municipal authority (Lusaka City Council (LCC) for Lusaka) is responsible for infrastructural development within their area of jurisdiction. Where this responsibility is not met and there is an absence of planning regulation, settlements develop in an informal and unplanned way. There has been little or no insistence on statutory building standards in Lusaka since the post-independence era (1964 onwards) (Banda, 2013). Informal settlements that developed in such a way are devoid of legal backing and therefore residents lack security of tenure (ibid). Banda's (2013) research highlighted that there are inherent complexities around tenure in informal settlements in Lusaka caused by inconsistency or conflict within existing legislation and this may be one reason for poor service delivery.

Contradictions exist in legislation that impact upon the legal status of settlements. The laws that govern settlement development define informal settlements as illegal (the **Local Government Act of Zambia Cap 281** (GRZ, 1991b) and the **Town and Country Planning Act Cap 283** (GRZ, 1962)) whilst those that oversee elections give informal settlements recognition as polling districts (the **Electoral Act** (GRZ, 1991a) and the **Local Government Election Act** (GRZ, 1991c). In the Zambian case study it is clear that precedence is given to legislation which enhances political advantage. This is shown to be commonplace worldwide as informal settlements serve as important areas where a large proportion of votes can be achieved and thus governments are more likely to give precedence to any legislation that enhances their political status (United Nations, 2003). Banda (2013) states that this inconsistency puts municipal authorities in a difficult position when trying to provide services due to the ambivalent legal status of such settlements.

The **Housing (Statutory and Improvement Areas) Act Cap 194** (GRZ, 1975) attempts to address these legal inconsistencies and has been used in Lusaka to grant legal recognition to informal areas with the eventual provision of legal titles to its residents. However, there are still a number of informal settlements without legal status that struggle to obtain it (Lusaka Times, 2014) and even in settlements which have gained legalisation, a lack of service provision still prevails.

4.3 The Status of the Enabling Environment for the Provision of Sanitation

The following section highlights the status of the enabling environment (presented in section 3.4.5) relating to sanitation and how this affects the sanitation sector within Zambia and more specifically in Lusaka. This section specifically relates to policy, legislation, institutional setup, financial situation and sanitation programmes which currently exists in Zambia that are related to both WSS, with a predominate focus on sanitation.

4.3.1 Policy framework

In 1994, the Government of Zambia embarked on a reform of the water sector which resulted in the development and adoption of the National Water Policy of 1994. The policy incorporates seven key sector principles (GRZ, 1994; Government of The Republic of Zambia, 2011), including;

1. Separation of water resources functions from WSS
2. Separation of regulatory and executive functions
3. Devolution of authority (from central government) to Local Authorities (LA) and private enterprises
4. Achievement of full cost recovery for the WSS services through user charges in the long run
5. Human resources development leading to more effective institutions
6. The use of technologies more appropriate to local conditions
7. Increased government priority and budget spending to the sector

A revision of the National Water Policy was undertaken in 2010 in which it was recognised that principle 2, 3 and 4 above had been largely achieved, however, the seven principles are still key to the new version of the policy (Government of The Republic of Zambia, 2011). The National Water Policy (both 1994 and 2010 versions) predominantly focused on water resources management with very little discussion of sanitation. The document mentions *"the policy is oriented to provide adequate, safe and cost effective water supply and sanitation services with due regard to environmental protection"* (GRZ, 1994). However, there are no specific strategies or measures outlined within the policy for how improvements in WSS should be achieved specifically within informal settlements. This highlights weakness in the current policy framework. It should be noted that there is currently a new water policy being developed in Zambia.

The National Policy on Environment (Ministry of Tourism Environment and Natural Resources, 2005) provides a framework for managing and caring for the environment. The policy recognises the need to improve upon the current sanitation situation in Lusaka and indicates that the *"Pollution of surface and ground water by human and domestic wastes should be prevented through improved sanitation and effective waste disposal systems"* (Ministry of Tourism Environment and Natural Resources, 2005). In terms of domestic sanitation the policy supports the decentralisation of responsibility (effective transfer) to districts for community based WSS and indicates that sanitation master plans should be developed, appropriately designed technologies should be implemented and that properly selected, licensed disposal sites and routes should be used to improve water borne sanitation systems and solid waste (ibid).

In terms of guiding principles for the water sector the policy indicates the following;

- *"When planning and providing water supply services, consideration should be given to the safe disposal of the resultant wastewater"*
- *"The responsibility of waterborne sanitation should be integrated into the water sector"* (Ministry of Tourism Environment and Natural Resources, 2005)

Strategies to achieve this relate to strengthening and institutionalising of the Water Sanitation Education (related to rural areas) and providing the Ministry of Local Government and Housing (MOLGH)/ Department of Infrastructure Support Services with adequate resource to rehabilitate and extend sewerage systems and other forms of sanitation (Ministry of Tourism Environment and Natural Resources, 2005). This policy lacks guidance as it does not provide specific strategies or measures as to how improvements in sanitation can be achieved in the informal settlements. The policy also focuses predominately on water-borne sewerage rather than other types of technology more commonly utilised in informal settlements (see section 4.4.2).

4.3.2 Legislation

Legislation relating to sanitation is found in several different acts, each having specific focus which will be described below. The WSS sector in Zambia is governed by two main legal frameworks, the **Local Government Act No 22 of 1991** (GRZ, 1991b) and **the Water Supply and Sanitation Act No.28 of 1997** (GRZ, 1997). The Local Government Act gives the responsibility of provision of WSS to LAs and defines their functions in terms of providing and maintaining WSS services. The LAs currently operate under the control of the MOLGH (Government of The Republic of Zambia, 2011). The WSS Act was a direct output of the reform process and specifies the obligation of the LA to provide WSS services;

> *Part III, section 10 (1):"Notwithstanding any other law to the contrary and subject to the other provisions of this Act, a local authority shall provide water supply and sanitation services to the area falling under its jurisdiction, except in any area where a person provides such services solely for that person's own benefit or a utility or a service provider is providing such services"(GRZ, 1997).*

It also indicates how WSS services can be provided on behalf of the LA; either through establishment of commercial utility, as a joint venture with a private or public company or as a joint venture with one other or several LAs (provided the majority share is held by the LA) (Government of The Republic of Zambia, 2011). It further defines the National WSS Council (NWASCO) as the regulator for the Urban WSS sector and defines its function as the licensee of service providers and as the entity that sets the conditions of the licenses and develops guidelines and standards for WSS service provision (Banda, 2013). However, the WSS Act (GRZ, 1997) is found to be lacking as it does not indicate or outline what level of sanitation access should be achieved in informal settlements.

The **Water Act Cap 198** (GRZ, 1948) relates to the development and management of surface water but does not include groundwater. The most recent act related to water legislations, the **Water Resources Management Act** (GRZ, 2011b) states that groundwater should be protected through appropriate measures and practice and includes requirements (notice, permission and appropriate management) for the construction of boreholes, stating that if the correct procedures are not followed, legal preceding can be taken against those responsible (GRZ, 2011b). This Act may have implications on current WSS practices in informal settlements particularly the setup and use of boreholes to abstract groundwater sources and the pollution of groundwater sources by sanitation facilities which are both deemed illegal by the act.

Relevant sanitation legislations is also included in the **Public Health Act of 1995** (PHA) (revised in 2006) (GRZ, 2006). Part IX relates to sanitation and housing; section 75 relates to drainage and latrines. Part IX dictates that nuisances or conditions liable to be injurious or dangerous to health are prohibited (on land, premises owned or occupied) and it is the duty of the LAs to prevent nuisances, maintain cleanliness and remedy danger to health arising from unsuitable dwellings (GRZ, 2006).

Section 75 defines in detail access requirements to sanitation facilities, the state the facility must be in and the type of technology, quality, location and number of households that will share that facility (Part XII). In particular, the building of pit latrines is stated as allowed if *"the site of such proposed accommodation and the character of the soil are in every respect suitable and satisfactory for such a purpose and the Local Authority shall have signified its approval thereof in writing, and then only subject to such conditions as the Local Authority may prescribe."*

The PHA is very descriptive about what is required to prevent public health impacts, the number and type of sanitation facilities that are required for domestic dwellings and the role of the LA to ensure the law is enforced. The realities of whether this law is adhered to in informal settlements of Lusaka will be discussed later in this chapter.

Relevant sanitation legislation is also included in the **Environmental Protection and Pollution Control Act of 2011** (GRZ, 2011a). The legislation improves upon shortfalls within the previous act of 1990 (GRZ, 1990) which only focused on wastewater discharge from sewerage systems and did not focus on waste management at the domestic level. The 2011 Act states that the discharge of any contaminant or pollutant which is likely to cause adverse effect to the environment is prohibited (GRZ, 2011a). In terms of the aquatic environment the legislation indicates that it should not become polluted by wastewater or any other fluid which is discharged, directly or indirectly (ibid). The legislation also defines the responsibilities of the Zambian Environmental Management Agency (ZEMA) (in collaboration with the appropriate agency) to establish water quality and pollution standards, determine conditions for the discharge of effluents, formulate rules for the preservation of aquatic environments and to carry out investigations (including data collection and interpretation) (GRZ, 2011a).

It is also of interest to establish what this act means for the management of Municipal Solid Waste (MSW). The updated act now focuses on MSW from domestic activities and states that a person shall not manage waste in a way that causes adverse effect or creates significant risk to the environment (ibid). It also defines the role of the LAs and states that they must collect and dispose of all household waste (in accordance with the act) within their area of jurisdiction. The Act reflects a shift in thinking as it indicates that practical measures should be taken to promote and support the minimisation of waste and recovery of waste at the point of production and waste management services that prioritise recovery, reuse or recycling of MSW. If any of these laws are not adhered to, the agency (ZEMA) also has the power to serve an enforcement notice and can begin legal proceedings against the relevant body (ibid). This legislation provides clear definitions of what is required and expected to be achieved to ensure environmental protection. These rules also relate to informal settlements and define clearly the role of various bodies (ZEMA and LA) in achieving this.

Overall, the existing legislation available in Zambia related to WSS, settlement development, public health and environmental protection is very comprehensive. However the applicability of these laws to informal settlements is arguable as there are legal inconsistencies. These inconsistencies can be exploited by institutions focusing on certain laws to the exclusion of others (discussed further in section 4.3.3). Many contradictions and overlaps between various forms of legislation were identified which are intensified by the focus of institutional bodies on specific laws without reasonable consideration of others that exist (discussed further in section 4.3.3). There is little evidence of enforcing legislation in informal settlements where aspects relating to legal tenure and enforcement responsibilities are blurred (discussed further in section 4.3.3). Dominant agendas are shown to cause preference to be given to certain laws over others.

4.3.3 Institutional framework

The institutional framework for urban WSS in Zambia is organised as shown in Figure 4-2 below.

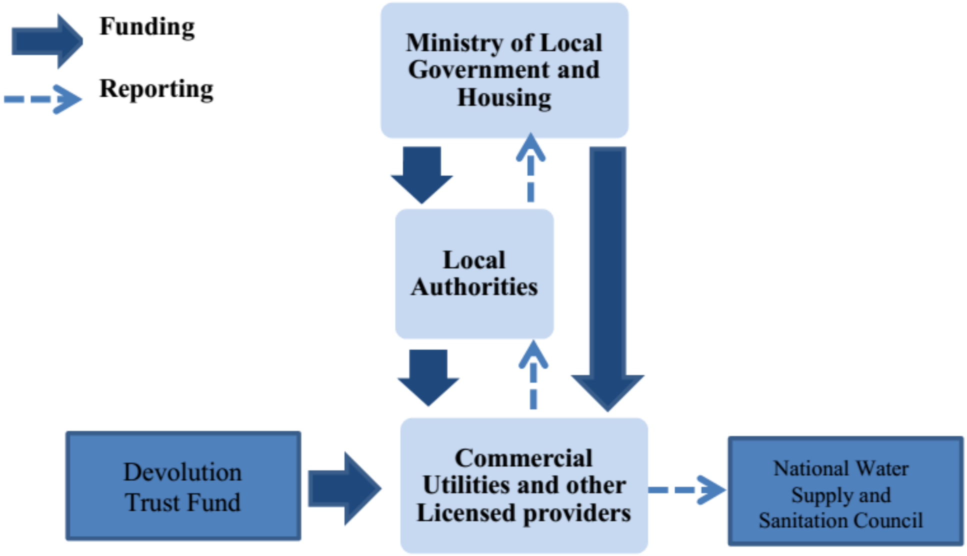


Figure 4-2: Institutional framework of urban WSS sector for Zambia (Adapted from (Government of The Republic of Zambia, 2011)

The overarching institution responsible for WSS delivery, policy creation and resource mobilisation for the sector is the MOLGH. In each province the principal providers of WSS are the LAs. The WSS Act (GRZ, 1997) allows LAs to establish commercial utilities. In the case of Lusaka the commercial utility, Lusaka Water and Sewerage Company (LWSC), was set up by LCC in 1988 to manage both urban WSS in 4 towns (including Lusaka) (NWASCO, 2011). Within LWSC there is a Peri-Urban Department (PUD) that specifically focuses on WSS in informal settlements. As an outcome of the National Water Policy creation, the independent regulatory authority, NWASCO, was created who are in place to regulate the activities of the commercial utilities related to urban WSS. The Devolution Trust Fund (DTF) was also developed to mobile resources for the improvement of WSS service delivery in low income communities. Other national level ministries of importance related to Urban WSS are:

- The Ministry of Energy and Water Development which deals with water resource development management through the Department of Water Affairs and is responsible for implementing the Water Act Cap 198 and the Water Resources Management Act.
- The Ministry of Environment and Natural Resources which ensures environmental standards are met through ZEMA. ZEMA (previously known as the Environmental Council of Zambia) is responsible for implementing and enforcing the legislation set out in the Environmental Management Act (No 12 of 2011) along with the delegated authority (LCC).

- The Ministry of Health (MOH) (Directorate of Public Health and Research) who is responsible for health and hygiene promotion and enforcement of the PHA along with the delegated authority (LCC).

In 12 out of the 36 informal settlements in Lusaka, the provision of water has been organised (since 2000) by community based entities such as the Water Sub Committee of the Residents' Development Committee and Water Trusts (WTs) (Figure 4-3). These were formed by communities through support given by NGOs or donor agencies who were invited by the Government of Zambia to help overcome issues in these areas caused by drought and previously failed programmes (Mwanamwambwa *et al.*, 2005; Banda, 2006). They operate under license from LWSC, through service management contracts. In the case of WTs they report to the Board of Trustees and work directly with LWSC as the registered license holder and mandated institution (Figure 4-3) (Banda, 2006). LWSC provide technical assistance to the WTs and ensure that they are supplied with an acceptable quality of water by creating Improved Service Management Contracts (Banda, 2006). These WTs are identified as playing an important role in the provision of water to informal settlements in Lusaka (Government of The Republic of Zambia, 2011).

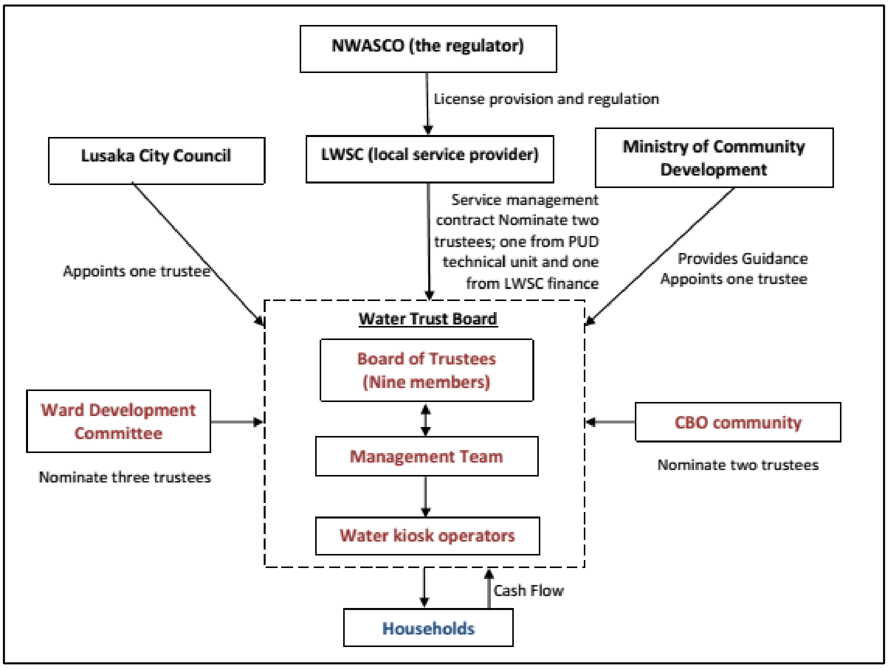


Figure 4-3: Institutional set up of water trusts in Lusaka (Adapted from Peal (2012))

WTs are not licensed by the water regulator, NWASCO as a service provider and so they are not subject to any direct regulation from them (Banda, 2013). In areas were

WTs have not been established (24 of the informal settlements in Lusaka) water is supplied either directly by LWSC or community formed enterprises. Similarly, as with the case for WTs, community formed enterprises are not licensed as a service provider. However, their operations do not conform to the WSS Act (part IV section 11(1)) which states that "*A utility or a service provider shall not operate except in accordance with this Act and under the authority of a licence issued under this Act.*" (GRZ, 1997; Banda, 2013). Whilst LWSC and LCC have a link to these Community Based Organisations (CBO) through their institutional set up (example shown in Figure 4-3) the lack of license and its implication on their legality (in terms of the WSS act) may pose problems with their functionality, how they are regulated and how their activities are controlled.

There has been very limited intervention with informal settlements regarding sanitation such that no community based institutions exist which focus on sanitation. Although the PUD within LWSC focuses on WSS within informal settlements, their focus has predominately been on water supply.

Three other institutions that have an indirect role with the provision of sanitation in informal settlements are;

- The local health centres and health committees (community level representative of the MOH) who promote health and hygiene practices.
- The Ward Development Committees (WDC) (community level representative of LCC) who lease and support any new interventions (service provision) within the communities and make up part of the WT board. Within the WDC there is also often a specific Water Committee that exists to deal with issues of water supply.
- NGOs such as CARE International and WSUP, have implemented WSS projects in informal settlements.

Institutions such as the town planning department and engineering services department of LCC and ECZ currently have no role in sanitation in informal settlements of Lusaka. However, it would appear that they should have more of a role to ensure and enforce that infrastructure development (especially onsite ones such as septic tanks) adhere to the Town and Country Planning Act, Environmental Protection and Pollution Control Act and PHA.

The current arrangement for the Solid Waste Management (SWM) in informal settlements is the responsibility of LCC and the Waste Management Unit within it. In informal settlements, LCC have sought partnerships with CBO and Community Based Enterprises (CBE) to form Waste Management Committees (Munthali, 2006). These committees are responsible for the day to day management of the waste and primary collection whilst LCC is responsible for secondary collection from the informal settlements to the final disposal site (landfill) (ibid). However, the current low levels of MSW disposed to an environmentally sound landfill indicates that current SWM practices in Lusaka and in informal settlements are weak (UN Habitat, 2010; Wilson *et al.*, 2012) .

Figure 4-4 highlights the wide range of ministries, institutions and stakeholders involved in WSS provision in Lusaka (those highlighted in grey relate to sanitation) at the various domains based on those identified in the national urban WSS programme 2011-2030 (Government of The Republic of Zambia, 2011). It portrays the paucity of organisations working in sanitation at the community and household level.

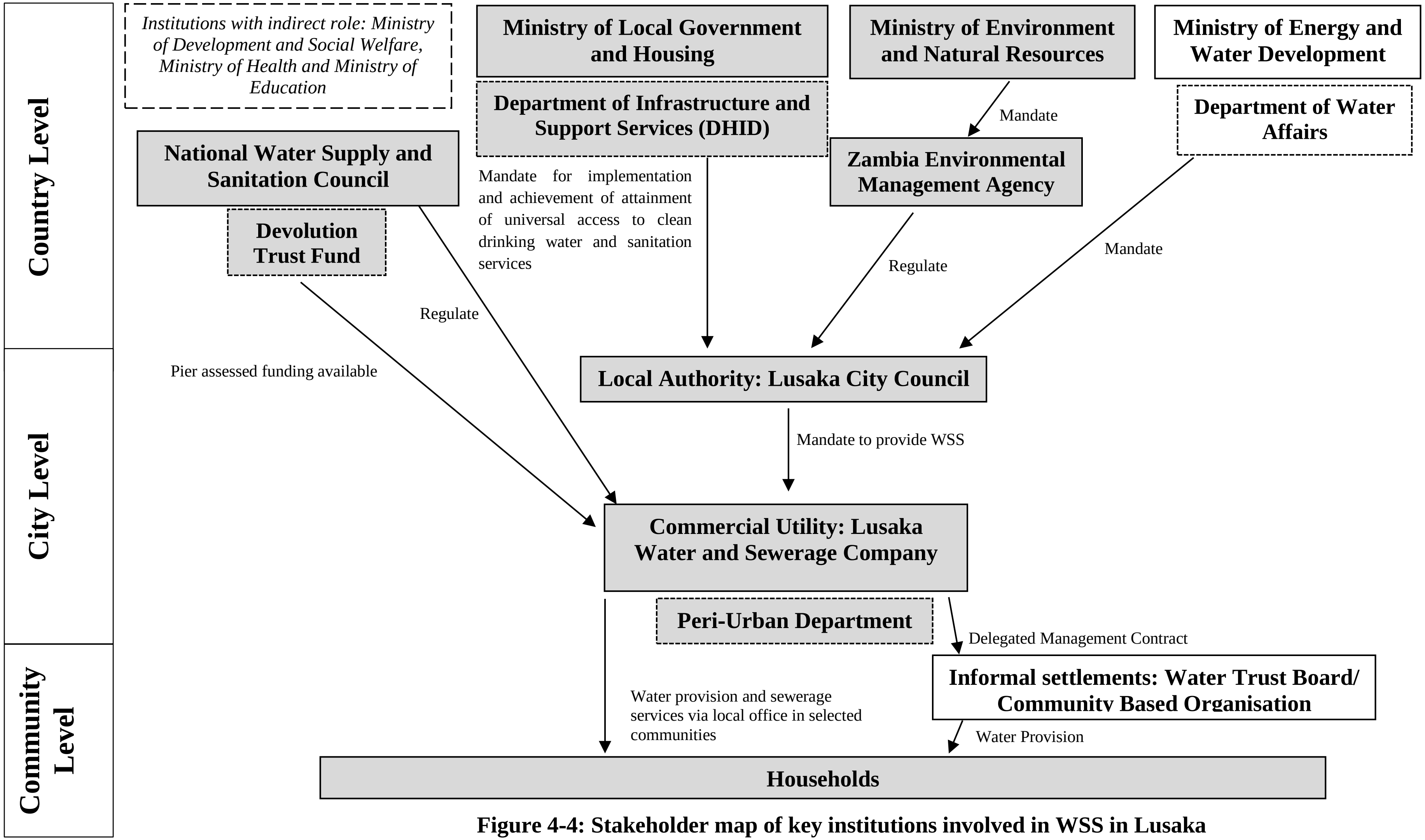


Figure 4-4: Stakeholder map of key institutions involved in WSS in Lusaka

4.3.4 Sanitation programmes and plans

The 6th National Development Plan (2011-2015) and its revision in 2014 outline Zambia's road to achieving the UN Millennium Development Goals and recognises that major investments are required in particular for WSS countrywide (Ministry of Finance and National Planning, 2011). The National Urban Water Supply and Sanitation Programme (NUWSSP 2011-2030) was developed as the long term national programme to outline how Zambia's vision that 'every household have access to adequate, clean and safe drinking water and sanitation service by 2030' could be achieved (NWASCO, 2009; Government of The Republic of Zambia, 2011). Whilst this document outlines a development framework it lacks clarity on how this will be achieved by stakeholders. This programme and its related documentation does not provide adequate baseline data on current levels and types of sanitation, analysis of previous interventions as to what works, projected costs, investment proposals and the relationship between stakeholders and their relative responsibilities. There is limited accompanying technical and financial information to support how this vision will be achieved thus reducing its credibility.

4.3.5 Financial arrangements

It is reported that between 2011-2030, US$ 640 million would be required to implement the sanitation components of the NUWSSP (both replacement and building of new infrastructure throughout Zambia) (Government of The Republic of Zambia, 2011). However, a sanitation master plan developed by an external organisation indicated that in Lusaka alone US $1.9 billion of investment is required over a 25 year period (see section 4.5 for more detail) (TetraTech, 2011). This master plan would result in 57% of the Greater Lusaka population having access to household sewerage connections and the remainder using onsite systems (ibid). The difference in estimated costs observed may be down to the level of detail that has been taken to establish each of the predicted investment needs.

Overall the financial expenditure to date on WSS and in particular Urban WSS is relatively low. Between 1997-2007 the authorised national budget provision on Urban WSS was only 0.3% of the total budget (Government of The Republic of Zambia, 2011). Reviews on the financing of the WSS sector indicate that the sector is heavily reliant on donor funding (Government of the Republic of Zambia *et al.*, 2004; Government of The Republic of Zambia, 2011). Some argue that this dependency can undermine strategic thinking with regard to the allocation of resources, can reduce the drive to achieve an increase in internally generated funds and can cause unsustainable technologies and solutions to be implemented (Zambia, 2004).

The DTF is a basket fund, financed through the Government of Zambia and donor grants, that targets funding for improved access to WSS for the urban poor. It does this through the provision of grants to commercial utilities. Between 2006-2013, ZMW 193.3 million was committed to urban WSS by DTF, however only a small percentage went to financing programmes related to sanitation (i.e. only 9% overall in 2013) (Devolution Trust Fund, 2013).

4.4 Status of Sanitation Provision in Lusaka

The JMP estimates, on the use of improved sanitation facilities, indicate that sanitation coverage in urban Zambia is relatively low with only 56% of the urban population being reported to have access to an improved facility in 2012 (24% shared, 18% other unimproved and 2% open defecation) (WHO/UNICEF JMP, 2014c). WHO/UNICEF JMP (2014b) reported that between 1990-2010 whilst there had been increasing equality there had been a decrease in urban sanitation coverage in Zambia. The following section provides more detail related to the current status of sanitation in the high income and low income areas of Lusaka.

4.4.1 Provision in high income areas

Sanitation systems used in Lusaka are sewers to centralised Wastewater Treatment Plants (WwTPs), onsite systems and privately owned systems (TetraTech, 2011). In Lusaka's planned settlements (predominantly high-middle income areas), households either have access to the centralised conventional sewerage network or build onsite septic tanks which are emptied once full. The LWSC managed sewerage network is reported to cover between 10% and 20% of Lusaka's population and estimates show that 69% of those served by LWSC have adequate sanitation coverage which they define as access to the centralised sewerage system or a septic tank (TetraTech, 2011; Mansuri and Rao, 2013). The current sewerage network (Figure 4-5) covers approximately 30% of the area currently served by water supply and is made up of 480 km of sewers (TetraTech, 2011). The sewerage network is poorly maintained and has not been expanded much in the last 40 years to cope with ongoing population growth. Models produced for the development of a recent sewerage master plan for Lusaka highlighted that over half of the existing interceptors are under capacity with the existing flow and significant investment is required to improve the network (collapsed sewers and stolen manholes are noted as major problems) (TetraTech, 2011).

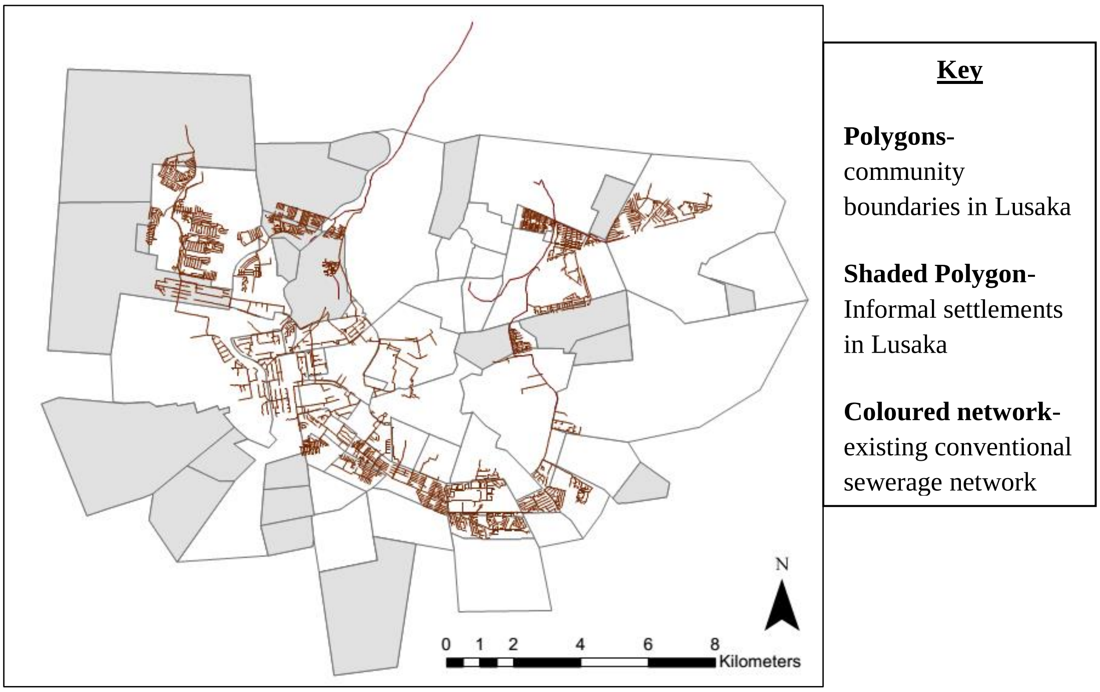


Figure 4-5: Geographic Information System (GIS) map highlighting the proximity of informal settlements in Lusaka to the centralised network[1]

There are a total of 7 WwTPs in Lusaka, mainly utilising stabilisation pond technology (ibid). The largest treatment facility in Lusaka is Manchinchi WwTP which was originally built in the 1950s as a conventional biological treatment plant (utilising gravity clarification and trickling filter unit process) with a reported design capacity of 36,000 m^3 per day (TetraTech, 2011). The effluent from Manchinchi WwTP flows directly to stabilisation ponds (Garden). The plant is practically inoperable and defunct due to consistently poor maintenance. The lack of improvements made (since the 1970's) means wastewater is poorly treated there and a similar situation is reported at the other 6 WwTPs (ibid). Manchinchi consistently fails to meet ZEMAs effluent standards for wastewater (in particular faecal coliform level, turbidity and Carbon Oxygen Demand) (TetraTech, 2011). Despite the low levels of wastewater treatment achieved, drying beds are utilised downstream of the works. There is reported to be a demand for the dried sludge produced from the WwTPs (Mikhael and Clouet, 2012). However, because of low levels of treatment and low retention time achieved on the drying beds (reported less than 1 week) the produced sludge (biosolids) pose a risk to

1 *Data supplied by LWSC*

public health due to high pathogen load. A study in 2011 which looked at the pathogen concentration in biosolids produced at Manchinchi WwTP confirmed this risk however, the sludge produced is still sold (Phiri *et al.*, 2011).

For those in planned settlements served by onsite facilities, pour flush to onsite septic tanks are predominantly in use. Poorly or unsuitably constructed onsite facilities can cause groundwater contamination and public health risks (see section 4.4.2 below), however for planned areas the quality of facilities and their potential associated risk have not been evaluated. The construction of onsite facilities creates a possible loophole in terms of LA responsibility under the **WSS Act (no 28 of 1997)** as it suggests that because the household has provided a service (built their own onsite facility) solely for their own benefit then the LAs obligation to provide WSS services no longer exists (GRZ, 1997).

Once onsite facilities become full there are formalised private emptying services which utilise vacuum tankers for the removal of FS in Lusaka. There were reported to be 30 companies operating emptying services in 2012 (Mikhael and Clouet, 2012). Figure 4-6 below shows an example of the vacuum tankers which are used. Each vacuum tanker was reported to cost in the region of ZMK 85,000-110,000 (US$ 16- 21) per load per km (Mikhael and Clouet, 2012). Manchinchi WwTP has a septage hauling drop off facility for septic and industrial waste where the vacuum tankers can dispose of the septage into the head of the treatment works. It was noted that in 2012 a disposal fee of ZMK 30,000/m^3 (US$5.66/$m^3$) was in place at Manchinchi WwTP and between 10-18 tankers were emptied into the plant each day (Mikhael and Clouet, 2012).

Figure 4-6: Example of vacuum tankers which are used in Lusaka[2]

[2] Photograph taken by Ruth Kennedy-Walker in 2013

4.4.2 Sanitation provision in low income areas

In the case of informal settlements, onsite sanitation provision is the only type in use, outlined in Table 4-2 below.

Table 4-2: Common forms of onsite sanitation in Lusaka (adapted from (TetraTech, 2011))

Facility Type	Improved/ Unimproved	Description
Open Defecation	UI	Defecation directly into the environment
Kavela	UI	Defecation into any sort of transportable container which is then discarded unsafely.
Simple Pit Latrine	Unspecified	Latrine which is defined as improved or unimproved depending on a number of performance-based criteria set out by NUWSSP.
VIP Latrine	I	Latrine which includes a pipe attached to the substructure and extends beyond the top of the superstructure.
Flush Toilet connected to septic tank and leachfield/soakaway	I	Enclosed tank where settling of solids and anaerobic treatment occurs and the sewage is stored until emptying. Leachfield and soakaway provide outflow for liquid fraction.
Ecosan Toilet	I	Separates urine and faeces so both can be utilised separately as resources.
Composting Toilet	I	Similar to Ecosan, however may not be urine diverting.

In Lusaka Province, pit latrines account for approximately 72.6% of total number of sanitation facilities, while individual/communal flush toilets account for 24.3% of which 69.9% of facilities are defined as improved (Central Statistics Office, 2012). The majority of low income households are shown to use pit latrines rather than flushing systems (septic tanks) (ibid).

In informal settlements an estimated 90% of households use onsite facilities which are commonly shared among several households due to limited space (UN Habitat, 2007). Similar situations are common place in low income urban environments worldwide whereby households have become the sole responsible party for the building and managing of their sanitation needs because of inaction and support of government (Scott *et al.*, 2013). As highlighted above the construction of onsite facilities by the household may cause implications for the obligation of LA and LWSC to provide WSS.

These onsite facilities are most commonly poorly designed (unlined) and constructed devoid of formalised design standards (Von Münch and Mayumbelo, 2007). In areas of high ground water (groundwater table ranges from 30m- 1m in Lusaka) there is a risk that onsite facilities may contaminate groundwater resources as the liquid fraction of the excreta percolates through the ground (Von Münch and Mayumbelo, 2007). In the rainy season the groundwater quality commonly deteriorates because of the combination of groundwater recharge, use of onsite facilities and the presence of fast flow mechanisms in the karst rock formation in some areas (Mayumbelo, 2006).

Figure 4-7 below shows that all of the informal settlements in Lusaka are located in areas which have high to moderate vulnerability to groundwater pollution (Bäumle *et al.*, 2012; Nick *et al.*, 2012). Groundwater currently supplies approximately 65% of the drinking water volume distributed by LWSC and residents of informal settlements are dependent on community based wells, private boreholes or hand dug wells which are often shallow (Eawag, 2013). Where onsite facilities have been built in areas of rocky geological formation, the facilities can fill up quickly as limited percolation of the liquid fraction occurs (Wamukwamba and Share, 2001). In the rainy season, issues of water backing up into the onsite facility causes further risks to the environment and health (Wamukwamba and Share, 2001).Where onsite facilities are used in such conditions, outbreaks of waterborne diseases such as cholera can occur and are common occurrence in informal settlements in Lusaka (Von Münch and Mayumbelo, 2007; WHO, 2011). Despite current sanitation practices causing a danger to health the detailed PHA (section 4.3.2) seems to not be being enforced to ensure that the risk is prevented or eradicated.

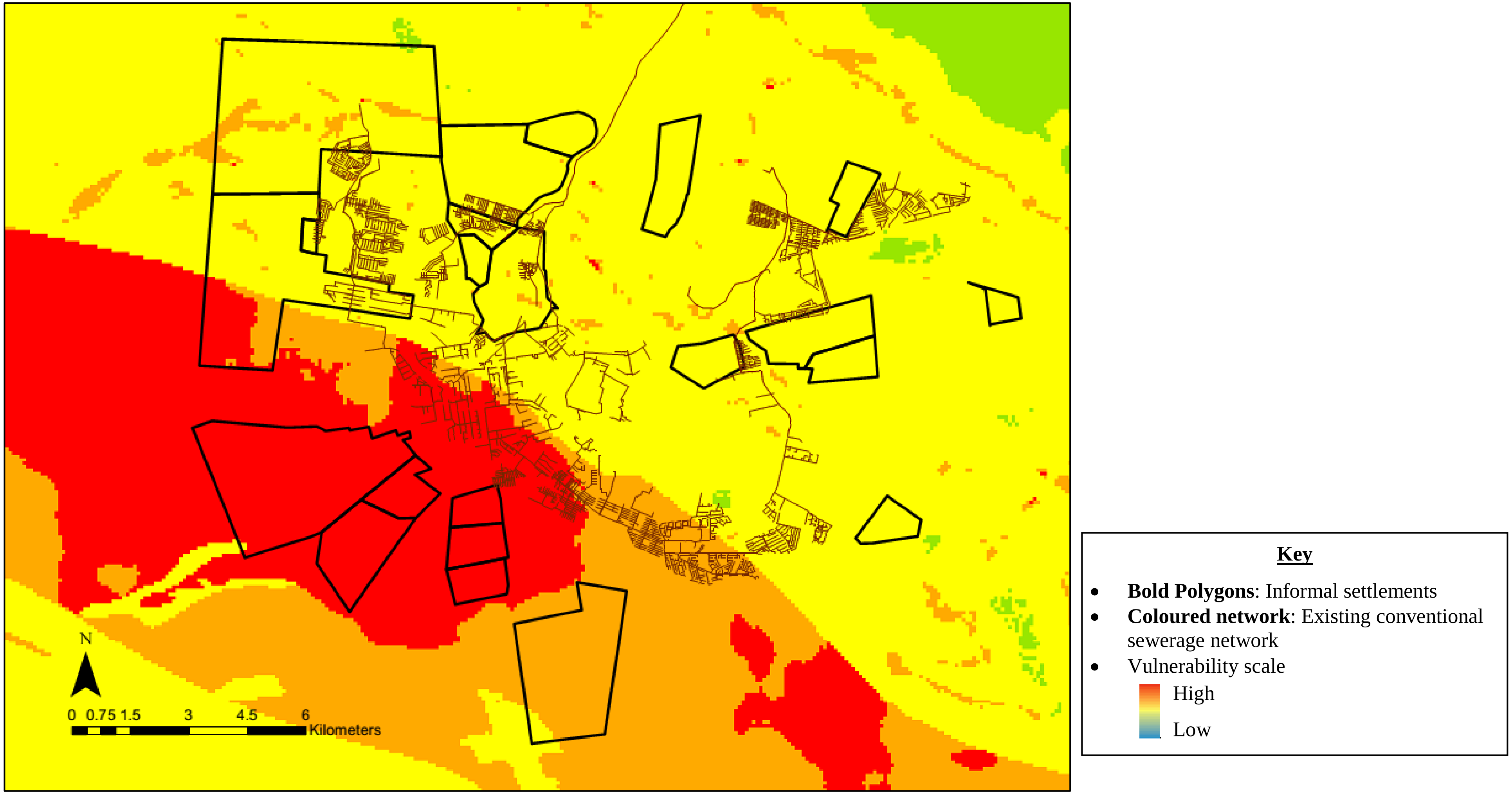


Figure 4-7: Map showing groundwater vulnerability related to location of informal settlements and sewerage network in Lusaka produced using data from Department of Water Affairs and LWSC (Koch *et al.*, 2012)

Once these onsite facilities become full it is difficult for them to be emptied using formalised services because of access constraints (location and road access) and the unaffordable cost of emptying in such areas. It is reported that to empty latrines in informal settlements (Kanyama and Chazanga specifically) it can cost approximately ZMW 600,000-700,000 (US$ 113-132) (Mikhael and Clouet, 2012). This results in full pits being covered over with soil and left (Peal, 2012). However, in locations where housing density means this cannot be done or where septic tanks are in use, it is common practice for the facilities to be manually emptied by informal emptiers or the household themselves using makeshift equipment and with limited personal protective equipment (Peal, 2012). Once emptied the FS is commonly indiscriminately dumped adjacent to the emptied latrine or in nearby open ditches or watercourses (Peal, 2012). The lack of regulation and enforcement in these areas from institutions, such as ZEMA, means that this practice happens without consequence. There are additional problems with this removal process as the procedure of digging a hole into the wall of the latrines can cause latrines to collapse once the integral substructure has been compromised (Peal, 2012). The treatment, safe disposal or reuse of FS does not occur in these informal settlements.

4.4.3 Overview of sanitation provision in Lusaka

It is evident from the information provided in sections 4.4.1 and 4.4.2 that the majority of the FS produced by the population of Lusaka is not being safely managed through the SVC. Even in those situations where FS is being properly contained, removed and transported once it reaches the existing WwTPs, the subsequent poor treatment capacity means the effluent produced is a risk to public health. It is clear from this analysis that interventions to improve the sanitation situation for the whole of Lusaka are required.

4.5 Proposed and Undertaken Sanitation Interventions

To date in Lusaka there has been limited expansion or maintenance of the existing centralised sewerage network and a lack of intervention at scale to improve sanitation access within informal settlements. Historically, sanitation has been weak on the agenda with water supply issues being given far greater attention (Zulu, 2009). However, in recent years LWSC has expressed its commitment to sanitation access in informal settlements through the introduction of a sanitation levy. The sanitation levy, which began in 2007, is charged to all customers who have a sewer connection (approx. 3-4% of bill) and is ring-fenced for expenditure on sanitation improvements in informal settlements (Norman *et al.*, 2012a). The fund is closely controlled by the regulator, NWASCO, whereby LWSC must seek authorisation for its expenditure.

Since 2007, a legal enforcement approach to sanitation has been implemented in urban areas of Zambia and specifically trialed in Lusaka. This method was adapted from the Community-Led Total Sanitation (CLTS) approach which has been widely implemented in rural Zambia (Zulu *et al.*, 2010). CLTS is a participatory approach which aims to change the behaviour of community members and promote 'Open Defecation Free' communities through empowerment, by creating a sense of shame for those that do not act as part of the community, and is predominantly used in rural areas (Mehta and Movik, 2011). However the 'legal-enforcement' approach used in urban Zambia is different to the standard CLTS approach although some of the same triggering methods are utilised. The approach was adopted to ensure adequate sanitation in communities and aimed to establish a mechanism for enforcement of the PHA to prevent public nuisances within urban and peri-urban areas (Zulu *et al.*, 2010). It specifically targeted public buildings, food establishments and lodges rather than domestic properties (Morris-Iveson and Siantumbu, 2011). Urban CLTS (legal enforcement) was implemented initially as an emergency response to cholera outbreaks for Lusaka. There is limited evidence of the approach's success in Lusaka nor whether it has been expanded beyond its targeted and emergency specific focus.

Progress has been made however through the implementation of three sanitation pilot studies in informal settlements of Lusaka. In the late 2000s a number of Ecosan facilities were implemented in informal settlements through the support of NGOs such as CARE International, Water for Kids and WSUP (Figure 4-8). Evaluations of these projects indicate however that their success was limited due to poor cultural acceptance (expected household handling of FS), limited use of manure in agriculture and the absence of policy and legislation enforcing or supporting the safe disposal of FS (Nyambe *et al.*, 2010).

Figure 4-8: Ecosan (dry) toilet in informal settlement of George
Urine collection (left), urine diverting slab (right) [3]

In 2013, LWSC implemented two further pilot sanitation projects in informal settlements- a FSM project in Kanyama and a condominal sewerage system in Kalingalinga. The FSM project consisted of a formalised pit emptying service which was administered through the WT. The project, led by LWSC and the Kanyama WT, was supported by WSUP with technical inputs from BORDA, and funding from the Stone Family Foundation. This system combines the use of a formalised pit emptying service, manual transportation (manual carts shown below in Figure 4-9), decentralised and secondary treatment (anaerobic CARTMEC facility) and offsite sludge biosolids drying (1km from site of decentralised treatment) (Linyama *et al.*, 2014; WSUP, 2014). In 2014 the pilot was expanded to provide a similar system in the informal settlement of Chazanga. The second pilot is a condominal sewerage project which was supported by the World Bank in terms of the social marketing, technical assistance and information communication technology based components of the project. The project was financed partly by LWSC's sanitation levy fund (sewer network extension) and partly by the MOLGH (primary sewer lines and sanitation marketing campaign) (The World Bank, 2013). The potential of these pilots schemes is not fully known as there is little evaluated data and limited scale up.

[3] Both photographs taken by Ruth Kennedy-Walker in 2013

Figure 4-9: Manual faecal sludge removal and transportation equipment in use in Kanyama[4]

Baseline data collection of the sanitation situations in selected informal settlements have been completed by a number of organisations. They present a quantitative assessment of the facilities in use and the associated environmental conditions in a number of informal settlements (Otiego and Kamundi, 2012a; DTF, 2013; Mtonga, 2013). Beyond these reports there is no evidence of the same organisations outlining proposals to resolve the identified problems.

With regard to improving the existing conventional sewerage and treatment system a comprehensive sanitation master plan for Lusaka was produced by the United States Army Corps of Engineers and the Millennium Challenge Account in 2011 (TetraTech, 2011). The aim of the document was to establish the investment needs of LWSC over a 25 year period and act as a principal framework for planning investment in the sanitation sector. The plan identified a total of 130 projects that required implementation at an estimated cost of $1.9 billion with the majority of these investments being improvements to the centralised conventional sewerage system (assigned $1.3 billion of investment required) (ibid). The remainder of the required investment relates to providing solutions for informal settlements and predominately focuses on improvements to onsite systems (septic tanks with soakaways where appropriate and use of elevated Ecosan in areas of high groundwater or flooding) (ibid). The focus on onsite sanitation facilities such as Ecosan by the master plan may cause some controversy. In NWASCO's, most recent annual report it was highlighted that *"Sanitation coverage consists of the population serviced by offsite (centralised system) and septic tanks only. Other onsite facilities such as pit latrines are not considered acceptable for urban sanitation[s]"* (NWASCO, 2014). Therefore, onsite technologies

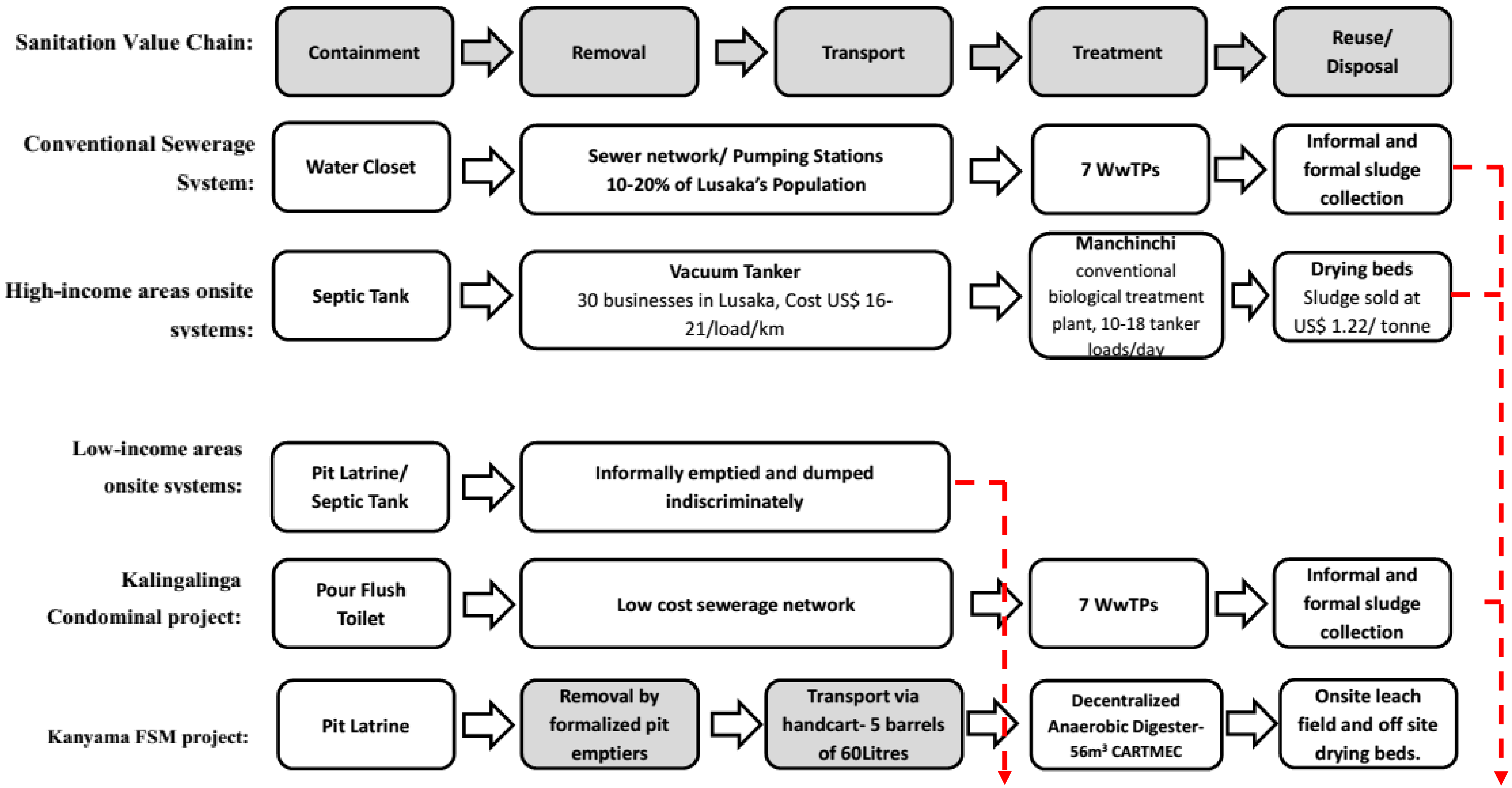
[4] Photograph taken by Ruth Kennedy-Walker in 2013

other than septic tanks would need to be accepted as improved technology types first. Very little detail is given about how FS collected by onsite facilities in informal settlements should be or will be safely managed and treated. However, this master plan is now being used as the strategic plan by LWSC and has prompted interest for investment into sanitation from a number of donors (as well as for water supply in line with a similar master plan) (Lusaka Times, 2013).

4.5.1 Overview of current sanitation situation and interventions to date

The section above highlights that improvements are required for FSM in both high and low income areas of Lusaka. Figure 4-10 depicts the current FSM practices in Lusaka using a simplified version of the 'Sludge Flow Diagram' approach used by Peal *et al.* (2014a) however it does not include FS volumes or proportions. The red downward arrow indicates those situations where FS is not safely contained or managed.

Figure 4-10: Sanitation systems in use in Lusaka



4.6 Sanitation Situation in Selected Informal Settlements

This section provides more details about the three informal settlements (Kanyama, Chazanga and George) that have been selected for closer analysis as part of this research as outlined in chapter 2 (Figure 4-11). The information was collected from secondary sources but also primary observations made during field visits to the areas. Reasons for selection of these areas are discussed in Chapter 5. Photographs from each settlement can be found in Appendix B.

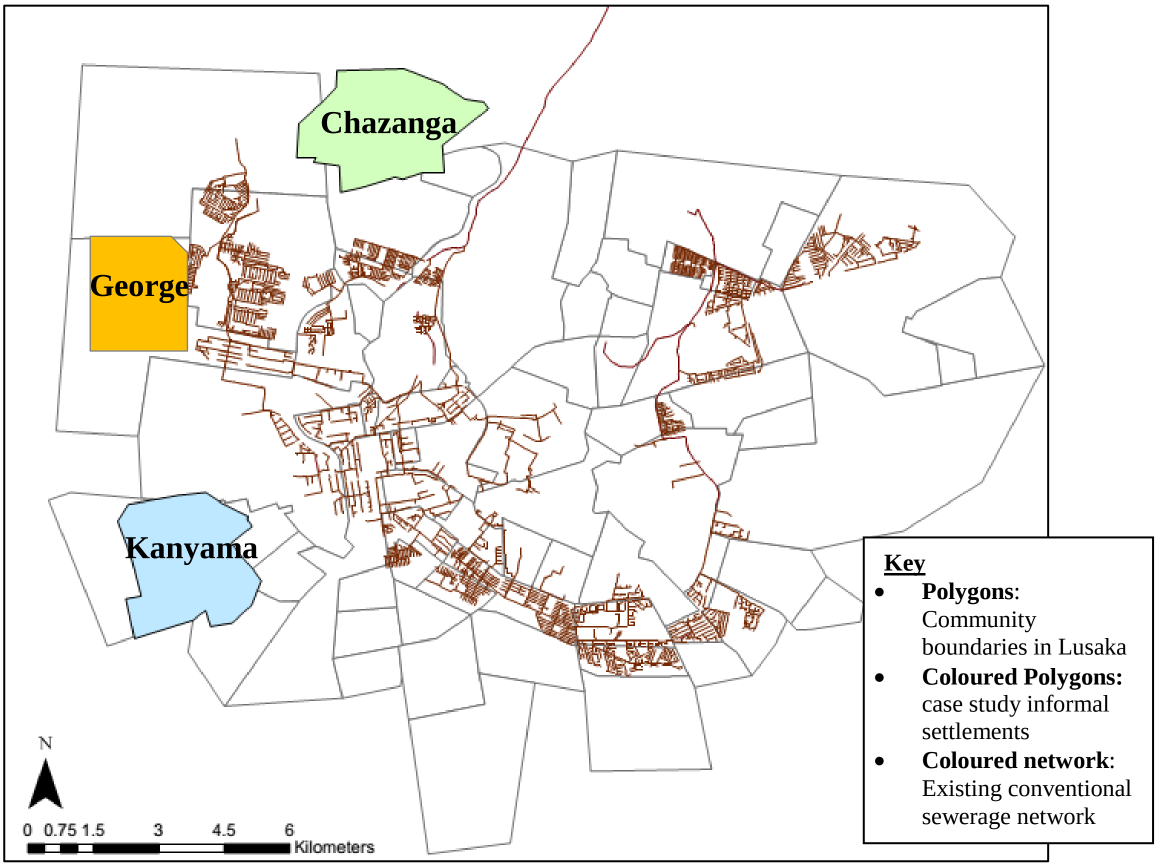


Figure 4-11: Map of Lusaka with highlighted areas of research[5]

4.6.1 Kanyama

Kanyama is an informal settlement on the western boundary of Lusaka city. It is a legalised settlement with a population reported in 2010 of 366,170 (Central Statistics Office, 2011). During discussions with the WT in Lusaka they indicated that the population served with water through them is 137,000**.** The topography of the land is low lying and flat with a geology composed of Lusaka Dolomite which combined with a shallow groundwater table has resulted in karst sinkholes and depressions evident

[5] Data provided by LWSC

throughout the area (Bäumle *et al.*, 2012). The area is liable to flooding due to high groundwater levels and poor drainage and there is a high risk of groundwater vulnerability here (ibid). Cholera outbreaks commonly occur in Kanyama and in 2009/2010 there was a 1000 cases reported (MSF, 2010). Since 2013 a formalised pit emptying service has also been provided by the WT (section 4.5).

4.6.2 Chazanga

Chazanga is an informal settlement on the north-western outskirts of Lusaka city. During discussions with the WT the population was highlighted at approximately 86,000. It is not yet a legalised settlement and therefore residents have no title deeds for their dwellings (Mtonga, 2013). Chunga Landfill, Lusaka's only engineered landfill, borders Chazanga and the Great North Road divides the area in two. The settlement slopes from East to West with average slopes of 2% and the geology consists of metamorphic schist and quartzite (Bäumle *et al.*, 2012). The water table is reported to be high in the rainy season (1.5m) dropping to about 7-20m in the dry season (Bäumle *et al.*, 2012). There is a relatively high risk of flooding due to poor drainage and high ground water levels, however the risk of groundwater pollution is shown to be less than that observed in Kanyama (ibid). The number of cholera cases observed in Chazanga could not be found, however during discussions with the WT it was indicated that the numbers are much lower than other informal settlements in Lusaka. Water is supplied to the area through a WT Board which abstract groundwater from 3 locally positioned boreholes which supply 46 communal stand pipes, 10 water kiosks and 600 individual household connections (DTF, 2013). During discussions with the WT they highlighted that in 2013 one of the boreholes in Chazanga collapsed leading to issues with water supply pressure throughout the area. In 2014, a FSM scheme similar to the one set up in Kanyama was implemented in Chazanga.

4.6.3 George

George compound has an estimated population of 145,230 (24,205 households) (Otiego and Kamundi, 2012b). George is a fully legalised settlement located close to inner city Lusaka and is adjacent to the main manufacturing area within the city. The compound is relatively flat and the topography gently slopes to the west (Bäumle *et al.*, 2012). The geology is metamorphic marble and the water table is relatively low (ibid). There is a risk of flooding due to poor drainage in the area (Otiego and Kamundi, 2012b). Waterborne disease prevalence is high in George with 1110 cases of cholera and 60 cases of typhoid recorded and between 2009 and 2011 (Otiego and Kamundi, 2012b). Water is supplied to this area through LWSC directly, with the main source of water coming from 7 local boreholes.

4.7 Conclusion

A situational analysis of the current sanitation provision within informal settlements in Lusaka has been presented in this chapter. It shows that the sanitation provision for informal settlements is relatively poor, with FS not being safely managed. The onsite technologies used in these communities have been constructed without reference to planning guidance or regulations, with many householders constructing their own facilities. These settlements are located in areas with sensitive hydrogeological characteristics and climatic conditions which can exacerbate the environmental and public health risk posed by these unregulated systems. In contrast, provision for planned areas of the city (high-middle income) appears far superior with access to conventional systems or onsite systems and properly managed FSM services. However, due to the current state of the conventional WwTPs, FS is not properly treated and therefore disposal or reuse poses risks to public health even in the more affluent areas of the city. The weak status of the enabling environment was shown to be present at all domains of decision making (country, city and community), however, this review emphasised how inadequacies at country level directly impacts upon city and community activities.

Although there are a large number of ministries and institutions involved in sanitation, there is a lack of clarity around leadership, roles and responsibilities. Whilst in theory MOLGH is the overarching institution responsible for WSS delivery, there was little evidence (apart from NUWSPP) that they are successfully leading the sanitation agenda at a country wide level. In particular, there was no evidence that the specific needs of informal settlements were being presented at the national level. This lack of support for sanitation present at the highest level may in turn be a cause for the lack of support/institutions observed at the city/community levels. This needs to be addressed by either strengthening their role to support sanitation service delivery or to create a designated institution to undertake this role and provide clear leadership to the sector. The review also indicated that enhanced coordination between MOLGH and other Ministries that have alternative and indirect interests in sanitation service delivery should be attained.

The inconsistencies in law, questions over the legality of informal settlements, the lack of clear legislation and policy for informal settlements needs to be addressed. Without legal status being granted, the ambiguity around service provision responsibility will always be an issue. However, legalisation of such settlements is just the first step. The legislative obligation of mandated authorities needs to be better defined in the case of informal settlements and more specific strategies and policies need to be created (or existing updated) that are specific to their needs. Current contradictions between different sets of legislation need to be addressed and the rights of householders and the responsibilities of agencies in providing service provision to informal settlements need to be clearly defined. In particular, the conflicting laws that exist which indicate that institutional obligations are invalid where householders have provided their own sanitation access. The WSS Act, as the leading act used by commercial utilities, should be updated to include more detail on the responsibilities of utilities (or allocated others) to sanitation provision in informal settlements. Other relevant legislation, such as the PHA and the Environment Protection and Pollution Act, should be closely aligned to an updated WSS Act. In line with this, the regulatory authority, NWASCO, should take a leadership role to regulate sanitation provision, create standards and support local commercial utilities to improve sanitation provision in informal settlements.

National policies, in particular the National Water Policy, need to be updated so that clear applicable strategies to address the sanitation issues inherent to informal settlements are provided. Existing strategies in relation to sanitation focus on water-borne technologies. Alternative technological approaches, such as FSM, need to be included in strategies to address the needs of the high proportion of Zambia's population who use onsite sanitation systems. In the case of Lusaka, this equates to 80-90% of the population. Specific technological solutions which are the most applicable, appropriate and cost effective to use in informal settlements need to be included. Such policies need to not only focus on the containment technology but also to support the safe management of FS along the SVC. This could be further supported by regulation and guidance by NWASCO.

The situational analysis showed that limited budgets for sanitation, over reliance on donors and external supports, alongside poorly defined strategies which do not include adequate baseline data, accurate costings nor detailed plans of how targets are to be met, accentuate the problem even further. To overcome this issue, programmes need to be developed based on reliable primary evidence which is collected and drawn upon to develop targeted plans and strategies to address the identified issues. Detailed situational analysis, such as the one conducted in this chapter, needs to be conducted at the various domains so that the true complexities and issues present are identified. Further national budget should be allocated to urban WSS to heighten its importance on the national agenda but finance should be allocated to well targeted and evidence based plans. The allocation of finance should be focused on interventions which aim to recoup costs in a bid to create sustainable interventions which move away from donor reliance. The DTF could play an important role here by encouraging commercial utilities to focus more expenditure on sanitation and providing support and examples of how return on investments can be made.

Whilst a majority of the issues are caused by inherent problems at the national level, specific issues were shown to be present at the local level. There was shown to be limited coordination of institutions of city level institutions (i.e. LWSC, LCC, Local MOH- also seemed to be the case nationally) and that a number of key institutions currently only play a limited role in sanitation within the city. Sanitation service provision in informal settlements sits within a wider problem of housing development, planning and basic service provision. Therefore, issues of sanitation cannot be addressed unless inclusion and coordination between key institutions working in these areas is achieved. Better coordination would also facilitate the pooling of the existing limited resources and in turn would help streamline programmes and plans. A wider perspective, such as this, is needed for the planning of services in Lusaka. Existing plans and master plans were shown to need further development so that clearly proposed solutions for informal settlements, where the majority of the population of Lusaka live, are defined.

The existing sanitation service provision inequality needs to be addressed in Lusaka. Either through an increase in public sector support for sanitation in such areas (LWSC) or through incentivizing the existing private sector to extend service provision to informal areas. The construction of improved containment facilities and downstream end points (treatment and reuse) needs to occur to increase the city's capacity to manage FS and in turn would encourage and support improved FSM and service provision. The existing legal enforcement approach could be used to encourage the proper management of FS city wide and support the enforcement of associated legislations or regulations.

At the community level, the analysis showed there to be limited involvement of institutional bodies contributing to sanitation provision. This is likely to impact upon knowledge transfer, capacity building and the overall development of communities and needs to be addressed. This may be achieved through the creation of new institutions exclusively concerned with sanitation or through coordination with existing organisations (e.g. CBOs, WTs, local health clinics). If existing CBOs were targeted, the capacity of such organisations to implement sanitation programs alongside their existing remit needs to be explored.

Where interventions have been piloted, long term monitoring and evaluation needs to take place so that evidence of what works can be established. It may be useful at this stage for an historic review of WSS programs and interventions in Lusaka to be conducted so lessons can be learnt moving forward. This evidence will strengthen future programming and plans and allow these to be based on facts. The creation of an institution that enforces the collection of such information and stores it centrally would be advantageous.

Overall, the chapter highlights that there are a wide range of complex dynamics that exist which are hindering progress and suggests a number of steps which could be taken to improve the situation. The subsequent chapter considers primary data collected in Lusaka and aims to provide further understanding of the situation.

Chapter 5. Exploration of Factors at the Community Level which may Affect Access to Improved Sanitation and FSM Service Delivery

5.1 Introduction

This chapter addresses the third research objective by presenting the findings of primary data collected at household and community level within selected informal settlements in Lusaka. This data provides further insight into the current state of FSM in informal settlements in Lusaka (above that explored in Chapter 4) and identifies key factors, beyond those presented in existing planning approaches, which may prevent access to improved sanitation and/or the implementation of FSM services.

Chapter 1 indicated that informal settlements have inherent complex dynamics which can make the provision of services within them extremely difficult. The current situation in relation to sanitation within the Zambian context was discussed in Chapter 4, based on secondary data predominately related to the city and country level domains. Secondary sources provide little insight into the causal factors for the current sanitation situation at household and community levels nor how to ameliorate this. Whilst detailed situational analysis forms a key part of the planning process as prescribed by the sector, (see section 5.2 below) Chapter 4 indicates that in the field such analysis and overall detailed planning is not being undertaken in Zambia.

Even in situations where planning approaches are being used, as previously discussed, scholars have indicated that there is scope for further exploration and diagnosis of the complexities inherent to informal settlements which may inhibit progress (Marshall *et al.*, 2009; Institute of Development Studies, 2012a). Other scholars argue that understanding social issues including perceptions and behaviours related to WASH activities, is critical for the sector to move beyond commonly reported failures (Whittington *et al.*, 1993; Anderson *et al.*, 2007; Van-Vliet *et al.*, 2011). Chapter 3 builds on these ideas by arguing that going forward the planning sector needs to invest more time in gathering a better understanding of factors affecting situational capacity.

This chapter will consider how exploring these factors (that go beyond those currently recommended in existing planning approaches) may provide insights, which lead to more successful planning and implementation of sanitation interventions in informal settlements ensuring FS is safely managed.

5.2 Existing Approaches and Methods

Within the existing urban sanitation planning approaches presented in Chapter 3, the necessity to understand the status of the current sanitation environment in order to establish programme needs and requirements for success is discussed (Eawag, 2005; Lüthi *et al.*, 2011; Parkinson and Luthi, 2013). This is commonly undertaken within the planning process as a detailed situational analysis where the current situation is defined. Situational analysis exercises are commonly used to identify stakeholders and their roles in sanitation service provision and understand specifically the interests, priorities and incentives of individuals or collectives. Household level baseline surveys are commonly used to gather quantitative data about the level of access to sanitation which is often based on the JMP ladder definition, assessing the number of households sharing and the type of technology in use (Shordt *et al.*, 2004). A number of scholars have argued that the JMP indicators are poor gauges of progress due to their sole focus on technology and 'counting toilets', which does not divulge other critical factors, such as how excreta is managed (along the SVC), user habits or the sustainability of the facility (Jenkins and Sugden, 2006; Sutton, 2008; Kvarnström *et al.*, 2011; Reed, 2011). Some of the issues may be overcome by the proposed post 2015 targets and indicators for WASH which are likely to replace the current JMP indicators. With target 3 defining the use of a 'safely managed sanitation service' as one that also ensures the safe management of FS at the household and beyond (WSSCC, 2014).

Beyond technical assessments, socially-orientated factors, such as perceptions and behaviours of households are rarely completed within the WASH sector (Whittington *et al.*, 1993; Jenkins and Scott, 2007). Within the wider development sector these factors are commonly explored using Knowledge, Attitude and Practice (KAP) survey methodologies which are among the most common types of cross sectional methods used to collect information on various socio-cultural aspects in relation to a particular topic (WHO, 2008; Launiala, 2009). In most cases data is collected through a structured questionnaire (WHO, 2008). This can be utilised at any stage of a project's implementation; at the early stages of a project to provide baseline information or throughout to monitor progress (WHO, 2008). The approach is often used by organisations required to identify intervention strategies that will address needs and gaps in knowledge (Ali, 2009). KAP methodologies are recognised for their usefulness when trying to gather information about respondents' knowledge (understanding of a topic of focus), attitudes (feelings towards a topic of focus) and practice (how they demonstrate their knowledge and attitude through action). In the WASH sector some examples of its use can be seen, for instance by UNICEF within its programmes (UNICEF, 1999; UNICEF, 2012). Scholars indicate that whilst KAP methodologies are useful, other ethnographic methods such as focus groups, in-depth interviews and participation observation should be used to strengthen validity and to underpin such population level approaches (Quy Anh, 2005; Launiala, 2009).

Ali (2009) states that the use of KAP methods in the WASH sector has high relevance, however this is said to depend on the nature of the project and the focus it gives to human aspects. Other research highlights the merits of exploring the social context of WASH and in particular household attitudes and perceptions to the current WASH situation and possible solutions (Whittington *et al.*, 1993; Banda *et al.*, 2007; Jenkins and Scott, 2007; Mugambe *et al.*, 2014). Despite these merits, exploration of these concepts is not currently inherent or deeply entrenched within existing planning approaches and limited research has been conducted on the impact of these factors on service provision in the WASH sector.

An understanding of people's knowledge and its effect on their existing or potential capacity to make improvements to their situation could provide useful insights for facilitating successful development. Capacity can be defined as *"the capability of a society or a community to identify and understand its development issues, to act to address these, and to learn from experience and accumulate knowledge for the future"* (Alaerts and Kaspersma, 2009). Whilst increasing individuals' knowledge is important for building capacity, an appropriate environment and mix of opportunities and incentives to use the acquired knowledge is also shown to be required (ibid). In the more recently developed planning approaches (section 3.3), the importance of establishing an environment where capacity can be built is outlined (Lüthi *et al.*, 2011). This suggests that it could be useful to explore how an individual's knowledge of sanitation affects their capacity to improve their sanitation situation.

Research conducted by Tukahirwa *et al.* (2011) explored the influence of four main sets of 'social' factors (socio-economic, perception, social proximity and social network) on access to sanitation services provided by NGOs or CBOs by the urban poor in informal settlements in Uganda. The impact of socio-economic factors (i.e. income, education, employment status) were explored as it was hypothesised that they may play a significant role in individuals' social status, which could then affect their ability to access services such as sanitation. Literature highlights that individuals' behaviour and willingness to pay or use services can be influenced by their perception and in particular, how users perceive the quality of services available and service provider competence (Webster, 1991; Cronin and Taylor, 1992). Spacial proximity is thought to influence service uptake with distance to service providers impacting upon the likelihood of service utilisation and access to information (Allard *et al.*, 2003). Finally, social networks, which relate to the interaction and 'bonding' of social relations, were considered important factors to explore as they relate to the strength and types of links and ties (including communication, trust and influence) between various stakeholders, which may impact on access to services (Reed, 2008; Prell *et al.*, 2009). Whilst the influence of each factor varied within the study (discussed in more detail in section 5.4) useful insights into the role of social factors on service access and uptake which related directly to households' sanitation access were presented. Therefore, exploration of these social factors could provide useful insight into dynamics operating in informal settlements and whether the safe management of FS can be achieved or not.

Chapter 3 and this section highlights the need for the sector to go beyond current ideologies and understand the merits that exploration of wider socio-technical factors can bring. The findings presented in Chapter 4 relating to Lusaka provide further weight for the need to explore socio-technical factors which could affect whether the safe management of FS is achieved or not in such complex informal settlements. This chapter seeks to establish whether knowledge of socio-technical factors can render increased success in sanitation implementation.

5.3 Methodology

As defined in Chapter 2, a mixed methods approach was adopted. There was a focus on obtaining an in-depth understanding of socio-technical factors and dynamics which exist at the household and community level within the selected settlements in order to establish if these factors are inhibiting progress in the sanitation sector. The methodology used draws from concepts and ideas discussed in section 5.2.

5.3.1 Data collection methods

At the household level domain an administered questionnaire survey was conducted as it allowed for large amounts of data to be gathered from individual households and ensured that the same questions could be asked to a larger number of respondents, when compared with other methods such as interviews (Bryman, 2008). The household questionnaire consisted of both closed and open ended questions (detailed in Appendix C). The open ended questions allowed qualitative reasoning or explanation for the respondents' answers to the closed questions to be gathered (Cohen *et al.*, 2007). This data collection method was supported by structured observations, Global Positioning Satellite (GPS) recording, photographs and field observations.

The first few sections of the questionnaire were designed to build rapport with the respondents consisting of simple questions requesting household and sanitation service provision details (Fowler, 1995). The latter sections were made up of more complex and personal questions (ibid). Good practice guidelines for developing questionnaires were referred to and in particular those related to surveys focusing on water and sanitation (UNICEF, 2006). The content of the questionnaire was inspired by the ideas discussed in section 5.2. Firstly, the questionnaire sought to establish existing FS practices and inherent capacity in these settlements and how these might impact upon the possibility of achieving improved FSM (practicalities). The ideas presented by Kvarnström *et al.* (2011) were drawn upon and adapted and indicators of the functionality of sanitation facilities (to safely manage excreta) were used (section 3.4.4). In particular, assessment of the household's knowledge level about sanitation, more focus on the status of the facilities substructure and exploration of factors relating to the practicalities of being able to deliver FSM, were added. Secondly, the status of a range of social factors, the effect these factors had on the current sanitation situation and the possible impact on service delivery/uptake (thus achieving improved FSM in these settlements) were explored. The approach and factors used in the study by Tukahirwa *et al.* (2011) drew upon similar ideas to that of KAP surveys and were considered to be particularly insightful. Therefore, Tukahirwa *et al.* (2011) study influenced the questionnaire content, however additional social factors were included (see below for further details) and ethnographic methods (i.e. open-ended questions, participant observation, photographs) were used to underpin and strengthen the approach.

The first section of the questionnaire collected information on the respondents': socio-economic situation; sanitation provision; current FSM practices; current MSW practices; involvement in community networks; and perceptions towards reuse. Within this part of the questionnaire the respondents were asked a range of questions relating to the enabling environment concepts. The responses were then used to provide an indication of the respondents' level of knowledge related to sanitation.

The middle section of the questionnaire presented a number of attitudinal statements which aimed to obtain an insight into the respondents' perceptions and attitudes towards their current water and sanitation provision, their priorities related to sanitation and their future sanitation needs. A Likert scale response mechanism was used to detect underlying attitude differences between respondents. This method was selected because it provided information on the respondents' agreement or disagreement to a single statement and was deemed appropriate (the most simple method) for use in the chosen context (Oppenheim, 1992). The attitudinal statements were formed from the first round of coding from initial semi-structured KIIs conducted at the community and city level domain (described in Chapter 6). The final section of the questionnaire for completion by the householder included personal questions such as age, household income etc. (Fowler, 1995).

The penultimate section of the questionnaire was used by the questionnaire administrator to collect GPS coordinates locating each household and to take a picture of every household's facility. The GPS information was used to calculate the distance from each household to the locations of interest (section 2.5). The final section of the questionnaire was an observational checklist for the questionnaire administrator to complete that provided information about the status of: the household's sanitation facility; management of FS; user habits and behaviour; and the surrounding environment. The majority of the checklist was based on characteristics from the first rung of the functionality sanitation ladder approach which attempts to assess the functionality of sanitation systems and how FS is managed at the household and beyond using observational indicators (section 3.4.4) (Kvarnström *et al.*, 2011).

The variables explored within the household questionnaire and the associated response categories are outlined in Table 5-1 below. The sanitation provision variables provided information on the level of sanitation access, the functionality of that facility to manage FS, the status of FSM, super and substructure facility quality, level of knowledge expressed and perceptions of reuse. All of the variables explored in the study by Tukahirwa *et al.* (2011) were used in this study. However, additional socially-orientated variables of: employment status; service access; duration lived in the community; and willingness to participate were added to the questionnaire in order to explore their possible impact. In the selected informal settlements in Lusaka, sanitation service provision does not currently exist (formalised emptying service in Kanyama had only just begun when this survey as undertaken), unlike those communities targeted for the study in Uganda (Tukahirwa *et al.*, 2011). Therefore, this study does not attempt to analyse the effect of the social factors on sanitation service uptake or access but instead on the existing sanitation provision situation (i.e. level of access, functionality of system and level of knowledge). Some of the questions asked focused on existing services within these settlements (i.e. water, electricity, education and SWM) and looked to establish whether useful insights into factors which may affect the uptake or sustainability of new services (i.e. FSM) could be made. It should be noted that tenancy is an important socio-economic factor that can affect sanitation access (Scott *et al.*, 2013). However, this was not included in this study, the reasons for this being explained in section 5.4.2.

At the community level domain, semi-structured KIIs were considered to be the most appropriate data collection method to use as the questions could be tailored to the various stakeholders being targeted. This technique allowed for the interview guide (Appendix C) to ensure specific themes were covered and echoed across all informant groups and domains and allowed informants to be able to express their views (Drever, 1995; Longhurst, 2010). In situations where large numbers of participants from the same organisation were available, focus groups were also utilised (using the same interview guide) so that the range of perspectives could be drawn on at once and to save time (Bryman, 2008; Longhurst, 2010). The focus of the interviews was to gain a greater understanding of the current sanitation situation and sanitation/FSM practices in informal settlements in Lusaka (and the city in general), to draw upon interviewees' attitudes towards current sanitation provision and possible solutions and to establish whether any socially driven dynamics existed which could be responsible for the current situation.

Both data collection methods were complemented by participant observations; specifically of pit emptying procedures, WT activities and community meetings. Participant observation is a widely used qualitative research method which often complements other methods (Cohen *et al.*, 2007; Bryman, 2008). Participant observation involves the researcher immersing themselves in the social context they aim to observe and taking qualitative notes on what is seen. A field observation diary was kept which recorded observations made whilst I was in the three communities, including: weather conditions, comments and any additional information or feelings that came to mind during the implementation of the methods described above.

Table 5-1: Definition of selected questionnaire variables (Adapted from Tukahirwa *et al.* (2011))

Category	Variable	Explanation	Response Categories
Sanitation Provision Factors	Functionality of sanitation system	Administrator completed observation checklist related to containment facility	Clean facility in obvious use; no flies or other vectors; no feacal matter lingering; hand-washing facility in obvious use with soap; lid; odour- free facility; good quality of construction; contained emptying in operation.
	JMP indicator	Indicators to establish access to sanitation in line with JMP criteria	Type of technology, number of households sharing
	FSM practices	Current FSM practices	Engage people to empty; build a new pit; abandon and use other facility; other; never been full
	Facility construction	Containment facility construction	Method of construction; materials; techniques; who built it; size; cost.
	Knowledge level	Questions exploring households knowledge related to sanitation	*Assigned categories based on responses:* Lack of knowledge; limited knowledge; immediate knowledge, wide range of knowledge
	Reuse	Perception of safety of reuse of FS	Yes; No; don't know
Socio-Economic Factors	Age	Age of respondent	10-19; 20-29; 30-39; 40-49; 50-59; 60-69; 70-79; 80-89.
	Gender	Gender of head of household and respondent	Gender: Female or Male Role: Head of Household; Spouse; Other
	Education	Level of formal education of respondent	None; Grade 1-7; Grade 8-12; Above Grade 12
	Income	Total weekly income of household	ZMW 0-999; 1000-1999; 2000+
	Employment status	Highest level of occupation held within the household	None; Informal; Formal
	Level of access to services	Level of access to services (Water, Electricity, Education, Health, Sanitation, Solid Waste Management)	No access; categories of cost spent per month
Perception Factors - How users perceive services/current access	Attitude	A measure of positive or negative feeling of the household toward current sanitation access and responsibility for change.	Attitudinal statements with responses on a 5 point Likert scale (strongly disagree; disagree; neutral; agree; strongly agree)
Spatial Proximity Factors -Influence of distance on service provision	Distance to Water Trust/WDC	Proximity of household to water provider head office in community and ward development committee (next to WT in all three communities)	GPS coordinates, Kilometres
	Distance to Health Centre	Proximity of household to health centre	GPS coordinates, Kilometres
Social Network Factors - Interaction and bonding of social relationships	Duration lived in community	Duration currently lived in the community	0-5;6-10;11-15;16-20;20+ years
	Cooperation	Involvement of household in community based organisation or interventions related to sanitation	Yes or No
	Competence	The perceived capability of the water provider, local government, household and community related to sanitation	Attitudinal statements with responses on a 5 point Likert scale (categories as above)
	Willingness to Participate	A measure of willingness to participate for change in sanitation	Attitudinal statements with responses on a 5 point Likert scale (categories as above)

5.3.2 Sampling

The three study locations were selected because they had similar surface area (m^2) and provided representation of the main WSS service provision setups in informal settlements of Lusaka (Table 5-2). Their locations were selected after discussions with the manager and staff from the PUD of LWSC who identified possible areas where household questionnaires could be administered.

Table 5-2: Community parameters of sampled areas

Community	Total area surveyed (m^2)	Population in area[6]	Water supply provision
Kanyama	173,864	137,000	Water Trust
Chazanga	169,050	86,000	Water Trust
George	139,200	145, 230	LWSC

The effect of spatial proximity was key to this study and therefore it was decided that the questionnaires should be administered throughout the whole communities using a spatial sampling frame. Each compound is split into administrative zones by LCC, however these zones vary in size and composition therefore a method of area sampling was used. To achieve an evenly distributed spatial sampling frame, the *Stratified Random Unaligned Sampling* method was used (Burt *et al.*, 2009); whereby the sampled area was split into grid squares and a household was selected to be interviewed within each grid square by the questionnaire administrator. Other spatial sampling methods are available however this one was selected based on the capabilities of the questionnaire administrators. GPS devices (Trimble Juno) were used by the questionnaire administrators to identify which area (grid square) they needed to select a household from, the location of which was recorded (results in Appendix D).

During pilot testing of the survey (see section 5.3.3) it became clear that when tenants were approached to answer the survey, the detail of answers, specifically related to the containment facility, was limited. It was therefore decided that within each grid square, households that were owner occupied dwellings would be targeted and where possible the heads of households targeted. In the case where no owner occupied dwellings were available in the area, the next available long term tenanted household was targeted. Where the head of household was not available the next lead household member was approached.

The sample size selected depends on the purpose of the study and the nature of the population under survey with larger sample sizes giving greater reliability and representation of the population (Cohen *et al.*, 2007). The ideal sample size for this study to be representative, based on various levels of confidence, are presented in Appendix E. Many researchers state that a minimum sample size of thirty per group is required as a rule of thumb (ibid). Due to the available resources (money, time and administrative support) an achievable sample size of 100 questionnaires for each

[6] Population was provided during interviews with WDC and WT.

community was defined (total 300). This sample size would allow a representative sample at 90% confidence interval (N=298) to be achieved and was deemed suitable during the piloting of the questionnaire (section 5.3.3) based on the observed distributions of responses.

However, once the survey had begun being administered, a number of issues became apparent which caused the sample size to be less than anticipated. Some of the sampling grid squares had no residents in them and in some cases the sampling locations actually went beyond the community boundary as the administered boundaries in the maps provided were incorrect. The number of administered questionnaires achieved in each community were; Kanyama: 58 samples, Chazanga: 54 samples and George: 57 samples, giving an overall total of 169 questionnaires administered over the three communities. Questionnaires took between 30 minutes to an hour to complete. Therefore, the sample size achieved is not representative of the total populations within the selected settlements or beyond and therefore this study does not intend to draw conclusions about the population of informal settlements of Lusaka. However, because of the qualitative nature of the questionnaire the size sample achieved provided good representation of the numerous variables explored and it was deemed that theoretical saturation was achieved (Bryman, 2008).

In the case of the community level semi-structured interviews and focus groups, key organisations within the community were identified from a stakeholder mapping exercise (section 2.6.2). Direct contact was made with representatives from a few key institutions through support from WSUP and LWSC. From there, contacts with further stakeholders and institutions was made by asking interviewees for further contacts, a method known as snowball sampling (Bryman, 2008). Interviews lasted on average 45 minutes. A total of 10 semi-structured KIIs and 4 focus group discussions were conducted with key informants from community level organisations which included employees of community based water providers, WDC, ward water committees, pit emptiers, CBEs and local health centres. Details of these interviews and focus groups conducted can be found in Appendix A.

5.3.3 Administrating the methods

The household level questionnaire was administered by two individuals (one female and one male) who were identified as suitable for the role after consulting with two local NGOs that had experience in using interpreters to administer questionnaires. The two administrators selected had previous experience of administrating such questionnaires, had completed a university degree in social sciences and had good spoken Bemba and Nyanja (the two most common local languages spoken in Lusaka). Originally, administrators with an engineering background were sought but without success. Although neither of the selected administrators had a background in sanitation or civil engineering they had both administered questionnaires in other regions on similar subject areas. In each community each interpreter was accompanied by a member or associate of the WDC who acted as gatekeepers for the communities. I accompanied the survey administrators for all the pilot questionnaires and was present for 46% of the overall questionnaires completed. However, I was never directly involved with administrating the questionnaires but was present as an observer. It should be noted that the questionnaires were undertaken in Kanyama approximately one month after the introduction of the FSM service by the WT, however this did not appear to influence respondents' answers

The questionnaires were written in English; however, they were administered in Bemba or Nyanja, which are the most commonly spoken local languages. This could have introduced potential errors in intra and inter-interviewer variation in translation. Prior to the survey testing and administration each translator verbally translated the questionnaire from English to both Bemba and Nyanja. The other translator then dictated what was said back to me in English. The meaning of each question was checked and verified (both translators did the exercise) so I could ensure that the meanings had not been lost during translation. At this point some of the language used in the questionnaire was modified to suit the local language more appropriately.

Before the testing of the questionnaire, administrators were trained by me to ensure they understood the aim of the research, the rationale for the questions and basic administration techniques including introductions and closing protocol of the survey. Further to this, training was also given on the basic sanitation knowledge required to administer the questionnaire, how to conduct the more participatory questions, the observational checklist and how to use the Trimble Juno machine to record GPS coordinates and to take photographs. A draft of the household level questionnaire was piloted in each of the three chosen wards with a total of 5 questionnaires being administered across the three chosen communities (total of 15 test questionnaires). Modifications were made to the questionnaire after the pilot including deletion of 3 attitudinal questions and deletion of 3 further questions that were deemed to not be required.

The community level interviews with individual KIIs were conducted in English. In the case of the focus groups (with pit emptiers, ward water committee and CBEs) a separate interviewer (from those used to administer the household questionnaires) was used to run the focus groups in Nyanja. This interviewer was selected because of their availability and because they had experience of conducting focus groups on WSS from work with an NGO based in Lusaka. Prior to the focus group they received training as discussed above. Prior to the KIIs commencing (where deemed appropriate) permission to record the interviews was requested. Where it was not deemed appropriate, brief written notes were made during the interview. Further notes were then added after the individual interviews. In the case of the focus groups the interpreter wrote brief notes of the responses and where natural pauses in conversation occurred the interpreter highlighted the main points being discussed to me in English and notes were written. At the end of the focus group the interpreter and I discussed the findings of the focus group to ensure all parts of the discussion had been captured in my notes. The notes were transcribed as quickly as possible using Microsoft word.

5.3.4 Ethical practice

The research strove to adhere to good ethical practice at all times. Prior to undertaking fieldwork, the methodology and fieldwork protocol was approved by Newcastle University Science, Agriculture and Engineering faculty’s ethics committee. Participants at the household and city level were guaranteed confidentiality and anonymity through a coding system for each questionnaire. Prior to administering the questionnaire in the three communities, meetings were held with the WDC and the WT/water provider at which the objectives and details of the study were explained and authorisation was sought. Before questionnaire, interview or focus group administration had begun, informed consent was received by every participant prior to data collection. The respondents’ right to decline to answer any questions and/or withdraw from the questionnaire at any time was explained. The anonymity and confidentiality of respondents was achieved through the use of a coding system whereby each was assigned a unique code (only know by me) so that none of the data collected could be traced back to individuals.

Informants were advised that the knowledge and information produced as a result of the study would be made available to the supporting organisations WSUP and LWSC and be published online.

5.3.5 Data analysis

SPSS for Windows, version 18.0 was used to process (code and analyse) the quantitative data produced from the household level questionnaires. The main aim of the quantitative data analysis was to explore statistical significance between key sanitation provision factors (functionality of sanitation system, JMP indicator and knowledge level) and the key social factors of interest (socio-economic, perception, spatial proximity and social network) from responses to the questionnaire. A wide range of tests can be used to explore statistical significance and they broadly fall into two groups- parametric tests and non-parametric tests. Whilst parametric tests are generally more powerful, the data must be normally distributed and have at least an interval level of measurement for them to be an option (Field, 2000). The majority of the data had nominal properties, however for those that had interval properties the Kolmogorov-Smirnov one sample test was used (which compares the set of scores in the sample to a normally distributed set with the same mean and standard deviation (Field, 2000)). The results concluded that the data sets were not normally distributed. Therefore all the data collected was shown to violate the parametric data requirements, so non-parametric statistical tests were used to analyse the data.

The choice of which non-parametric test to employ depends on a number of factors including: the variables scale of measurement (e.g. nominal, ordinal, interval or cardinal); the number of sub groups being compared; the independence of the sub groups; the purpose of the analysis; and the analyst’s preference (Pallant, 2010). No repeated measures were taken in this analysis and so only Chi-Squared tests for independence and Mann-Whitney U tests were used. The Chi-Squared test is used when you wish to explore the relationship between two categorical variables and Mann-Whitney U when the differences between two independent groups on a continuous measure are to be tested (Pallant, 2010). Due to the fact that the final sample size achieved was smaller than expected, the responses from each community were combined so that reliable statistical analysis could be conducted (i.e. chi-square statistic requires there to be an expected count of five cases or more in 80% of the cells).

All of qualitative data collected, relating to both the household and community level domains of the research framework, was transcribed into Microsoft Word. Prior to further analysis of the data, the transcripts were prepared for manual pre-coding through specific formatting and preliminary jotting (Saldana, 2009). The data was then further coded and a code book was created (Braun and Clarke, 2006). From these codes, sub categories and categories were created which allowed dominant themes (possible theories) to be revealed. The method of analysis was varied slightly for the data obtained from the household level questionnaires as the data was synthesised and structured prior to analysis through the building of tables. These tables were constructed so the data on the impact of each factor (both positive and negative) on sanitation access and knowledge level could be summarised (Ashley and Hussein, 2000). Although the coding process was exclusively conducted by me, on several occasions throughout the coding procedure a colleague was engaged to discuss the coding system and results as a way of bringing new perspectives and insights to the data (Saldana, 2009).

The GPS coordinates collected as part of the household questionnaire and field observations were input into the ARCGIS programme. The distances between the questionnaired households and the selected institutions were automatically generated using the point distance proximity tool in Arc Toolbox.

5.4 Results and Discussion

The following section presents the results obtained from the household and community level domain at the three selected informal settlements. The results of the sanitation provision factors are firstly discussed. The results of statistical analysis conducted between selected sanitation provision factors (sanitation access and knowledge level) and social factors of interest are then presented. Drawing upon qualitative responses from the questionnaire where possible, reasons for the statistical results are discussed. The final part of this section draws upon findings from the community level KIIs conducted.

5.4.1 Current level of access to sanitation

The current level of sanitation access was identified in all three communities using two definitions. Firstly, those households that achieved access to an improved facility based on JMP criteria were defined as having access to a 'JMP Improved Facility' (JIF) (Table 5-1). Secondly, those households that were observed as achieving a functioning sanitation system based on categories outlined in Table 5-1 were defined as having access to an ‘Excreta Containing Facility’ (ECF). These two definitions were used because it allowed the level of sanitation observed to be expressed in the standard way used by the sector (based on JMP indicators) but also provided more in-depth technical information about whether FS is being safely contained at the household domain or not.

For the three selected informal settlements the level of sanitation access using both categories was shown to be poor (Figure 5-1) with only 36% of respondents achieving access to a JIF and 23% achieving access to an ECF (N=169 for both). The reason why households were reported not to achieve access to a JIF was related to the number of households sharing a facility with 65% of households sharing their facility with 2 or more households (N=169). The results seen are lower than those reported by the JMP for urban Zambia (56% of urban population have access to a JIF (WHO/UNICEF JMP, 2014c)). This is to be expected as this study focused on informal settlements which are likely to have the lowest levels of sanitation access when compared with results for the whole urban area of Lusaka.

Only 8.3% (N=169) of households were observed to have access to a ‘hand-washing facility in obvious use with soap’. Due to the extremely low level of access, this category was removed and did not contribute to whether a household achieved access to an ECF or not. The results showed that the main reason why facilities did not achieve ECF status was their observed failure to achieve an ‘odour free’ facility (only 39% achieved, N=169) and a facility with ‘no flies or other vectors’ present (only 40% achieved, N=169). This indicates that the majority of facilities in use are not containing FS safely, in particular the presence of flies which can transmit diseases from FS via the faecal-oral transmission route (Peal *et al.*, 2010).

Overall, Kanyama was shown to have the poorest level of sanitation access out of the three communities. The results show that in Chazanga there was a large difference between facilities which achieved JIF access and those that achieved ECF (reduced by 23%) when compared with the other two settlements. This indicates that despite a high percentage of households having access to a facility deemed improved by the JMP, the functionality of a large number of those facilities (48%) to contain excreta is actually poor and so health and environmental risks may still be prevalent.

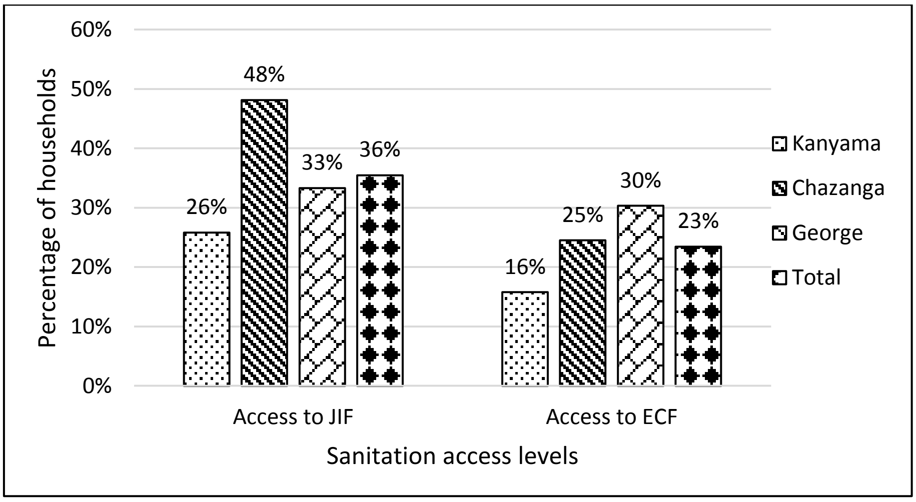


Figure 5-1: Levels of sanitation recorded in each community

Pit latrines and septic tanks (improved technologies defined by JMP) were the only types of sanitation technologies observed in these communities. An improved pit latrine is defined by the JMP as 'one where the pit is fully covered by a slab or platform that is fitted either with a squatting hole or seat' and the septic tank 'is an excreta collection device consisting of a water tight settling tank' (WHO/UNICEF JMP, 2014a). The type and quality of construction of sanitation facilities were shown to vary in all communities signifying that no pit latrine standards, enforcement of standards or technical support for the construction of pit latrines had been used or undertaken at the community level. A picture was taken of every facility where household questionnaires were undertaken and a selection of these pictures can be seen in Appendix B.

All the pit latrines observed were shown to have a single chamber (N=143), however their volumes and sizes were shown to vary (ranging from 1 to 5 metres deep with the mode being 3m, N=44). For the majority of the latrines observed, the substructure of the latrine was constructed using hollow (highly permeable) concrete blocks (80%, N=143). The next most common construction technique was to have an open pit as the substructure (11%, N=143). In 16% of the cases where the pit latrine substructure was constructed using blocks (N=114), these blocks had been further plastered with mortar. The base of all the pit latrines observed were left open (unlined) allowing for direct percolation in to the ground from the base (N=143).

The majority of the respondents noted that they had employed untrained local masons (52%, N=129) to construct the pit latrine, however in Chazanga a large percentage of households had built the pit themselves (48%, N=42). Only 18 septic tanks were observed (N=169) in the selected informal settlements and all were constructed with only one chamber which is not the normal recommended septic tank design (Tilley *et al.*, 2008). The results highlight that the existing containment facilities used in informal settlements in Lusaka are not standardised in their construction, which may have implications for future FSM interventions (discussed further in Chapter 7).

Without further detailed study, it is difficult to state the level of public health risk caused by the construction type and quality of sanitation facilities observed in the selected informal settlements. Standard pit latrine designs promote the bottom of the pit to remain unlined so percolation of the liquid fraction of the FS out of the pit can occur, however these facilities are not deemed appropriate for areas with high ground water tables (Tilley *et al.*, 2008).

Despite Chapter 4 indicating that NGOs (which have focused on sanitation provision (Ecosan)) have previously been present in informal settlements in Lusaka, none of the questionnaired households were utilising such technologies and only two facilities were observed whilst walking through the three informal settlements. Therefore, indicating a low level of successful intervention by NGOs in these informal settlements.

In relation to the FSM, only 67% (N=169) of respondents indicated that their facility had never become full. In those cases the most common emptying practice was to cover the old pit and build a new one (43.5%, N= 111). Some respondents (13.7%, N=111) reported that they engaged people to empty their pit, referring to the informal pit emptying practice which occurs in these communities (explained in section 4.4.2). This confirmed that poor FSM currently exists in these settlements and that there is no safe hygienic method of FS removal, transportation, treatment and reuse or disposal available. In the case of the septic tanks, only 10 out of the 18 septic tanks had access holes for desludging. In the case of pit latrines observed, the majority had no access holes (94%, N= 143). It was observed that the majority of households had some form of access path next to their plots (82.9%, N=169). However, the quality of the access pathways were poor as few were tarmacked and most were under 2m in width, therefore making them inaccessible to FS removal equipment (i.e. vacuum tankers).

5.4.2 Assessed levels of knowledge related to sanitation

The assessed level of knowledge of respondents towards sanitation was shown to be particularly low for all three informal settlements. This may indicate that households in these communities have a low capacity to improve their sanitation situation (section 5.2.1). Figure 5-2 shows that respondents in Kanyama had the lowest level of knowledge overall out of the three communities (note that they also had lowest levels of sanitation access (both JIF and ECF)). Respondents from Chazanga had the highest percentage of respondents achieving the highest two categories of knowledge level (52%, N=54) when compared with the other two communities (and the highest levels of sanitation access defined as JIF). The household respondents' knowledge about issues beyond the household level, especially their rights, laws related to sanitation provision and which agencies are responsible for sanitation provision, was shown to be very poor in all three informal settlements.

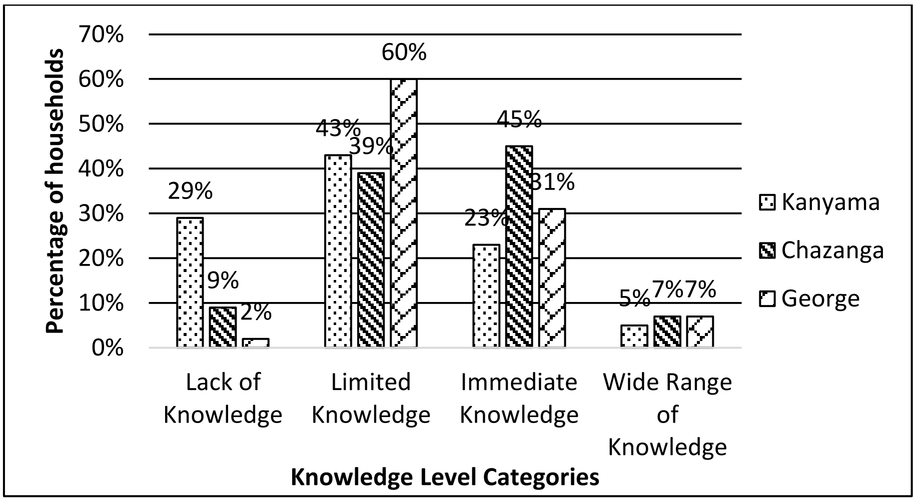


Figure 5-2: Assessed level of knowledge related to sanitation for each community

For all three settlements combined, a statistically significant relationship (using chi squared analysis) was seen between the level of respondents' assessed knowledge and their access to a JIF (X^2 (3) = 30.719, p=0.000, N=169 with a moderate level of association, Cramer's V = 0.426) and their access to an ECF (X^2 (3) = 10.877, p=0.012, N=169 with a low- moderate level of association, Cramer's V = 0.2887). These results indicate that respondents' level of knowledge regarding sanitation directly impacts upon their level of access to sanitation.

A total of 61% (N=169) of respondents indicated that they did not think it was safe to use FS as a fertiliser after treatment. This will be discussed in Chapter 8.

5.4.3 The effect of selected social factors on sanitation access, level of knowledge and the creation of an enabling environment

Table 5-3 provides an overview of the results achieved from the questionnaire data and highlights the cases where statistically significant relationships were seen between the social variables explored and the current level of sanitation access and knowledge reported for the three communities combined. The p value indicates whether statistical significance was observed or not and the Cramer V value (r in the case of Mann-Whitney U) provides an indication of the strength of association of the results. Overall, some statistical significance was observed (results observed $p<0.05$), however there was only a low- moderate level of association in those cases indicating that the factors explored had little overall effect on households' sanitation level or knowledge level. As discussed in section 5.3.2 the sample size achieved was not high enough to be representative of the population living in informal settlements in Lusaka but the results do provide useful insights despite this.

The following section provides further discussion about the results presented in Table 5-3 and includes the findings from the analysis of the in-depth qualitative components of the questionnaire. Where the statistical relationships between the social factors and the selected sanitation provision factors are discussed, the results can be found in Table 5-3. In a few cases extra statistical analysis was performed beyond these selected variables and these results are included directly in the text.

Table 5-3: Indicators of relationship between social factors and sanitation access and knowledge level [7]

Factors	Variables	Statistical test used	Sanitation Access (JIF)	Sanitation Access (ECF)	Assessed Knowledge Level
Socio Economic Factors	Age	Chi Squared	p= 0.944	p=0.352	p=0.472
	Gender	Chi Squared	p= 0.389	p=1	p=0.182
	Education	Chi Squared	p=0.513	p=0.137	X^2 (5) = 18.065, p=0.003, Cramer's V = 0.327 [8]
	Income	Chi Squared	p= 0.161	p=0.264	p= 0.288
	Employment Status	Chi Squared	X^2 (2) = 6.967, p=0.031, Cramer V = 0.203	X^2 (2) = 6.204, p=0.045, Cramer's V = 0.193	p= 0.111
	Service Costs or Access (also used in SNF)	Chi Squared	Water: X^2 (3) = 10.087, p=0.007, Cramer V = 0.244	Electricity: X^2 (1) = 4.930, p=0.027, Cramer V = 0.187 Education: X^2 (3) = 10.056, p=0.018, Cramer's V = 0.246 Water: X^2(2)= 7.175, p=0.028, Cramer V = 0.208	Education: X^2 (3) = 11.709, p=0.008, Cramer V = 0.263 Electricity: X^2 (3) = 12.864, p=0.007, Cramer V = 0.267
Perception Factors	Attitude (attitudinal statements)	Mann-Whitney U	Statement 1: p=0.005, Z=-2.813, r=-0.217	Statement 1: p= 0.003, Z= -2.945, r= -0.219	Statement 3: p=0.027, Z=-2.211, r= 0.171
Spatial Proximity Factors	Distance to Water Trust/WDC	Mann-Whitney U	p=0.168	p=0.771	p=0.847 (Kruskal-Wallis test)
	Distance to Health Centre	Mann-Whitney U	p=0.451	p=0.071	p= 0.417 (Kruskal-Wallis test)
Social Network Factors	Duration lived in community	Chi Squared	p=0.494	p=0.538	p= 0.355
	Cooperation	Chi Squared	X^2 (1) = 7.003, p=0.008, Cramer V= 0.225	p=0.988	X^2 (3) = 13.549, p=0.004, Cramer V= 0.283
	Competence (attitudinal statements)	Chi Squared	-	-	-
	Willingness to Participate	Chi Squared	p= 0.388	p= 0.720	p=0.996

5.4.4 Socio-economic factors

The majority of respondents were female (75%, N=169) and the most common age category was 30-39 years old (26%, N=164). It was observed that men are usually away from the households during the daytime and therefore it was expected that the majority of respondents would be female. Questioning females was deemed to be appropriate. Female household members in Zambia are often in charge of issues related to WSS (Central Statistical Office *et al.*, 2009). Therefore by interviewing them it was ensured that the responses of the stakeholders most involved with its management at the household level were captured. Age and gender were shown to have no significant effect on the households' access to sanitation or the level of knowledge.

[7] All results are for the sample combined which is N=169 unless otherwise stated in the text below. A significant relationship is observed if p<0.05 (indicated by bold shaded cells).
[8] So that a reliable statistical analysis could be conducted the assessed knowledge level had to be reduced to two categories of 'lowest assessed levels of knowledge' and 'highest assessed levels of knowledge'.

A total of 31% of the female respondents reported that they were the head of the household and 69% were spouses (N=127). It could be hypothesised that female headed households may be more vulnerable as they are shown to be typically poorer than male-headed households (Central Statistical Office *et al.*, 2009). However, the results showed there to be no significance between gender of household head and level of sanitation access or knowledge level.

The highest proportion of respondents were shown to have only completed education up to grade 7 (primary level) (46%, N=169). A significant relationship was seen between respondents' education level and sanitation access and knowledge level with a moderate level of association. The results showed that the majority of respondents stated that their household income was ZMW499 or less per week (approx. US$ 80 based on a conversion rate of 1 ZMW to US$ 0.1602 (XE, 2014)) (62%, N=169). There was shown to be no significant relationship between income level and sanitation access or assessed level of knowledge. This was not expected as it could be hypothesised that the wealthier households would be able to afford better facilities. It may also be hypothesised that household income could also be an indication of employment status with wealthier households being more likely to have members in formal employment. This was confirmed by the statistically significant relationship observed between income and employment status for these settlements (X^2 (2)=13.014, p=0.001, N=169 with a moderate level of association, Cramer's V=0.307). We may also expect those in formal employment to be better educated, however reliable statistical analysis could not be achieved to confirm this relationship due to sample size.

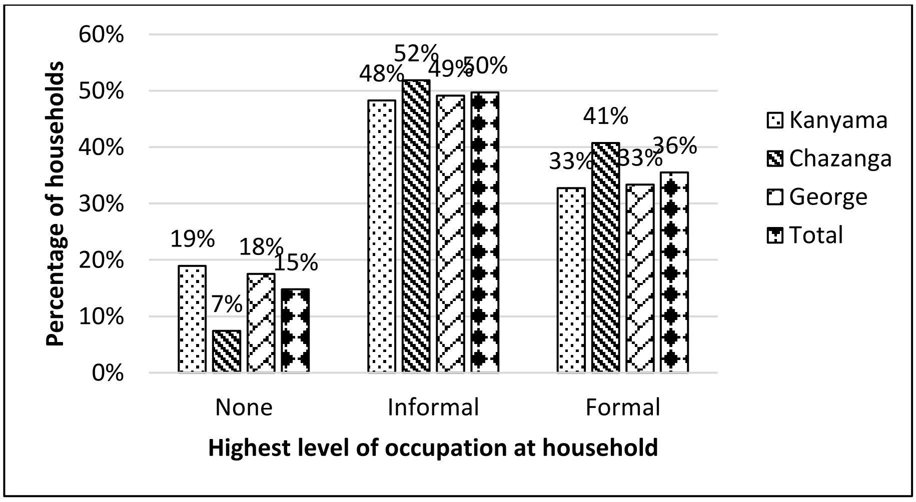


Figure 5-3: Occupation level observed in each community

The majority of households were shown (Figure 5-3) to have members employed in informal occupations (noted to be predominantly market sellers). Chazanga had the highest number of respondents with a household member employed in a formal occupation (52%, N=54), many of these being teachers. In Zambia, hygiene promotion and behaviour change initiatives have been promoted through schools. The prevalence of teachers in this community, who may be educated on issues of hygiene at their place of work, may be one reason for the higher levels of overall knowledge and JIF access seen in Chazanga. There was shown to be a statistical significance observed between the level of employment and the two sanitation access criteria, thus indicating that the highest level of employment at the household may impact upon the sanitation level accessed (as discussed above). However, the strength of these relationships was shown to be weak (Cramer V value approx. 0.2). This relationship may be seen because those in higher levels of employment status (formal employment) may have exposures to networks (i.e. contacts, education and organisations outside of the community), which could directly impact their household's level of sanitation access.

The results indicated that most respondents did not access health services or sanitation services in all three informal settlements (62% and 99% respectively N=169). Education and electricity access was shown to be similar for all three communities with households most commonly spending between ZMW1-249 (US$ 1-40 based on a conversion rate of 1 ZMW to US$ 0.1602 (XE, 2014)) per month on each (50% and 47% of respondents spending ZMW 1-249 on access respectively, N=169).

The majority of respondents in Kanyama (65%, N=58) and George (78%, N=54) were shown to access water through water kiosks. In Chazanga, the majority of households utilised individual piped access (56%, N=56). A statistically significant relationship was seen between the type of water access utilised and sanitation access, with those with individual taps being more likely to have access to an ECF and JIF. The most recent JMP progress report highlighted that most of the people who are using improved drinking water sources also use improved sanitation, indicating a relationship between level of access to water and sanitation (WHO/UNICEF JMP, 2014b). The results of this study may indicate that the level of water access of the household may directly affect the level of sanitation (based on both JIF and ECF criteria). Levels of access to electricity and education services, were also shown to statistically impact household's access to an ECF facility and their level of knowledge. These results indicate that household's access to alternative services (i.e. water, electricity, education) may impact upon their sanitation access and related knowledge.

The results achieved show that socio-economic aspects such as education, occupation and current access to other services have a statistically significant effect on the level of sanitation access and knowledge currently observed in these informal settlements, though the strength of this relationship was shown to be relatively weak for all cases. These results concur with those found by Tukahirwa *et al.* (2011) which indicated that socio-economic factors can have an impact on factors associated with sanitation, however the impact may be more limited than expected. These aspects which were shown to impact on the level of sanitation access and knowledge achieved, also relate directly with the social network factors explored below. This indicates that the status of the household and the type of networks they are involved with or exposed to (related to occupation and access to services) could positively impact upon household sanitation access and knowledge. These findings are also similar to those by Tukahirwa *et al.* (2011) and will be discussed in more detail in section 5.4.7 below.

5.4.5 Perception factors

Within the questionnaire, four attitudinal statements were used to provide an indication of how respondents perceive their current sanitation situation. Firstly, for the statement, 'I am happy with my household's current access to a toilet facility,' similar percentages of respondents (49%, N=169) both agreed and disagreed with the statement (with the remaining 2% being neutral). The qualitative reasoning given by respondents related to the facilities' cleanliness, quality of construction, perceived building strength, ease of access, numbers sharing, cost, maintenance required and whether there was perceived to be a better alternative type of technology available. These responses provide an indication of the aspects households perceived as important in relation to their sanitation facility. There was a statistically significant relationship observed between the answer to this first statement and the level of sanitation access achieved (both JIF & ECF), which is to be expected as those who are unhappy with their sanitation provision are likely to have poor current access.

For the second statement, 'Nobody understands my sanitation access needs,' the majority of the respondents (73%, N=169) either agreed or strongly agreed. The current lack of physical presence of stakeholders to assist in improving sanitation and the lack of a protocol for complaining about issues faced, were the main reasons given for respondents agreeing with this statement. The responses indicate that for households to feel their needs are understood (and possibly being met) they need to observe some sort of physical presence at the community level and for a channel of communication to be available to them. This could provide a useful insight for the introduction of new services in the future. There was shown to be no statistically significant relationship observed between this statement and sanitation access highlighting that no matter what level of sanitation provision or knowledge level the household may currently have, the majority of them felt that their sanitation needs are not currently understood.

The third statement, 'I would like to have more knowledge about how to design and construct my toilet facility,' received a positive response with 95% of respondents (N=169) either agreeing or strongly agreeing. Respondents indicated that they wanted more knowledge so that they could build good facilities, gain new ideas, teach others, ensure they had access to a safe facility that is correctly designed to help improve the future of their household. There was shown to be a statistical significance observed between the third statement and the assessed level of knowledge of households. This was to be expected as households with limited current knowledge are most likely to want more knowledge.

The majority of respondents (90%, N=169) either agreed or strongly agreed with the final statement, 'I am happy to pay for an improved toilet facility'. Reasons given were that respondents perceived that it would reduce diseases and provide access to a cleaner, stronger, better facility. However, respondents stated that issues of space, ensuring the cost of service was within their means and their financial capacity would impact upon their willingness to pay in reality. This statement reiterates the facts that households perceive that improved facilities should be healthy, clean, strong and better than what was there previously. The study of Tukahirwa *et al.* (2011) showed that in households currently without access to services, the households level of income and the sanitation service costs were factors which influenced whether they would uptake services or not. Similar results are seen within this study.

These responses provide an understanding of householders' priorities, what they perceive as important factors or requirements for a functioning sanitation system and service delivery and their perceived needs at the grassroots level.

5.4.6 Spatial proximity factors

In the Ugandan study (Tukahirwa *et al.*, 2011) the spatial proximity of households to facilities had an impact on households' access to sanitation services and therefore it was recommended that this should be considered when planning for interventions. Within this study there was no significant relationship seen between the distance of questioned households to key institutions (LWSC/WDC and health centre) and the level of access to sanitation or knowledge level regarding sanitation. This may be because in this case study there was limited institutions or offices present in the community linked to sanitation interventions or service provision. However, in the case of water provision there was also shown to be no statistically significant relationship (p=0.487) between the perceived quality of service provided by the WT or LWSC and the distance from the water supplier office in the community.

However, despite a lack of statistical significance, the qualitative questionnaire responses indicated that the physical presence of a service provider or institution within the community can affect households' perceptions. In particular, if households did not perceive a route of communication is present then they may feel their needs are not known or appreciated. The results indicate that spatial proximity is an important concept to consider during planning in these settlements. Literature suggests that when services are being provided in large informal settlements offices may be required at more than one location as the distance to service providers can affect service uptake (James *et al.*, 2001; Tukahirwa *et al.*, 2011).

5.4.7 Social network factors

The results indicated that many of the residents have lived in the community for a relatively short period (37% responded 0-5 years, N=169) with a stepwise decline in numbers as the length of residence increased. Thus suggesting that recent urbanisation is occurring in the settlements studied which is a characteristic of many African cities where informal settlements have developed as a result of rapid urbanisation (UNHabitat, 2014). These informal settlements are often characterised by insecure tenancy statuses and limited social cohesion which can directly affect residents ability to defend themselves and achieve better service provision (Durand-Lasserve, 2006). Social cohesion and integration may also be affected by the length of residence, as scholars indicate that it can take time to develop supportive social ties (Keene *et al.*, 2013). Whilst in this study there was no statistical significant relationship seen between length of residency and sanitation access or knowledge, Scott (2011) et al indicate that the length of duration of residency may have an effect on the household's type of sanitation access. Therefore, in these settlements there may be a requirement to ensure that residency length, type and its impact on social cohesion is explored.

The results show that very few households had members who cooperate in CBOs (Kanyama= 21%, N=58; Chazanga= 17%, N=54 and George= 14%, N=57). For those that did the majority were based in church as well as through community clubs, farming cooperatives, health centre, schools or local NGOs. No statistical relationship was observed between level of sanitation access or knowledge and cooperation in a CBO. Only a small number had taken part in any form of activities related to sanitation (Kanyama= 9%, N=58; Chazanga= 13%, N=54; and George= 7%, n=57) and it was highlighted that sanitation related activities in these areas had come through the local health centre, WDC or NGOs. The responses revealed that the water service providers had not been involved in the implementation of any initiative related to sanitation to date in these communities. The statistical results indicated that those respondents who had been involved in sanitation related activities were more likely to have access to a JIF and have higher assessed levels of knowledge (strength of association is low). This may indicate that sanitation activities that are implemented at the community or household level have a positive impact on sanitation access (JIF criteria) and increases their knowledge which in turn may increase their capacity.

The majority of respondents indicated that they were willing to participate in a group that worked to improve sanitation access (86%, N=169). The reasons given were that respondents wanted to learn and teach others about how to access improved sanitation, contribute to their community and work together to prevent diseases. The majority of respondents also stated that they thought the community should do more to improve sanitation access (66% agreeing or strongly agreeing with statement, N=169) because they felt sanitation was an issue that affects the whole community and working collectively could increase their ability to create change. However, some respondents indicated that they felt sanitation was an individual's responsibility, that community members had low capacity to solve such problems and that community members often have other problems to deal with (e.g. health issues, money, eviction) meaning they cannot focus on sanitation. The responses discussed here show that the respondents' willingness to work within a community group to improve the status of sanitation is present, however obstacles exist such as perceived responsibility of households, their capacity and their priorities may inhibit this happening in reality.

Further attitudinal statements were asked about the perceived competence of current service providers and the community itself to make improvements in sanitation. In relation to these attitudinal statements no statistical significance was observed. The responses indicated that the government and local councils are perceived by households as competent in terms of their financial capacity and skills for building safe facilities. However, they are perceived to lack competence because of their lack of intervention related to sanitation to date in the selected informal settlements. Some of the qualitative responses showed that the limited presence and level of intervention within the communities was causing households to distrust institutions and service providers.

Qualitative responses indicated that the current water service providers were perceived competent by respondents if the following was achieved: the water supply was reliable and consistent (e.g. access to water 7 days a week and during daytime hours); they trusted their activities (e.g. treatment of water, they were transparent with activities); access was close to home; the service was affordable; there was customer care available (i.e. a complaint system); and the service provided was better than what was previously in place. Despite not being directly related to sanitation, these responses help to generate an idea of what households within these informal settlements expect from a good service provider. These findings are consistent with other studies where trust and the perceived reliability of service were reported as essential factors that affect customers' willingness to pay for services (Manase *et al.*, 2001; Tukahirwa *et al.*, 2011).

In Chazanga, respondents perceived their WT as poor; because of issues with water pressure, time of available access and not receiving water after payment. In George, the households were shown to be very suspicious about their water supplier (LWSC) in terms of the safety of the water received and the volume of water (alleged that they were receiving less water than what they were paying for). Some respondents (5 in total) indicated that they felt the water service providers should also deal and assist with sanitation service provision, as they perceived them to have the capacity, understating and presence within the community to do so. When questioned, the majority of respondents (51%, N=169) said that it was their own responsibility to provide sanitation access. Some respondents indicated that they perceived local government to be responsible, others indicated landlords.

Households were also asked about their current SWM provision with the majority (60%, N=169) stating that they use onsite hand dug pits to dispose of their garbage. Household MSW collection services (by CBEs or informal emptiers) were used by 22% of the households (N=169). Qualitative statements indicated that respondents are unwilling to pay for SWM collection services in cases where the services are continuously poor with infrequent and unreliable collection and transportation. Similar to the findings discussed above, the reliability of service provision was shown to be an important factor to respondents which can directly affect their service uptake.

The results showed that cooperation with sanitation interventions was the only social network factor which statistically impacted on the level of sanitation access and knowledge in these informal settlements. However, similarly to results found by Tukahirwa *et al.* (2011), the qualitative findings uncovered the importance of the role of social networks in ensuring access to services and households' willingness to engage. In particular, the presence of organisations at the community level, the creation of functioning social networks and social cohesion, the establishment of trust between households and organisations and ensuring the creation of reliable, good quality services were identified as key requirements that may impact on the success of sanitation interventions in these informal settlements.

5.5 Community Level Perceptions

The community level KIIs undertaken (see section 5.4.2) provided further insight into inherent community dynamics and possible causal factors for the low levels of sanitation and knowledge present in the selected informal settlements which could impact on the provision of future sanitation services.

In George, community level representatives indicated that there was tension and distrust felt by the community towards LWSC who reported incidents of vandalism and encroachment onto their infrastructure assets. This coincided with findings from the household level questionnaires, where households were suspicious of the activity of LWSC. These problems were not reported in Kanyama or Chazanga. One possible reason given by respondents was that although LWSC provides water directly to the community in George, historically there had been minimal community involvement, causing the communities to feel no ownership or trust towards their service provider. In contrast, during the setup of the WTs in both Kanyama and Chazanga, the community were involved in its set up (through manpower) and are continually involved with its running, with the management and staff all coming from the community themselves, creating a sense of community ownership. Kanyama WT was observed to be a stronger organisation than Chazanga WT (supported by household findings on perceptions of WTs). Particularly in relation to staffing levels, professionalism of the institution's setup and availability and use of financial assets. However, Kanyama settlement was shown to have the lowest level of access to improved sanitation indicating that despite the presence of a strong CBO (which is focused on water) their existence does not currently impact on sanitation access.

Another issue affecting trust in George was related to historic activity. Previously in George a sub charge was included in the water bill (for two years) by LWSC which was to be spent on sanitation but the money was never used for sanitation improvements nor returned to the community. This issue was raised in the community interviews although not in householder interviews. This may contribute to the feeling of distrust by households or community institutions towards LWSC. During a focus group discussion one representative from George indicated the following:

> *'People's trust needs to be earnt and people need to see a service working that they want to pay for'*

During discussions with representatives from the WTs, representatives stated that there was tension between them and LWSC (city level) as the WT perceived that LWSC does not support them as they should. In particular, it was discussed that despite LWSC's reliance on the WTs to supply water in informal settlements and their proven ability (for over 10 years), they are unwilling to support the WTs in their discussions with NWASCO about increasing the water tariff. Representatives from the WTs think an increase in water tariffs is vital for their long term sustainability which they feel LWSC is jeopardising by not supporting them. They also indicated that they want to be recognised as a separate entity by NWASCO so they have more power and their efforts would then be better recognised. Representatives from the WTs and WDC indicated that they perceive LWSC to have weak capacity and that informal settlements suffer because they have other priorities.

Formalised networks between community level bodies (e.g. monthly meetings between health centres, WTs and WDCs) were shown not to be happening in all three communities. This may have a negative effect on collaborations between the various institutions. Representatives from all the community level water providers and water committees (subcommittee of WDC) discussed the fact that they felt LWSC should do more to support WSS and that currently there is a lack of attention and support by government, especially for sanitation, which affects their progress. These comments may indicate that community level institutions require more high level support to expand or increase their deliverables. In all three communities, representatives from the interviewed community committees expressed the view that powers and resources should be decentralised to the community level to combat this issue. Decentralisation has been an agenda within Zambian politics for a number of years, however it has never truly been realised to date (Lunga and Harvey, 2009).

In George, representatives from LWSC and the water committee stated that political activity and interference at the community level negatively affects service provision and development of these communities. In particular, the selling of land by politicians and cadres and their encroachment onto infrastructure, which endangers the community's water supply infrastructure. There was discussion about the institutions' limited power to stop such activity; one representative from LWSC stated;

> '*For the first 2 years they are in power it is very difficult to work with them. Ministers cannot be told about [the] problem as you may lose your job if you raise the issue.'*

Concerns about political gain were expressed in a number of the interviews (in all three settlements) and focus groups conducted. It was stated that politicians promise improvements in WSS provision during election periods which are subsequently not delivered. This results in the community attributing blame to LWSC when improvements are not made. This issue was not discussed by the householders themselves in these informal settlements. This may be directly related to the fact that households have a poor level of knowledge about their rights and who is mandated to provide sanitation service provision in informal settlements and so they don't perceive politicians to cause any problems (section 5.4.2). Representatives from George and Kanyama also indicated that politicians try to (and in some cases successfully) infiltrate organisations like the WDC or water committees (without fair community voting taking place) so that they can politically drive and influence community based decisions and allocation of money to these organisations by LCC.

Community representatives stated that difficulties arise because organisations such as LWSC and the MOH are inactive until the times of the year when disease prevalence is higher in informal settlements (i.e. during Zambia's rainy season). During a focus group discussion one representative indicated:

> *'They [MOH/LWSC] form a habit in us which is not health sensitive all the time but instead focuses during the rainy season.'*

Overall, the community level KIIs demonstrated that issues of trust, ownership, lack of high level support, lack of a continuous presence and unregulated political activity impacts on the functionality of CBOs. The current capacity of community level institutions to deal with issues of sanitation is unclear, with some communities likely to be more capable than others. The tense and fractured relationships described by respondents between the mandated institutions and CBOs is likely to be weakening their capacity to make changes at the community level and would need to be addressed in the future. A key issue highlighted by the community level interviews was the role and power of politicians and the effect their activities have on current (and potentially the future) WSS supply. Whilst it is unclear how this may be overcome in the current environment, one representative from George indicated that households should be sensitised about the role of politicians. Examples from literature indicate that raising householders' political awareness can be successful at creating change. In particular, it can increase political competition and provide households with awareness of their rights so that they have the power to hold the mandated entities responsible for meeting their needs (Kacker and Joshi, 2012). This can increase the pressure on politicians and may force them to act more honestly and properly in line with the communities' needs as they would be held more accountable. Another solution is to work more closely with politicians to achieve progress by using their power and influence to focus on and improve access to sanitation. Lane (2012) states that connecting with politicians is vital for the success of WSS and ensures these issues become high on the political agenda.

5.6 Conclusion

This chapter provides a detailed assessment of the current FSM situation at household and community level within selected informal settlements in Lusaka. This chapter aimed to overcome shortcomings identified with existing planning approaches and draw on primary research to present the benefits of exploring novel socio-technical factors within the planning process. Despite the limited statistical significance observed related to the factors explored, the results achieved provided useful insight into the current sanitation situation and possible obstacles to future intervention success within these informal settlements. The analysis successfully drew on primary data collected from the ground to establish in-depth insights into the realities of the situation and possible causes, beyond those available from the available secondary data (Chapter 4).

The current practices in the three selected informal settlements were shown to be poor with households having limited access to 'improved' sanitation facilities that safely contain excreta. Households were shown not to be exploiting the SVC as they had no access to formal FSM services. The majority were dealing with FSM themselves and managing FS at the household plot. The containment facilities in use were shown to be highly variable (i.e. volume, construction type and quality) with no standard design being used. The design of the facilities did not make provisions for future FS emptying (i.e. access hole or access pathway), therefore creating problems directly for the removal and transportation process. There were low levels of intervention, support and knowledge sharing related to sanitation observed at the community level as well as a lack of access to formal sanitation services (FSM or containment construction). In this study the additional factors considered, which go beyond those prescribed by the JMP, have provided useful information regarding FSM. In particular, defining how FS is currently managed, possible reasons for the current FSM situation and technical features which currently impact or could potentially impact the viability of future FSM service delivery (discussed further in Chapter 8).

The results indicated that households' status and their level of access to external networks (impacted by socio-economic factors of employment, current service access and cooperation with sanitation interventions) may support knowledge increase and household capacity to improve their sanitation access. Exploration of social network and spatial proximity factors were useful in indicating influences which may affect future interventions or service delivery in these informal settlements. In particular, the physical presence of institutions or service providers within the community and the availability of a line of communication between the household and the community was shown to be vital for those bodies to be perceived positively (competent and trustworthy) by the households. Factors of trust, transparency, reliability and affordability were also shown to be vital for households to perceive a service and its delivery positively and for them to be willing to pay for those services. Households were shown to be willing to pay for improved sanitation facilities, however the strength, cleanliness, accessibility, cost and perceived improvement from what currently exists were factors that may affect how happy householders would be with any new facility.

The environment required for capacity building is shown to be similar to that required for successful participation (Chapter 3). The results show that the current environment in these informal settlements is non-conducive for successful participation and households have limited ability to increase their capacity related to sanitation. This may explain why households were shown to have such low levels of knowledge related to sanitation. It may also provide a reason for why households have such poor sanitation access, have limited capacity to make moves up the sanitation ladder and do not exploit the SVC as the existing community environment (technical and social) does not support this.

Within the literature related to participation, power and trust are also identified as key elements which need to be in place for success (Reed, 2008). It was evident from the research findings that power and trust were indeed issues at the household level but these were shown to be more prominent at the community level. Here the ability of institutions to perform in these communities was shown to be being affected by political interference and their lack of power to stop these activities. Progress was also shown to be affected by a lack of cooperation between organisations, a lack support from higher level institutions, a lack of continuous presence of institutions at the community level and issues surrounding trust and perceived competence between institutions. All of which need to be recognised and steps made to overcome them in order for improved access to sanitation to be achieved in these informal settlements.

In Lusaka, successful interventions will not be possible unless appropriate institutions are created which have the capacity to promote and support the sanitation improvements required and have a continuous presence at the community level. Collaborations with existing CBOs should be considered, however their role, their capacity (existing and potential) and existing social dynamics related to such organisations need to be explored and understood. The effect of trust and perceptions between CBOs (existing and newly created) and households needs to be considered as this may impact upon their ability to engage and create improvements at the household level. Finally, local political leaders and representatives (both formal and informal) need to be directly engaged in discussions and interventions so that they are convinced by the wider benefits of achieving an improved sanitation situation in these informal settlements.

The results presented in this chapter highlight the need for further socio-technical factors to be explored during the baseline data collection and sanitation planning stages. The importance of spending time collecting in-depth information from the ground from a wide range of stakeholders was also presented by this analysis. If such factors are not considered and such a process is not accomplished, key dynamics and the true complexities of the situation may not be understood causing inappropriate planning and development to occur. The subsequent chapter draws from primary data collected at the city level in Lusaka and aims to provide further insight into factors which may impact upon the sanitation service delivery in informal settlements.

Chapter 6. Factors at the City and Country Level Domains Preventing Improved Sanitation Service Provision in Informal Settlements

6.1 Chapter Overview

The merits of further exploring social factors at the household and community level domain within the situational analysis phase of the planning process were presented in Chapter 5. The chapter argues that without an understanding of these factors, development and successful sanitation interventions may not be achieved. This chapter draws upon primary data collected from the city and country level domains and aims to investigate how factors present in these domains may affect sanitation provision and potential development in informal settlements. It also aims to identify whether those factors identified as important within the household and community level domains, are also apparent in this domain.

6.2 Introduction

The rationale for this chapter and the methodology selected is similar to that outlined in Chapter 5. Chapter 3 reported that despite a lack of enabling environment being quoted as the main cause of failure within the sanitation sector, more needs to be done to better understand the status of the current sanitation situation and the existing capacity to make improvements. Chapter 4 analysed the current sanitation situation in Lusaka and highlighted possible reasons for this by drawing upon secondary data sources. Within the available sources there was shown to be very little discussion or exploration of the various stakeholders' interests, priorities and incentives or existing social dynamics and their effect on planning and improving the current poor status of sanitation in informal settlements. The focus of the sources was also shown to be at the country and city level domains and very little representation of how the situation at these domains effects progress at the grassroots level was made. Chapter 5 supported numerous scholars and presented primary evidence from the household and community domains that argued that current sanitation planning approaches need to go further in specific social factors to ensure the success of sanitation interventions.

This chapter presents findings from the city and country level domains where primary data was collected from a wide range of stakeholders. The data was collected to provide further insight into which factors (present at the city and country level domains) were causing the current sanitation situation, whether they could cause future intervention failure and whether current approaches used by the urban planning sector would be successful in discovering such factors.

6.3 Methodology

The methodologies selected to collect data from the city and country level domains were almost identical to that which were selected for the community level domain (discussed in detail in Chapter 5). At these domains, semi-structured interviews were considered to be the most appropriate data collection method. An interview guide was created specifically to question city and country level stakeholders (Appendix C). The focus of the interviews was the same as described in section 5.3.1. The field observation diary was again used to record any comments or additional information or feelings that came to mind during the implementation of the methods.

Prior to the field study commencing key stakeholders has been identified to interview. Initial contact was made with a small number of institutions with WSUP’s support. Snowball sampling method as discussed in section 5.3.3 was then used to contact further stakeholders. All of the KIIs were conducted by me (in English) and they each lasted an average of 60 minutes. A total of 35 KIIs were conducted with various stakeholders involved in sanitation provision at the city and country level. These included individuals from the regulator, commercial utility, city council, university, ministries and various NGOs (listed in Appendix A).

Prior to beginning administration of the interview the objectives of the study and further details were explained and authorisation was sought. Informed consent was received by every participant prior to data collection and their right to decline to answer any questions or to withdraw from the project was explained. Anonymity and confidentiality of the KIIs conducted were achieved as described in section 5.3.4.

Where explicit permission was given, an audio recording of the interview was made. Where it was not granted basic hand written notes were made during the interview and then expanded upon them immediately after the interview. Where possible the notes were transcribed as soon as possible using Microsoft Word.

The interviews were analysed using the coding method outlined in section 5.3.5. During the analysis it was discovered that relating the dominant themes found to the enabling environment concept (described in section 3.4.5) was helpful and therefore this is how the results have been presented in this chapter. Secondary data was also used where appropriate to further triangulate findings from primary observations and interviews conducted in the field.

6.4 Dynamics Affecting Sanitation Service Provision in Lusaka

The analysis of the KIIs from these domains uncovered the existence of complex dynamics that directly affected sanitation service provision in informal settlements of Lusaka. These dynamics will be discussed in the following section in relation to the enabling environment criteria as outlined above.

6.4.1 Government support

Although national strategies and policies related to urban sanitation exist in Lusaka, the amount of intervention that has been undertaken on the ground in informal settlements is particularly limited. During the KIIs two key factors that were highlighted to affect successful intervention were political will and high level support for sanitation. In particular, the lack of a department at the ministry level devoted to sanitation prompted questions to be raised by interviewees about who is 'driving' these issues from above. Interviewees from LCC highlighted that overall there is a lack of will to make improvements at the government level as once people are employed in these positions of authority they have limited motivation to create change. They also highlighted that it is difficult for people to do their jobs correctly or create change as it may result in them getting fired if it is seen to go against the agenda of political leaders. A lack of manpower to implement strategies was also highlighted as a limitation.

The nature of how interventions are selected was another factor reported to potentially affect progress in this sector. A LWSC employee explained;

> *'For planning, each area has investment proposals drawn up for them which highlights where investment is required. They then look at these proposals and highlight the most affected areas e.g. areas with no capacity, cholera outbreak, political influences/pressure.'*

This statement indicates that although proposals and strategies are developed, external political influences and pressures can influence where investment and interventions are undertaken.

It became clear that the view of many interviewees in institutional roles is that conventional sewerage is the best option or in some cases the only option for informal settlements. However, none of the interviewees were able to identify details of how inherent technical and financial difficulties in informal settlements would be overcome to achieve a solution. Many respondents indicated that the funding or support of solutions that utilise onsite technologies is difficult, as there are issues with defining who is responsible for (who should pay, maintain and manage) onsite facilities. Another issue discussed was disputes over plot boundaries and their allocation, which have occurred because of the informal development of these settlements. This is further complicated by the historic lack of legalisation of these settlements and establishment of formalised plot boundaries.

The impact of power and politics on the success of service delivery and interventions was also a clear theme throughout the KIIs. In particular, community level politicians and political cadres were identified as the main stakeholders that have impacted on how informal settlements have developed (in terms of land allocation and encroachment) and how they operate. Interviewees indicated that informal settlements are a 'political playground' which are rife with political tension and struggles of power. The main reason given was that over 60% of Lusaka's population live in these areas (section 4.2.1), causing them to be seen as highly competitive areas to achieve electoral votes. This also creates an environment where precedence is given to any activity (both legal and illegal) which will improve individuals' and parties' political advantage in these informal settlements. One student studying politics in Lusaka indicated;

> '*With the current government this cadre scene is much stronger as their strategy was based on mobilising the unemployed youth… They are struggling with this issue as it is difficult to establish control. The high level politician will state that they want money for the cadres and the cadres then rule the streets.'*

Power struggles within political parties were shown to cause internal fractures that can complicate and prevent the implementation of strategies, as stakeholders act within their individual interests rather than with the government, city and community as a whole. These findings concur with findings from Chapter 4 and 5 and issues of power struggles within political parties has been an inherent part of Zambia's political history.

Overall, these findings show that issues of political will and high level government support may be a major cause of inaction related to sanitation. The role and impact of politicians and political activities at all levels of service delivery was found to be significant, with interviewees indicating that precedence is given to individuals/organisations/interventions that align with political interests and that there may be negative consequences for those that don't.

6.4.2 Legal and regulatory framework

Respondents indicated that the current legal and regulatory framework creates a 'grey area' for intervention within the city and results in a lack of action or enforcement of laws. Although laws do exist, they provide unclear procedures, inadequate clarity and conflicting legislation for the development and delivery of services in informal settlements (similar to discussions in Chapter 4). Respondents from the University of Zambia, LWSC and LCC indicated that even the name of the commercial utility 'Lusaka Water and Sewerage Company' causes people to perceive that their work is only in relation to the provision and maintenance of sewerage systems and not to onsite sanitation provision, such as pit latrines and septic tanks. Despite the utility being mandated to provide access to WSS to all under LCC jurisdiction (some contradictions to this outlined in Chapter 4).

In terms of the relationship between LWSC and WT, which was discussed in Chapter 5, the city level interviews provided a different perspective on the situation. A number of interviewees indicated that they had concerns with the existing arrangement in informal settlements and the effect it has on service provision, enforcement of standards and control within informal settlements. A LWSC employee indicated;

> *'The setup of WTs had implications on LWSC as they were very much their own entity that LWSC had little control over. The WTs see LWSC as an outsider and although this relationship has improved it has been a challenge'.*

Although this arrangement or relationship does not currently have direct implications for sanitation provision, the FSM pilot in Kanyama and discussions with LWSC employees indicated that in the future, WTs may be used by LWSC/NGOs/donors as the institutional body they work with or collaborate with at the community level. Therefore, understanding current dynamics and resulting problems is important.

The enforcement of standards and the way institutions are able to perform in informal settlements was again shown to be affected by political interference and also which networks' people are involved with (e.g. 'who people know'). One representative from LCC highlighted;

> *'This is a problem as when there is a problem there [in informal settlements] politicians create restrictions on how you can perform. You can be fired if you speak up about issues. [You] Can act but cannot implement what you are supposed to.'*

The lack of regulations stipulating how FS is managed, treated and disposed of was also shown to have affected sanitation service provision. In particular, the lack of regulation and legislation relating to the disposal of biosolids was shown to cause potential public health and environmental issues. Interviewees from donor agencies, University of Zambia and LCC also highlighted that the recovery of potential resources from FS is unsupported, as its collection, transportation, treatment and reuse is not prioritised or enforced by anyone.

The findings indicate that the unclear legal status of informal settlements, unclear responsibilities of institutions in delivering sanitation services, the lack of ability for institutions to enforce legislation in informal settlements and unclear or non-existent regulations related to planning, management of FS and its reuse has contributed to the poor level of sanitation access in informal settlements and the city as a whole.

6.4.3 Institutional arrangements

Chapter 4 highlighted the complex institutional situation related to sanitation in Zambia, where a number of ministries, agencies and institutions have some role or say in sanitation. Despite this, a limited number of institutions, service providers and regulatory bodies from the city level were shown to currently have a direct presence or continuous involvement at the community or household level in informal settlements. The historic lack of presence, involvement and communication from city level stakeholders has caused limited capacity, weak enforcement and a lack of resources being directed at sanitation service delivery at the household and community level. The functionality, priorities and sustainability of existing grassroots level institutions and their ability to support sanitation interventions was raised as an issue of concern by a number of interviewees, especially when politicians and political agendas infiltrate and influence such organisations.

During interviews with representatives from LCC, MOH and local political leaders, the 'Lusaka District Disaster Management Committee (DDMC)' was identified as a key player within the sector. The DDMC was originally developed to 'mitigate, prevent and manage' public health disasters, however during interviews it became clear that it currently focuses on managing public health outbreaks when they occur (often in the rainy season) rather than prevention or mitigation. The driving legislation for the committee is the PHA and the driving implementing bodies are the office of the District Commissioner (political leader) and the MOH. This was of interest as they were shown to be one of the dominant institutions working on sanitation within informal settlements. It is interesting to note that whilst the DDMC was discussed frequently by city level representatives and at community level domain, its role was scarcely mentioned in any of the secondary documentation reviewed in Chapter 4.

Another key factor discussed was how key institutions (LWSC, LCC and MOH) currently have unclear 'roles and responsibilities' and that this is affecting the management of public health, the regulation and standardisation of onsite facilities and the overall provision of sanitation services. In turn, this was said to cause a situation whereby nobody is actually regulating what is happening in informal settlements with regard to sanitation and limited intervention is occurring. In particular the views of institutions were shown to vary from those of NGOs and donors. One interviewee highlighted;

> *'View of donors and commercial utilities are very different, with commercial utilities stating onsite sanitation has nothing to do with them and dealing with it is non-sustainable. However, donors don't accept this lack of pro-poor provision. Where things are donor funded the utility is happy to use money for these areas [informal settlements]. However, when it is their own money they are less enthusiastic.'*

The priorities of various institutional bodies and individual employees was also shown to affect how they function. A number of clear examples of this were highlighted during the interviews. The priority of LWSC on commercial activities and the perceived lack of return on investment from the PUD was shown to cause a lack of recognition for the department and affect how it functions in terms of the financial resources it receives, status of job security and involvement with central business activities of the company. Another example was indicated by a MOH employee who reported the following in relation to implementation of the PHA;

> *'Many of people who run and organise things [in relation to the Public Health Act and MOH] are doctors who are focused on curative measures rather than preventative ones which are usually an afterthought.'*

The findings indicate that the lack of presence of institutions (at all levels) focusing specifically on sanitation, which have the required capacity, legal support and resources, impacts on sanitation provision in informal settlements. The unclear roles and responsibilities of institutions and the varying priorities of organisations and individuals working within them, was also shown to be an issue affecting how institutions perform. Dominant institutions that are present within the sector were shown to focus on curative measures to manage seasonal public health risks rather than striving for continuous prevention and mitigation. A number of these dominant institutions were also not identified by key literature reviewed for Chapter 4. The repercussions of this are discussed in more detail in section 6.5 below.

6.4.4 Effective skills and capacity

The lack of institutional presence in the community level has also led to a lack of effective skills and capacities to be present. The abandonment of support for households has caused there to be inadequate provision of sanitation at the containment level (pit latrine or septic tank) and FSM. This situation has also created an imbalance in power. Communities have not been given the opportunity to be empowered with the required knowledge to make improvements to their sanitation situations and understand regulations or their rights, so they can demand sanitation services from the mandated institutions.

A number of interviewees also highlighted that the perceived capacities of other institutions detrimentally affects how institutions work together to improve service delivery. In a number of cases LCC was perceived as having low capacity to deal with MSW, which both negatively affects public health and also impacts on FSM (see Chapter 7 for details). Despite an understanding that collaborating with LCC would be an important step for managing MSW and its associated problems, the perceived incapacity of LCC (perceived as lack of technical ability, financial ability, reliability and man power) was shown to prevent collaborations from occurring. A similar situation was recorded between LCC and the MOH in relation to management of public health in informal settlements. Here the low capacity of LCC, as perceived by MOH, was shown to affect their relationship and cause the MOH to want to collaborate with LCC only in times of crisis (e.g. public health outbreaks such as cholera).

Overall, limited skills and capacity were shown to impact on progress in sanitation at all three decision making domains. A lack of institutional presence causes limited community empowerment and capacity building to occur. The perceived incapacity of higher level institutions was also shown to affect how organisations work together and how effective these relationship are in achieving progress.

6.4.5 Financial arrangements

A number of key factors relating to finance were highlighted as deterrents to providing services in informal settlements. Firstly, a key perception of many of the informants was that providing services in informal settlements was unsustainable as they provided a poor return on investment caused by the 'low income' status of households, thus causing unwillingness to create services in these areas that are not going to be commercially viable. However, during an interview with a representative from MOLGH they disagreed with this perception, stating;

> *'I don't agree with this excuse. Mainly because 60% of Lusaka's population live in such environment so with usage of water and services there must be money to be captured from the areas. Problem is ensuring systems are in place to capture that money.'*

Another perception that was highlighted as affecting successful service provision was the lack of consumers' willingness to pay in informal settlements. Interviewees from the University of Zambia and LWSC indicated that low affordability and ability to pay were the main reasons for low willingness to pay in informal settlements of Lusaka. Interestingly other interviewees noted that history, transparency and service delivery more prominently affects households' willingness to pay. Both of these findings are consistent with results discussed in Chapter 5. A key informant from a donor funding institution stated;

> *'There is a trend in willingness to pay/operate and maintain well with regard to age. People who are aged 60 or over pay their bills and operate their systems well as they are used to a clean environment which was enjoyed historically in socialist times. Younger people don't pay bills or maintain toilet well as to them this situation is normal [lack of clean environment].'*

Interviewees also discussed the need for transparency as a critical factor in increasing consumers' willingness to pay for services. The provision of desirable, reliable and accessible services was also emphasised by interviewees. A representative from LWSC highlighted;

> *'People within these communities have an income and are looking for a good service within their means.'*

A representative from a local NGO stated;

> *'Willingness to pay for services is there as long as service levels are to a desired standard. Service providers need to be serious about service provision.'*

This point directly links with the need for institutional bodies to have a presence at the community level and to provide services that meet the community's perceptions (as discussed in Chapter 5).

Similarly to the community level interviews, the financial sustainability and role of WTs in informal settlements was discussed by city and community level interviewees. Many indicated that they felt the WTs are not sustainable as they do not have enough financial capacity, opportunities to cross-subsidise or extend beyond just being a social entity. Such a perception of the WT may impact on the use and support of WTs now and in the future. However, as the current situation stands in some informal settlements (limited presence of institutions at grassroots level), LWSC are solely reliant on the WTs to deliver services so they have little power or ability to change the situation.

Another important aspect discussed was the effect of donor funding on the sustainability, suitability and scale up of programme interventions. In particular, the idea that donor funding causes short lived programmes which do not create sustainable long-term outcomes at the scale required or that fit in with proper formulated city level planning programmes. This problem was identified within Chapter 4, where the financial arrangements for the WSS sector rely predominantly on donor funding. A politics student from Lusaka stated;

> *'They [donors] give them [government] no choice whereas they should allow them to do it themselves and make their own agenda not have them over a barrel in terms of giving funding for certain output and not letting them do what is right for them/ the country.'*

A number of interviewees indicated that the perceived commercial viability and willingness for customers to pay for services impacted on service providers' willingness to provide services in informal settlements. Discussions highlighted that interviewees thought that the perceived quality of the service provided, historical events and the physical presence of service providers within the community effected around customers' willingness to pay. The historic and current dominance and reliance on donor funding was also indicated as an issue in terms of the sustainability, suitability and ability for programmes to be scaled up.

6.4.6 Socio-cultural acceptance

As highlighted in Chapter 5 and section 6.4.5, the perception of what a 'good service' means, is key to whether a community will accept it and are willing to pay for it, with the provision of desirable, reliable and accessible services of high importance to customers. The priorities of users was also indicated as an important aspect to establish. Some interviewees indicated that sanitation is a key priority for households but that the lack of support and ability to improve their facilities is the reason why improvements haven't been achieved. However, other interviewees stated that households do not prioritise sanitation due to cultural and habitual reasons. Firstly, interviewees noted that people are historically used to openly defecating so when they migrated to the cities they were happy to continue the practice. Others indicated that low priority is given to sanitation as it is a culturally sensitive topic, which many people do not want to think about, speak of or manage the issue. An example was given of Ecosan toilets, which were provided to informal settlements but were not accepted because it was not culturally acceptable to touch FS.

The success of previous interventions was also shown to be one aspect that may affect the acceptance of future interventions. In particular, interviewees indicated that communities could become intolerant of pilot schemes as they feel there are no tangible outcomes from their participation and that they may perceive the government or LWSC to be working unprofessionally without any strategic plans or well considered solutions.

Perceptions of the communities were also shown to be affected by politicians who often use WSS for political gain. This was said to present mixed messages to the community about the role of the government and politicians and often causes tension within the community when services that have been promised do not materialise. A key informant from an international NGO stated;

> *'We have a situation where a politician sends messages into the community that contradicts national programmes. In that case as an implementer you face challenges in times of trying to help the communities move up the sanitation ladder. Can't underestimate the power of politicians- what they say is the good news so people believe in politicians.'*

The priorities of users, habits, cultural acceptance, historic interventions, householders' perceptions and how those perceptions are created, were all shown to be dominant themes that could affect the socio-cultural acceptance of sanitation interventions.

6.5 Stakeholder Map Based on Primary Findings

Primary data collected from the city and country level domains (triangulated with findings from Chapter 5) provided in-depth information on the stakeholders involved in sanitation service delivery for informal settlements. The findings depicted in Figure 6-1 show the reality of the wide range and type of stakeholders that are involved in sanitation in informal settlements which are far wider reaching than those defined in key secondary literature that was reviewed in Chapter 4 (Figure 4-4). The dominant stakeholders and those that were not part of the ‘formal’ sector were also represented. This diagram and the complexities observed only emerged once in-depth qualitative data had been collected from the ground from a wider range of stakeholders. To achieve such an in-depth understanding of the situational realities, time has to be spent on the ground gaining the trust of interviewees. Therefore, accrediting this type of data collection and methodology to ensure the complexities of informal settlements are really understood.

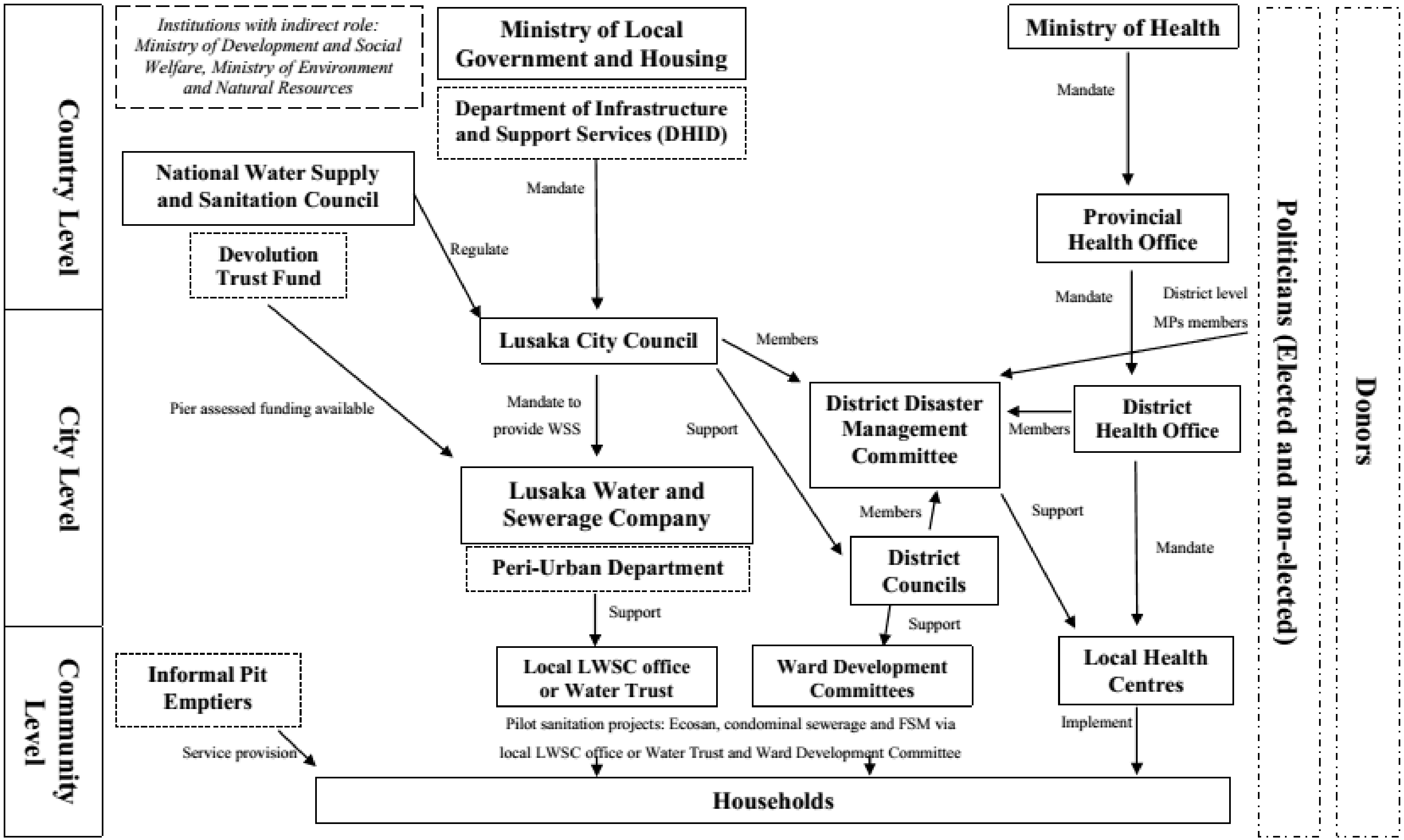


Figure 6-1: Stakeholder map of key stakeholders involved in sanitation in informal settlements based on primary findings

6.6 Conclusion

This chapter shows that factors attributing to the failure of sanitation service provision and development in Lusaka outlined by KIIs from these domains align with the enabling environment criteria but also go beyond them. Overall the enabling environment for providing sanitation provision in informal settlements was shown to be weak in Lusaka. However, the analysis identified that the primary cause of this weakness related to aspects of politics and power. These themes were similar to those found in Chapter 5 (specifically at community level) and were shown to be the dominant dynamics that govern perceptions of individuals and collectives (i.e. organisations) and govern how sanitation service delivery functions (or does not function) in informal settlements. Even in a politically stable and low-middle income country such as Zambia, these dynamics were shown to be at play and directly affecting how communities function and develop in such areas where the majority of the capital's population resides.

Whilst theoretical urban planning approaches go some way to try and explore such complexities through the situational analysis component, in particular within the Sanitation 21 and CLUES approaches (Lüthi *et al.*, 2011; Parkinson and Luthi, 2013) which recognise the need to understand and manage political economy, this analysis illustrates that the planning process needs to do more. They need to go beyond their current focus of identifying stakeholders and their roles, interests, priorities and incentives and ensure more attention is given to uncovering the true dynamics which govern how they operate and develop. Perhaps what is critical, as achieved in this analysis, is the need to spend time developing trust on the ground with a wider range of stakeholders from various domains so that the information gathered is founded on reality. If this is not done successfully, the inherent complexities and dynamic nature of such informal settlements will not be understood and therefore plans developed will fail to deliver suitable solutions.

These findings coincide with other literature which highlights the need for the sanitation sector to prioritise and understand better the influence that politics and power has on the evolution and functioning of complex systems, such as informal settlements (Institute of Development Studies, 2012b). Abrams (2003) indicates that water related activities are undertaken within complex political contexts, therefore a greater understanding of its political nature is required and political expertise should be included as part of the planning team. Beyond the sanitation sector the need to acknowledge the role of both politics and power for achieving success in development has also achieved traction. Clement (2010) proposes the need for better consideration of the historic, social and political context in which communities, institutions and individuals operate and of the role that power and interests take in the development of institutions and rules implemented. Similarly in this study the impact of historic events and process was also shown to have an effect on sanitation access and progress. Similarly, in their analysis of the evolution of the political economy sector, Hudson and Leftwich (2014) argue that to achieve sustainable outcomes in development, the structures and institutions of power and the agents (individual or collective) who control them or who are controlled by them must be understood. Previous studies in Zambia highlight that politics can have an effect on sanitation interventions, however its dominance (along with power) as a inhibiting factor to success in informal settlements is not discussed in detail (Manase *et al.*, 2001; Gutierrez, 2007; Lunga and Harvey, 2009) .

In the case of Lusaka, this research highlights that in-depth situational analysis must be internally conducted as the existing sanitation situation in informal settlements and reasons for it are shown not to be currently understood or highlighted within available secondary literature (Chapter 4).

The results show that more focus needs to be made in Lusaka on creating an enabling environment to support the delivery of improved sanitation access in informal settlements. Firstly, the creation or adaptation of CBOs that support and deliver sanitation interventions and build capacity are required in informal settlements in Lusaka. Better distinction of key legislation, stakeholders implementing such legislation, their roles, responsibilities and consequences for not meeting those responsibilities needs to be made in the case of sanitation and for wider basic service delivery in informal settlements. Also improved and regular co-ordination between the wide range of national and international agencies involved in sanitation needs to occur. Individuals and organisational interests, priorities and incentives need to be better understood and the dynamics of power, the influence of politics and the existence and influence of dominant players needs to be recognised and openly analysed. The implications (or lack) of previous research and interventions and historic events (i.e. changes in organisational setup, political structures and legislation) need to be better reported, the effect on the current sector documented and lessons learnt. Strategic plans needs to be developed which focus specifically on how improved sanitation can be achieved in informal areas. These need to be coordinated with development plans for the city as a whole (developed by city level stakeholders) and should be founded on a comprehensive understanding of viable solutions. Stakeholders in key institutional roles also need to be convinced that there is a potential return on investment in such areas and technical solutions beyond conventional sewerage are available and that these may be more appropriate for informal settlements. Targeted efforts need to be made to better understand any politically driven agendas or activities (at all decision making domains) that may inhibit progress and to directly engage such stakeholders so that strong political will can be created to tackle the current poor status of service delivery in informal settlements in Lusaka.

Overall, this chapter (along with Chapter 5) highlights the merits of drawing from in-depth qualitative data from a wide range of stakeholders from all decision making domains so that the real complexities and dynamics of the sanitation situation are identified and understood. In particular, the findings conclude that situational analysis must examine more socially-orientated factors and fundamentally how power, politics, trust and history effect how individuals act and how institutions are created, mobilised, utilised and organised to bring about change within these complex urban environments.

The next chapter presents a decision support tool which was developed to support planning for FSM intervention in informal settlements in Lusaka.

Chapter 7. Optimisation and Costing of Possible Faecal Sludge Management Networks for Lusaka's Informal Settlements

7.1 Introduction

Chapter 4 outlined the difficult task ahead for the city of Lusaka to achieve their long term vision that 'every household should have access to adequate, clean and safe drinking water and sanitation services by 2030' (NWASCO, 2009). During interviews with city level representatives from Lusaka (Chapter 6) there were shown to be mixed views on possible technical solutions to the sanitation problems in informal settlements, with many interviewees indicating conventional solutions (sewerage) as the only feasible solution. However, the lack of finance, manpower and the existence of informal settlements with low levels of current sanitation access and knowledge may mean that other (non-conventional) solutions may be more appropriate. Here, FSM may provide an ideal solution to ensure the safe management of FS by improving upon the current practice of informal pit emptying (as discussed in section 4.4.2).

Chapter 1 highlighted the sanitation sector's need to develop improved decision support tools for the implementation of FSM services, especially with regard to cost. This chapter introduces a long term costing methodology that has been developed for various FSM fixed infrastructure and technology scenarios for two informal settlements in Lusaka (Kanyama and Chazanga). Unfortunately, this analysis could not be conducted in the informal settlement of George because of poor data availability and quality that could not be rectified during the time frame of this research. It specifically addresses the need for improved decision support tools and costing methodologies for FSM provision, utilises a novel spatio-topological method to optimise transportation networks and highlights how optimisation of the containment component can affect the financial and logistical requirements of the whole FSM system.

7.2 Technical Components of Faecal Sludge Management

This section provides detail on the technical components of FSM and on the current sanitation situation within informal settlements in Lusaka which directly affect FSM service delivery.

FSM consists of the manual or mechanical removal of FS from onsite containment facilities (i.e. pit latrine or septic tanks) to treatment facilities via the road network (Chowdry and Kone, 2012).

Manual emptying methods involve accessing the containment structure of the pit latrine and removing the sludge using shovels and buckets (Tilley *et al.*, 2014). As discussed in section 4.4.2 in Lusaka it is common practice to gain access by breaking into the side of the latrine superstructure or in the case of septic tanks breaking a hole in the slab. Equipment such as gulpers or portable manually operated pumps can be used (e.g. Pooh Pump), however according to emptiers gulpers were trialled in Kanyama without success due to the presence of inert material in the majority of pits causing the equipment to block. Once emptied from the pits, the FS is then transported manually. In the case of the FSM service in Kanyama (detailed in section 4.5) the sludge is transported using specially designed manual carts (WSUP, 2014). The major benefits of manual emptying and transportation are the minimal technical requirements and low associated cost. However, this method is time consuming and can carry significant health and safety risk for emptiers, caused by collapsing pits and exposure to toxic fumes and unsanitary sludge (Thye *et al.*, 2011; Tilley *et al.*, 2014). The proposed post-2015 targets and indicators for WASH access defines safely managed sanitation services as those that hygienically collect from onsite containment facilities using equipment such as suction trucks or similar that limits human contact (WSSCC, 2014). Therefore, it appears as though manual emptying would not be deemed as a hygienic collection system based on these indicators, however this type of technology was included in this study so a comparison between different technologies could be made.

Mechanical options utilise a vacuum pump to empty pit latrines with a range of types of technologies available. The main advantage of mechanical options over manual ones is that they empty and contain sludge more hygienically (making it safer for operators as discussed above) and speed up the process of emptying (Tilley *et al.*, 2014). The Vacutug is a mini vacuum tanker that was developed by the United Nations Human Settlement Programme (UN HABITAT, 2004). It consists of a storage tank mounted on wheels that utilises a hose to suck sludge from latrines. A number of versions of the vacutug have since been developed in Bangladesh by the NGO Dushtha Shasthya Kendra (Parkinson and Quader, 2008). The Vacutug Mark II with a 2000 litre capacity is now the most commonly used and exported type of Vacutug (DSK, 2010). However, there are known limitations for the use of Vacutugs as they can only suck to a depth of

2m and are required to be within 30m of the pit to maintain sufficient suction (Harvey, 2007). Vacutugs were designed for unplanned settlements and therefore are a relatively low cost technology that can be manoeuvred easily through narrow, uneven roads prominent in such environments.

Larger conventional vacuum tankers (utilised currently in planned areas of Lusaka, as described in section 4.4.1) work in the same way as Vacutugs with the storage tank, vacuum pump and house fixed to the back of a truck. They commonly use a more powerful pump than Vacutugs (Tilley *et al.*, 2014). However, their larger size means they are generally unable to service unplanned settlements as they cannot get close enough to pit latrines due to the presence of narrow, unsurfaced roads (consistent with observations in Lusaka's informal settlements where access roads where commonly <10m in width). A study conducted by Boesch and Schertenleib (1985) showed that increasing the hose length to achieve access caused secondary problems of frequent FS blockages in the hose.

Once FS removal has occurred the next stage in the SVC is transportation of the FS to a safe end or mid-term location. One option is for the FS to be transported directly to a treatment facility located within the community (known as onsite or decentralised). Here both primary and secondary treatment can be combined or secondary treatment can be done offsite. Another option is for the FS to be transported offsite to a centralised treatment facility (such as Manchinchi WwTP- Chapter 4). Transfer Stations (TSs) can be utilised to reduce the distance over which pit emptiers have to transport sludge, therefore increasing the overall efficiency of the process (Chowdry and Kone, 2012; Tilley *et al.*, 2014). The FS from onsite facilities is transported either manually or mechanically to the TS which acts as an intermediate fixed storage facility ideally located at the edge of a settlement at the interface between the settlement and the main road network. TSs can either be fixed or mobile and can be used to simply store FS or can incorporate some form of pre or primary treatment within them (i.e. dewatering of anaerobic digestion) (Mikhael *et al.*, 2014).

From here the FS is then usually transported via conventional vacuum tankers from the TS to the end point (i.e. treatment facility). Another option is for the sludge to be transported from the community to a Sewer Discharge Station (SDS), which is similar to a TS, but is directly connected to a conventional gravity sewer main (Tilley *et al.*, 2008). The sludge is then released into the sewer main either directly or at timed intervals (e.g. by pumping) (ibid).

The next stage of the process is to adequately treat the FS (either at decentralised or centralised treatment facilities). There are many technologies available for the treatment of FS, both high tech and low tech (Figure 7-1). The research consortium that this research is part of (detailed in section 2.2) is focusing on the use of decentralised high rate anaerobic reactors, such as Upflow Anaerobic Sludge Blanket or Expanded Granular Sludge Blanket reactors, for the treatment of FS due to their ability to achieve high rates of treatment (lower retention time) to digest influent of high solids concentration (less dilute) (Seghezzo *et al.*, 1998). The rationale is that these reactors pose an optimum solution for the treatment of domestic FS in informal settlements where there is limited space, an abundant supply of FS, and where the FS has high solids content due to restricted water use. The details of the treatment technology being developed by the consortium will not be discussed in any further detail within this thesis.

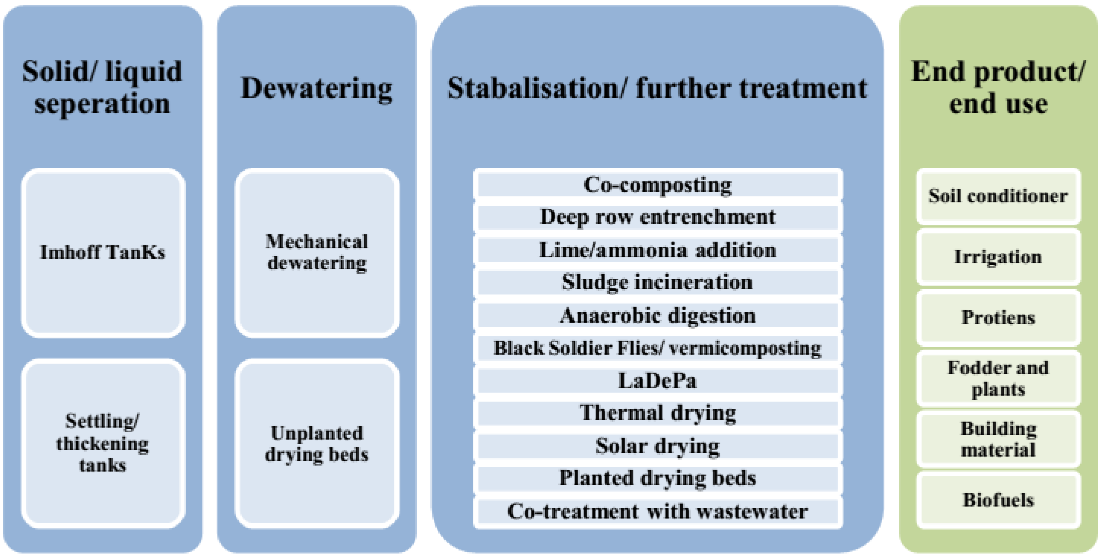


Figure 7-1: Possible treatment technologies and end uses for FS (Ronteltap *et al.*, 2014)

The final stage of the process is the safe disposal or reuse of FS, of which there are a number of options available (Figure 7-1). Whilst safe disposal of FS is an adequate option for treated sludge there is a compelling argument to promote resource recovery from FS, particularly in low income and water stressed regions (as discussed in section 3.4.5). Not only can it help combat uncontrolled discharge of excreta, but it can also trigger private entrepreneurs' involvement in sanitation, develop dual revenue streams (from front-end and back-end users) and provide an incentive for the improved operation and maintenance of the systems through the creation of a 'closed loop' sanitation solution (Werner *et al.*, 2003a; Murray, 2009; Gröber *et al.*, 2011).

For informal settlements of Lusaka, FSM could provide an ideal technical solution to ensure the safe management of FS because it does not require any underground construction or infrastructure to be built (sewers) and is similar to the current informal pit emptying practice (section 4.4.2).

7.2.1 Current FSM in Lusaka

As highlighted in Chapters 4 and 5, currently, the majority of FS produced by the population in Lusaka is not being safely managed. In planned settlements where FS is safely removed and transported the poor state of the centralised treatment facilities means that the treatment and safe disposal or reuse part of the chain is inadequate. Despite the low levels of FS treatment achieved there is reported to be a demand for the dried sludge produced at Manchinchi WwTP. During interviews with staff from LWSC (Chapter 6) they indicated that the dried sludge produced at Manchinchi is sold weeks in advance of being ready for collection for a price of 7.50 ZMW/tonne (US $ 1.2/tonne) (based on a conversion rate of 1 ZMW to US $ 0.1602 (XE, 2014)). However, the amount produced and sold was not known. It was noted that the sludge is sold for a low price because they need to dispose of it and they cannot guarantee its quality.

In informal settlements where the SVC is currently not exploited the only bit of fixed infrastructure in use is the containment facility. Literature highlights that it is difficult to predict emptying frequencies for FSM services without improved information on the status of containment facilities and FS accumulation rates (AECOM *et al.*, 2010). For pit latrines specifically, factors such as; the number of users and their behaviours (e.g. diet, use of cleansing material, use of latrine for liquid or solid waste), the volume of the chamber, the amount of water entering the chamber (flushwater, greywater or rain) in combination with the drainage capacity (affected by lining, soil condition and water table) will affect the filling rate of pit latrines (Still and Foxon, 2012). Biological activity (i.e. biological transformations and pathogen die off) are also shown to impact on the rate at which pits fill (Buckley *et al.*, 2008). Temperature and humidity also impacts upon the digestion rate (microbial activity) of FS within the latrines and the moisture content (Foxon *et al.*, 2011; Niwagaba *et al.*, 2014). To explore these factors and the effect they have on FS accumulation rate requires large scale longitudinal analysis of the conditions observed at the containment level which requires a large amount of capital and manpower which was not available as part of this study.

During data collection within the household domain (Chapter 5) information about the status of the existing containment facilities was collected. This data and secondary sources were used to develop Table 7-1 below. As part of the EPSRC research consortium, Chris Rose, a colleague from Cranfield University completed an in-depth characterisation of FS from 11 pit latrines in Kanyama which provided supplementary information for Table 7-1 (note these were not conducted as a longitudinal study) (Rose *et al.*, 2014).

Table 7-1: Existing variables affecting containment filling rate in Kanyama and Chazanga

Variables	**Kanyama situation** [1]	**Chazanga situation**
Number of users	• Average Households sharing facility: 3 * • Average number of people per household: 6 * • Average number of users per pit:	• Average Households sharing facility: 2 ** • Average number of people per household: 6 ** • Average number of users per pit:12
Diet	Not investigated	Not investigated
MSW content	MSW observed in approx. 10% of pits. Wiping material: toilet paper, newspaper, plastic bags observed	No Data-assume similar to Kanyama
Volume of chamber	Varied 1 to 5 metres deep all single pits*	Varied 1 to 5 metres deep all single pits**
Flushwater entering	Flush water used in 9% of cases *	Flush water used in 4% of cases * *
Greywater entering	Common practice to pour water from shower or washing.	Common practice to pour water from shower or washing.
Rain entering	• 52% of facilities had no roof* • Poor community drainage observed	• 37% of facilities had no roof** • Poor community drainage observed
Drainage capacity (affected by lining, soil condition and water table)	• High capacity • Open bottomed pits in use • Surrounding dolomite marble • Risk of ingression of groundwater and surface water in rainy season • High solid concentration (average of 19.2% total solids (N=11) (Rose et al., 2014))	• Medium capacity • Open bottomed pits in use • Surrounding metamorphic schist rock • Risk of ingression of groundwater and surface water in rainy season
Biological transformations	• Contents shown to be anaerobic and of high strength shown by the high total solids concentration and presence of significant concentrations of NH4-N, Carbon Oxygen Demand and other nutrients (N=11) (Rose et al., 2014). • Long periods of containment are typical, causing contents to become stabilised and have low methane yield potential (ibid. and household questionnaire)	No content analysis assume similar to Kanyama.
Pathogen die off	Pathogen concentration within pit latrines was not analysed during this study. However, previous analysis indicated high prevalence in the host populations of Lusaka (Phiri *et al.*, 2011).	
Climate	Sub-tropical climate (20-30^{o}C) with three distinct seasons (Climatic Research Unit 2012).	

[1] * Sample size N=57, ** Sample size N=54. Other sample sizes are highlighted within the table

Observations of the containment facilities highlighted that access (road and vault access hole) was relatively poor directly affecting the FS removal process (section 5.4.1). The majority of household respondents indicated that they utilise either separate onsite MSW pits or collection services for their SWM (section 5.4.1). However, during detailed pit latrine characterisation and field observations, MSW was observed in these pits (Figure 7-2). During interviews, many households indicated that they used additives (lime), disinfectants (sodium hypochlorite) or add charcoal ash to their pit latrines to reduce smell, kill off insects and is believed to slow the rate of filling. Tests conducted by the Water Research Commission (on a number of available additive products in South Africa) indicated that additives make no difference to the sludge build up in pit latrines (Still and Foxon, 2012). However, specific tests on the effect of additives used by households in Lusaka would be needed. The household questionnaires revealed that very few respondents knew how long their pit had taken to fill and so this was an unknown variable in both communities. It was noted that pit emptying services were utilised on an adhoc basis (not regularly), where informal emptiers are called upon only once the pit latrine becomes full or there are problems (smells) associated with the pit latrine. This indicates that the current FSM service is operated on an informal basis, and predictions of emptying schedules per annum, staffing and profits are problematic.

Figure 7-2 MSW observed in full pit latrine in Kanyama

Overall the results discussed in this chapter reveal that the poor sanitation status in informal settlements in Lusaka causes unpredictability and that there is a lack of attention given to the safe management of FS. The impact of this on FSM service delivery will be discussed in more detail in section 7.7.4.

7.3 Methodology for selection and optimisation of FSM scenarios

The following section provides an overview of the fixed infrastructure scenarios which were modelled for Kanyama and Chazanga. Based on the assumption that the centralised sewerage network and Manchinchi WwTP will be upgraded and expanded as set out in the sanitation master plan for Lusaka (Chapter 4), three suitable FSM fixed infrastructure scenarios were selected to be modelled (Table 7-2). Scenario 1 is based on a community level FSM system whereby FS is transported from the collection points (onsite containment facilities) directly to a community level treatment facility located in the community. In this scenario all components (apart from possibly disposal or reuse) are operated and managed within the community itself. The second scenario utilises TS(s) at the boundary of the community. Primary transportation (manual cart or Vacutug) takes FS from the collection points to the TS(s) and then secondary transportation (motorised vacuum tanker) transports the FS to the offsite centralised treatment facility of Manchinchi. In the third scenario FS is transported (using a variety of transportation options) from the collection points to a SDS that feeds directly into Lusaka's centralised sewerage network. In this scenario Variation A transports FS from the collection points directly to the SDS using primary transportation (manual cart or Vacutug). The other two scenario variations use TS(s) prior to transportation (using vacuum tanker) to the SDS. For all three fixed infrastructure scenarios a long term costing model was completed, simulating the use of both manual and motorised emptying and transportation technologies for the primary transportation section (in the community). The motorised option used was the Vacutug Mark II technology whilst the manual option was based on the manual technology currently being utilised in Kanyama's FSM project (i.e. buckets, spades and carts). Table 7-2 below summarises the fixed infrastructure scenarios selected for this study.

All of the modelled scenarios (both fixed infrastructure and containment design) were based on an optimised situation where it was assumed that MSW had minimal effect on the emptying process. This is different to the reality in Lusaka (Table 7-1) where MSW is present in pit latrines, however it was decided that an optimised solution should be used as there was limited information available on how MSW directly effects the emptying process. It was also assumed that with education and the introduction of SWM service the majority of issues associated with MSW presence could be mitigated if a FSM service was introduced (discussed in section 7.3.2 below).

Table 7-2: Overview of fixed infrastructure scenarios and variations modelled

Scenarios and Variations	Containment	Removal	Transportation			Treatment	Reuse/ Disposal
	Pit Latrine		Primary	TS(s)	Secondary		Not included
1A =>		Manual cart	Manual cart			Community Level Treatment Facility located next to WT	
		Vacutug	Vacutug				
1B =>		Manual cart	Manual cart			Community Level Treatment Facility located centrally	
		Vacutug	Vacutug				
2A =>		Manual cart	Manual cart	Single TS	Vacuum Tanker	Manchinchi WwTP	
		Vacutug	Vacutug				
2B =>		Manual cart	Manual cart	Multiple TSs	Vacuum Tanker	Manchinchi WwTP	
		Vacutug	Vacutug				
3A =>		Manual cart	Manual cart			Manchinchi WwTP via SDS	
		Vacutug	Vacutug				
3B =>		Manual cart	Manual cart	Single TS	Vacuum Tanker	Manchinchi WwTP via SDS	
		Vacutug	Vacutug				
3C =>		Manual cart	Manual cart	Multiple TSs	Vacuum Tanker	Manchinchi WwTP via SDS	
		Vacutug	Vacutug				

7.3.1 Fixed Infrastructure

The following section provides an overview of how the fixed infrastructure scenarios selected were developed and optimised for Kanyama and Chazanga.

Firstly, data on the existing physical networks was collected at the community and city-wide level. This included internal transport pathways in informal settlements, external transport roads within the city, location of households, location of possible end points (centralised or decentralised treatment facilities) and possible TS locations. Due to time, manpower and financial constraints the majority of information was gathered from existing secondary sources. Meetings were held with mapping departments at LCC, MOLGH, WDCs and LWSC. Overall, the availability of existing data for informal settlements in Lusaka was scarce with none of the organisations approached having access to complete formal spatial data sets.

During discussions with these organisations it was highlighted that a local engineering company had produced detailed maps of Kanyama as part of a donor funded project. However, attempts to obtain this data were unsuccessful. Another useful source of mapping data for informal settlements without formal well- established national mapping agencies such as Ordnance Survey in the UK is Google Earth, but attempts to gain access to the underlying data were also unsuccessful. The only data available for the informal settlements of interest were contained within ESRI ArcGIS-compatible maps, showing the current water supply distribution network (which were available from the mapping department of LWSC). The data included the location of pipelines, water kiosks and individual taps. The majority of this network was shown to be laid along existing road and pathways within the communities and therefore provided a primary indication of the road network within these settlements. For both informal settlements, the link between the water distribution network and the road network was verified by manually laying the ESRI ArcGIS-compatible maps over an image extracted from Google Earth. ESRI ArcGIS-compatible maps were also available from LWSC for the centralised road sewerage and water distribution networks for Lusaka. The road network was used to build the transportation network model external to the selected informal settlements. ESRI ArcGIS was used to manually add any further roads which were required to connect the informal settlements to the centralised road network, verified using the imagery from Google Earth.

The existing spatial data available for the informal settlements did not provide information on the exact locations of each household plot and containment facility in use. However, the locations of water kiosks (communal taps) provided by LWSC were used as a primary indication of the distribution of the population and where FSM emptying services would be in demand. FS collection (source) points were added at these locations and extra points were added manually where it was felt they were required (evenly distributed based on population density observed). This was based on remotely-sensed imagery (Google Earth), observations of population distribution in the field and the location of the available water distribution network. There were a total of 65 and 42 collection points allocated for Kanyama and Chazanga respectively.

For scenarios 2 and 3 (where variations required it) there were a range of potential locations where TS could be built in both settlements. A multi-criteria evaluation method was used to identify suitable locations. Multi-criteria evaluation was conducted using Google Earth Imagery and observations made during visits to the two informal settlements. Locations were deemed suitable if they fulfilled the following criteria: free of existing developments; being of greater than approximately 64m^2 in area (Tilley *et al.*, 2008; O’Riordan, 2009b); located within 5m of a main road; and within 50m of the community boundary (Kennedy-Walker *et al.*, 2014b). The identified locations were verified as suitable during observations made at each settlement and from a review of aerial imagery. There were a total of 6 suitable TS locations identified for Kanyama and 12 for Chazanga.

The end point locations were based on those that were deemed suitable for each area. For scenario 1, there were two suitable locations identified for the community level treatment facility to be located (variations A and B). The first (variation A) was located next to the existing WT's main office and the second (variation B) was located where there was available land for construction located as centrally as possible. Suitable locations were selected based on space available (using aerial imagery and field visits). Information about land ownership, permits required were not considered. For scenario 2, Manchinchi WwTP was selected as the end point as it is the only treatment facility with sludge dumping capacity, and within the sanitation master plan (section 4.5) it has been identified as one of the facilities that will be upgraded. For scenario 3 the location of the SDS was determined using the information provided in the sanitation master plan (TetraTech, 2011). This report highlighted which sewer networks currently had capacity or would be upgraded to allow for higher loading and therefore provided suitable location for the SDS. An overview of the various data sources utilised to construct the fixed infrastructure networks for each scenario is provided in Table 7-3 below.

Table 7-3: Overview of different data sources used and their purposes

Data Sources	Purpose
Primary	
Author observations during household questionnaires	• Verification of population distribution • Verification of possible locations of TSs, Community Treatment Facility and SDSs
Google Earth Imagery	• Verification of road/pathway networks • Construction of extra pathways and linking roads between community and centralised network • Verification of population distribution • Verification of possible locations of TSs, Community Treatment Facility and SDSs
Manually constructed ESRI ArcGIS-compatible maps	Network constructed consisted of: • Internal community pathways road • Collection points • Connecting pathways/roads (between primary and secondary) • Fixed infrastructure locations (TSs, SDSs)
Secondary	
ESRI ArcGIS-compatible maps 1. Water distribution network in informal settlements 2. Centralised road network 3. Centralised sewerage network	• Pipeline networks used as indicator of primary road and pathways network • Water kiosk and individual tap location used as indicator of distribution of population • Centralised networks used as secondary road network
Sanitation Master Plan	Identification of technically feasible locations for SDSs

Once this data had been collected spatial networks for each scenario and variations could then be built. For scenario 1 and 3A, the spatial network was built so that geometric road length between collection points and end points (community level treatment facility and SDS) could be established. For scenarios 2 and 3 an extra step was required so scenarios representing the least amount of transportation time could be identified for single and multiple TS variations.

For the routes representing the minimal transportation time across the network to be selected a python interface coupled with Network X graph analysis package developed by colleagues at Newcastle University was used (Barr *et al.*, 2012). This methodology was previously used by colleagues to develop least-cost network transportation solutions for high income countries (ibid). I identified that this software could be used and adapted to optimise the transportation component of FSM networks and worked directly with a colleague (Tomas Holderness) to adapt the methodology for the informal settlement of Kibera, Kenya and a paper was produced of the findings (Kennedy-Walker *et al.,* 2014b). Barbara Evans from Leeds University was involved in discussions to define the paper concept, use of the network optimisation tool and identifying application of the results to develop a costing methodology. The paper highlighted that the model could be successfully used to both identify optimum TS locations (based on least transport time) as well as provide an indication of the time required for FS transportation between collection and end point. This methodology could therefore be used to analyse and optimise possible FSM scenarios in Lusaka and the results could be used to develop a long term cost estimate, which includes most of the components of the SVC and highlights how fixed infrastructure optimisation affects the overall cost of FSM services. I established the spatial network required to run the model and was supported by colleagues (Tomas Holderness and David Alderson) to run the Network X graph analysis package to perform least-time/cost analysis.

The least-time transportation network methodology requires a number of pre-processing steps before the analysis can be completed. The first is to identify the complete road network and locations of possible fixed infrastructure (which is discussed above). The model requires that distance and speed both be included in the analysis so that the shortest transportation path is based on both attributes. Speeds of 2.5km/hour were attributed to the primary transportation pathways for both types of technologies (Vacutug and manual cart) based on maximum Vacutug velocity and average walking speeds adjusted to take into account uneven road surface in both communities (Tilley *et* *al.*, 2008) and secondary transportation speeds were set at 35km/hour, based on literature (JICA, 2011). The final pre-processing step was to construct a spatio-topological model of the sanitation network which allows the model to consider the spatial structure of the network as well as topology (Gastner and Newman, 2006). The networks were constructed and stored within a custom-built relational database schema via the use of bespoke Python-based modules to use the inherent geography of the underlying data to derive network typology (Barr *et al.*, 2012). Examination of the network can then be undertaken using the Network X Python package, which provides functions for exploration and analysis of the network (Hagberg *et al.*, 2008).

For scenarios 2 and 3, analysis of FS transportation time via different TS locations was created using two topological configurations. The first configuration was used to identify the location of the single TS where transporting one load of FS from each collection point to a TS and then on to the selected end point (either WwTP or SDS) took the least time (based on speed and distance). To achieve the results the sum of the journey time over the shortest path from each of the collection points to the TS plus the travel time from the TS to end point was computed for each TS (Kennedy-Walker *et al.*, 2014b). The shortest paths between network locations were calculated based on travel time for each road using Dijkstra's algorithm (Gastner and Newman, 2006; NetworkX Developers, 2012).

In the second model configuration the possibility of using more than one TS was modelled. In this scenario the TSs that gave the minimum transport time for each collection point were detailed, and the sum of the times for all collection points (travelling via multiple TSs) was the total transportation time for the network (Kennedy-Walker *et al.*, 2014b). This model optimises the TS locations on a per collection basis, with the number of TSs being limited only by the number of suitable areas identified in the multi criteria evaluation analysis.

7.3.2 Containment design

The following section highlights the containment design scenarios that were used to develop the long term cost analysis and the containment optimisation modelling that was completed.

Buckley *et al.* (2008) highlights that there is a high level of uncertainty in relation to the containment facility which make predictions on FS characterisation, accumulation rates and lifespans of pits difficult to establish. This is confirmed by the findings in section 7.2.1 above. It was decided that fixed input parameters relating to the containment facilities filling rate would be used for the fixed infrastructure scenario optimisation part of the analysis (see section 7.4.2 for details of input parameters used for this analysis).

Some of the uncertainties can be reduced and the containment facility optimised through education, system design and service delivery (Still and Foxon, 2012). For example, if the containment system is redesigned a number of these variables (volume, water in and out of the system, MSW content) can be controlled which makes predictions for the emptying schedule required much easier. This part of the analysis looked to optimise the design of the containment facility by establishing the effects various pit latrine volumes and FS generation rates (accumulation rates) had on the long term costs of the FSM service. For this optimisation the least cost fixed infrastructure scenarios identified for each settlement from the methodology outlined in section 7.3.1 was used for the containment design optimisation modelling.

The following paragraph outlines the parameters used during the containment design optimisation modelling (vary from those used in the fixed infrastructure optimisation). Due to the presence of high groundwater and the common occurrence of flooding in these areas both sealed and unsealed containment designs were modelled. The sealed option (non-permeable containment acting as a sealed vault) assumed an accumulation rate of 550 litres/capita/year (Still and Foxon, 2012). For the unsealed option (which allows percolation into the surrounding ground) an assumed accumulation rate of 60 litres/capita/year was used (Buckley *et al.*, 2008). The size of the container was varied for both accumulation rates and was incrementally increased from a minimum size of 60 litres up to 6000 litres. The minimum value of 60 litres was used as this is the volume of the transportation barrels currently used in the FSM service in Kanyama and 6000 litres was assumed to be a suitable maximum. It should be noted that a maximum depth of 1.5m should be used for any containment due to suction limitation of motorised emptying and ease of manual emptying (Tilley *et al.*, 2008). For the modeled scenarios where motorised primary transportation technology was used and the containment volumes were between 60 and 1800 litres the time to fill the tank was set at 5 minutes and the preparation time set to 10 minutes. These times were doubled for containment volumes over 1800 litres. For manual transportation scenarios the fill and preparation times were set to 20 minutes each. In reality, the sealed facilities may be quicker to empty than unsealed ones as they should have a higher water content making them easier to empty. However, a conservative estimate of time were used for both in this study. An unused zone of 10% was included in the model to minimize the risk of containment facilities overflowing. The model also assumed that every household had access to a latrine, which would be the ideal scenario. Equation 7-1 was used to establish the emptying frequency required for each containment design and volume scenario (shown in further detail in Appendix G).

Equation 7-1: Equation for calculating the emptying frequency required

$$Emptying\ Frequency\ (per\ year) = \frac{Volume\ (m^3)}{Number\ of\ user * Sludge\ generation\ rate\ (m^3\ /capita/year)}$$

(Still and Foxon, 2012)

The variations of the containment facility volume and design (affecting accumulation rate) were input into the developed long term costing methodology (section 7.5) and the output for each was established.

7.4 Costing Input Parameters

The input parameters required to conduct the long term cost analysis of the fixed-infrastructure optimisation (outlined in section 7.3.1) are discussed in the following section. The full list of parameters used are available in Appendix F. The parameters discussed relate to socio-economic data, fixed infrastructure data and transportation equipment data.

7.4.1 Socio- economic parameters

The socio-economic data used for both communities, where not explicitly referenced, was gathered from data collected for Chapter 4 and 5. A population of 137,000 was used for Kanyama and 86,000 for Chazanga. An average number of 6 people per household was used for both settlements and the average number of household sharing facilities was set to 3 for Kanyama and 2 for Chazanga based on household questionnaire results. The figure for household size was deemed appropriate based on findings from other studies which indicated urban populations in Lusaka to be between 5 and 10 inhabitants (Central Statistical Office *et al.*, 2009). The average annual urban population growth rate in Zambia was recorded as 4.2% (Central Statistics Office, 2012). This figure may be higher for informal settlements but no secondary data exists as an alternative.

For those in formalised employment the legal minimum wage in Zambia for category one employment (which includes general workers and cleaners) is 3646 ZMK per hour (approx. 0.68 US$/day based on a conversion rate of 5335 ZMK to US $ 1 (Norman *et al.,* 2012b)) (GRZ, 2012), the rate of which is based on a typical working day of 8 hours in length. This analysis assumes that a formalised FSM service would be created where employees have formal employment contracts and therefore these figures are used. Based on information collected during interviews in Lusaka and literature that outlined practical experience of using Vacutugs (O'Riordan, 2009b) a working week of 5.5 days and an operational year of 45 weeks was set.

The fuel price was set at US $1.48 per litre based on the average recorded between 2009 and 2013 (The World Bank, 2014a). The current discount rate of 12% was used for this analysis (Bank of Zambia, 2014). An annual inflation rate of 9.5% was used which was determined by averaging out the long term historic inflation rate for Zambia over the last 8 years (Trading Economics, 2014). The data is summarised in Table 7-4 below.

Table 7-4: Socio-economic data for Kanyama and Chazanga

Input Parameter	Unit	Kanyama Value	Chazanga Value
Baseline population	cap	137,000	86,000
Number of people per household	cap	6	6
Annual population rate	%/ year	4.2	
Average number of households per facility	-	3	2
Minimum Wage	US$/ day	0.68	
Working Hours	hours/ day	8	
Working Days	days/ week	5.5	
Working Weeks	weeks/ year	45	
Fuel price (petrol)	US$/ litre	1.48	
Discount Rate	%/year	12	
Inflation Rate	%/year	9.5	

7.4.2 Filling rate parameters

Due to the high variability of containment facilities used in informal settlements in Lusaka (see section 7.2.1 above) secondary data was used to establish sensible values for the filling rate parameters. Studies by the Water Research Commision in South Africa indicate that a sludge generation rate of 0.06m^3/capita/year should be used for designing pit latrines (Still and Foxon, 2012). In a study by Chowdry and Kone (2012) the average volume of pits were recorded for a number of African and Asian cities. In Kenya an average pit volume of 2.6m^3 was observed and therefore this value was used for this study. Table 7-5 summarises the filling rate parameters used.

Table 7-5: Filling rate data

Input Parameter	Unit	Chazanga Value	Kanyama Value
Sludge generation rate	m^3/cap/year	0.06	
Current pit size	m^3	2.6	

7.4.3 Motorised emptying parameters

A Vacutug cost of US $15,000 per unit was used based on conservative estimates quoted in literature (Parkinson and Quader, 2008; O'Riordan, 2009b; Sugden, 2013). The true cost of using a Vacutug in Lusaka would depend on the location of manufacturer and the production capacity of the supplier. Shipping cost was highlighted as a separate parameter and was set at US $8,000 based on literature (O'Riordan, 2009b; African Water Facility, 2012).

Studies have indicated that frequent breakdowns of Vacutugs result in high associated maintenance costs which can be reduced if regular maintenance checks are completed (O'Riordan, 2009b; Opel and Bashar, 2013). For this study it is assumed that the operation and maintenance costs are 10% and wear and tear are 7% of the capital cost per annum. The economic life of a Vacutug is widely reported to be between 4 and 5 years and therefore a conservative value of 4 years was used for this study (UN HABITAT, 2004; African Water Facility, 2012). There is limited data available on fuel consumption related to using a Vacutug, however fuel usage associated with transportation was set at 0.2 litres/km (www.fueleconomy.gov, 2014). Fuel usage associated with the vacuum pump required for removal and depositing of FS was set at 6 litres per hour based on literature which was adapted based on the assumed age and size of the pump (UN Habitat, 2002; MSP, 2014).

The Vacutug (Mark II) has a volume of 2000 litres (Parkinson and Quader, 2008). An average speed of 2.5km/hour was used for this study based on the conditions of the roads/ pathways in these informal settlements. Literature suggests that between 2 and 4 people are required to operate each Vacutug (Parkinson and Quader, 2008; O'Riordan, 2009b), therefore, a median value of 3 operators was used. Scholars report that it only take a few minutes to fill each Vacutug load, therefore, a figure of 10 minutes was used (Parkinson, 2005; Still and O'Riordan, 2012). Still and O'Riordan (2012) reported that it takes approximately 30 minutes per trip for the setup, evacuating of solid waste and for pre-pumping (liquefaction of FS) and therefore a value of 30 minutes was adopted. Table 7-6 defines the values used in relation to Vacutug equipment.

Table 7-6: Vacutug design data

Input Parameter	Unit	Kanyama Value	Chazanga Value
Cost per unit of equipment	US $/ unit	15,000	
Shipping costs	US $/ unit	8,000	
Maintenance	%/ year	10	
Wear and Tear	%/ year	7	
Economic life	years	4	
Fuel usage	litres/ km	0.2	
Vacuum Pump Fuel Usage	litres/hr	6	
Oil usage	US$/ year	Included in maintenance cost	
Volume	m^3	2	
Speed	km/ hour	2.5	
Number of operators	-	3	
Time to fill tank	minutes	10	
Preparation and setting up	minutes	30	

During field observations it was noted that vacuum tankers of $10m^3$ volume were the ones most commonly used to transport FS to Manchinchi WwTP and therefore this volume was used. The majority of vehicles used in Lusaka are second hand imported from Europe and Asia and prices of vacuum tankers are shown to vary depended on the size, model and make (range of ZMK 30 to 250 million (US$ 5,700–47,000)) (Mikhael and Clouet, 2012). A value of US$ 50,000 was used as a conservative estimate for the cost per vacuum tanker, including the associated shipping costs.

The maintenance and wear and tear values were set at 10% and 7% of unit cost per year respectively. In reality, this may be higher because the equipment used is often second hand. The economic life and associated fuel and oil consumption for a vacuum tanker is variable based on the quality and age of the equipment imported. For the case of this study an economic life of 10 years was used. There is limited data available on the fuel consumption rate of vacuum tankers. However, a figure of 0.5 litres/ km is assumed to be reasonable when compared to vehicles of a similar size and the study discussed above (www.fueleconomy.gov, 2014). A vacuum pump is also used within this set up and a fuel consumption rate of 10 litres per hour was assumed (MSP, 2014).

A speed of 35km per hour was used for the vacuum tanker based on the average speed referenced for major roads in Lusaka (JICA, 2011). It was noted that one driver and two workers are hired to operate each vacuum tanker (Mikhael and Clouet, 2012). It was assumed that a fill time and emptying time set at 15 minutes would be sufficient based on observations made of vacuum tanker equipment in Lusaka. Table 7-7 summarises the parameters used for the vacuum tanker equipment.

Table 7-7: Vacuum tanker design data

Input Parameter	Unit	Kanyama and Chazanga Values
Cost per unit of equipment including shipping cost	US $/ unit	50,000
Maintenance	%/ year	10
Wear and Tear	%/ year	7
Economic life	years	10
Fuel usage	litres/ km	0.5
Vacuum Pump Fuel Usage	litres/hr	10
Oil usage	US$/ year	Included in maintenance costs
Volume	m^3	10
Speed	km/hour	35
Number of operators	-	3
Time to fill	minutes	15
Time to empty	minutes	15

7.4.4 Manual emptying parameters

The parameters outlined in the following section relate to manual emptying and transportation of FS. The figures used were based on the FSM service in Kanyama where barrels, shovels and carts are used to empty the facility. The carts are specially designed for transportation and have been locally designed and built. The cost of the manual emptying equipment was assumed to be $800 based on discussion with WSUP (Sipuma, 2014).

The same maintenance costs (10% of unit cost per year) was assumed for the manual emptying option. However, the wear and tear value was set at 20% of the unit cost as it was observed that carts get frequently damaged by the pathway terrain in informal settlements in Lusaka. The economic life of the manual carts was set at 3 years because they were observed to be less robust than Vacutugs.

The volume capacity of each cart was set at 330 litres. For the existing FSM service in Kanyama each manual cart transports six barrels each filled with 55 litres of FS. It was observed that 2 manual carts are used per team and so each team's capacity would be 0.66 m^3 (660 litres). The speed attributed to the manual transportation option was 2.5 km per hour based on half of the average walking speed of people (5km per hour) to take account of the heavy loads and uneven surfaces.

During observations of the FSM service in Kanyama the time required for emptying and transporting varied based on access to the site of latrines, access to the pit latrine vault, presence of MSW and distance back to treatment facilities. However, for the case of this analysis it was defined that it would take 40 minutes to fill both carts (per 660 litres) based on 4 workers. Preparation and setting up time was assumed to be 30 minutes for each pit which accounts for liquidation of FS, breaking of slab/wall of pit to gain entry and fixing and closing the pit. The parameters used are summarised in Table 7-8.

Table 7-8: Manual emptying design data

Input Parameter	Unit	Kanyama and Chazanga Values
Cost per unit of equipment	US $/ unit	800
Maintenance	%/year	10
Wear and Tear	%/year	20
Economic life	years	3
Volume	m^3	0.33
Speed	km/hour	2.5
Number of operators	-	4
Time to fill cart	minutes/ load	40
Preparation time	minutes/ pit	30

7.4.5 Transfer Station parameters

The type of TS assumed in this cost analysis was a fixed one that just contains the sludge and does not pre-treat the FS (e.g. digest or dewater). A TS volume of 135 m^3 was used based on literature, available land assigned (64 m^3 as discussed in chapter 7.3.1) and the estimated volume of sludge that could be collected and transferred to the TS per day (based on household emptying frequency) (Murungi and van Dijk, 2014). A cost of each TS of $100,000 was used based on literature that outlined the cost of a FSM project in Senegal (ONAS, 2011). Due to limited information on TSs a more accurate value for the capital costs associated for building TSs in Lusaka would be required. An economic life of 25 years was assumed for TSs. It was assumed that only 2 operators would be required to run the TS and similar to above an operation and maintenance figure of 10% (per year) of the unit cost was assumed. The parameters used in the case of TSs are outlined in Table 7-9 below.

Table 7-9: Transfer station parameters

Input Parameter	Unit	Kanyama and Chazanga Values
Cost per unit	US $/ unit	100,000
Operation and Maintenance	%/ year	10
Economic life	years	25
Volume	m^3	135
Number of operators	-	2

7.4.6 Sewer discharge station parameters

A SDS volume of 50 m^3 was used based on the amount of sludge expected to be received daily and because it was presumed that the space available for building this facility would be more restricted than for the TS as the sewerage network predominantly lies along main roads. Similarly to the TSs an economic life of 25 years was used. However, an economic life of 5 years was assumed for the pump equipment required for this set up. Two operators were assumed to be required. Due to limited data availability of the capital costs associated with SDSs the cost used was based on the same study used for the TSs (ONAS, 2011) and extra costs were added for the cost of the pump. The operation and maintenance cost associated with the SDS infrastructure and pump were assumed to be 10% of the capital cost per year. The values assigned to the SDS can be seen in Table 7-10 below.

Table 7-10: Sewer discharge station parameters

Input Parameter	Unit	Kanyama and Chazanga Values
Cost per unit	US $/ unit	40,000
Operation and Maintenance	%/year	10
Economic life	years	25
Volume	m^3	50
Number of operators	-	2
Cost per unit (pump)	US $/ unit	40,000
Operation and Maintenance	%/year	10
Economic life	years	5

7.4.7 Community level treatment facility parameters

Due to the focus of the research consortium and the existing technology in use in Kanyama, anaerobic treatment was selected as the technology of choice for the community level treatment facilities. Two different size treatment facilities were assumed for Kanyama and Chazanga. In Kanyama the higher population meant a facility with a volume of 100 m^3 per day was assumed to be adequate for the treatment needs of the community over a 25 year design period (detailed in section 7.4.10). At the start of the project the treatment facility volume required is approximately 40 m^3 per day. However, at the end of the 25 year period the volume required is much greater. In a real world scenario a modular treatment facility may be considered were extra treatment volume can be added to the faculty when the influent volume required increases. In the case of Chazanga a facility with a capacity of 60 m^3 per day was deemed appropriate to meet the treatment needs of the community. Due to limited data availability the costs assigned were based on reports from a small number of FSM projects (ONAS, 2011; Dodane *et al.*, 2012). Similar to above, a 25 year economic life was used for this infrastructure, the number of operators was set at 2, and the operation and maintenance budget was set at 10% of the capital cost per year. The parameters used for the community level treatment facilities are summarised in Table 7-11.

Table 7-11: Community level treatment facility parameters

Input Parameter	Unit	Kanyama Value	Chazanga Value
Cost per unit	US $/ unit	600,000	400,000
Operation and Maintenance	%/year	10	10
Economic life	years	25	25
Volume	m^3	100	60
Number of operators	-	2	2

7.4.8 Disposal costs at Manchinchi WwTP

In 2012, the disposal costs at Manchinchi WwTP were recorded as ZMK 30,000 per m^3 of sludge delivered (US$ 5.6/ m^3 based on conversion rate of 5335ZMK to US$1 (Norman *et al.*, 2012b)) (Mikhael and Clouet, 2012). It is assumed that the full cost of treatment is covered by the disposal cost for this analysis, however this would require further investigation to ensure this cost is not subsidised.

7.4.9 Sewerage disposal charges

A charge also needs to be incorporated into the costs associated for scenario 3, where a SDS is used, to account for the treatment of the FS downstream at Manchinchi WwTP. Currently sewerage charges for households in Lusaka (domestic use) are 40% of the water bill and the maximum sewerage charge for metered customers is approximately US$ 0.90/m^3 of water consumed (were consumption is above 170m^3) (Norman *et al.*, 2012b). However, it is unclear whether this tariff fully covers the cost of sewerage treatment for those connected to the sewerage network, or whether the cost is subsidised. Therefore, the same fee as defined in section 7.4.8 above (US$5.6/$m^3$ of FS disposed) will be used instead for this scenario.

7.5 Financial Costing Methodology

The long term costs associated with each fixed infrastructure scenario and variation within it was developed for a 25 year design period. This design period was selected based on the typical concession period (financing period) defined for such projects and because this value is often used in life cycle cost calculations and design (Whittington *et al.*, 2008; American Water Works Association, 2012). The model incorporates annual population growth for each settlement and thus the increase in accumulation rate and associated requirements for the FS to be emptied. The economic life of equipment and infrastructure used was also accounted for in the model.

To calculate the long term costs, both the capital costs and operation and maintenance costs associated with each scenario and variation were included. The total capital costs were produced for each year based on the cost of each unit of equipment or infrastructure and included any new equipment required, accounting for inflation. The operation and maintenance costs were calculated based on the annual costs associated with each piece of infrastructure or equipment that was required, again adjusted for inflation.

For each scenario and variation the Net Present Value (NPV) was calculated. This method is often used in engineering projects to assess long term cash flows (Equation 7-2) (Von Münch and Mayumbelo, 2007). The minimum household charge (monthly) required for each scenario to break even (NPV=0) over the 25 year design life was determined.

Equation 7-2: Net Present Value

$$\text{NPV}\ (\$)(r_{d,}, \text{n}) = \sum_{t=0}^{n} \frac{C_t}{(1 + \ r_d\ )^t}$$

where, n = design life, t = year, C_t = net cash flow per year (total yearly expenditure minus total yearly income) and r_d= discount rate

(Von Münch and Mayumbelo, 2007)

The Average Incremental Cost (AIC) can be used to estimate the average unit cost of service provision and is a widely used approach in the sector when comparing potential costs between varying engineering projects (The World Bank, 2008). For this analysis AIC was calculated to compare the various scenarios modelled objectively based on US$ cost per m^3 of FS emptied and transported. This calculation is useful as each of the options use varying infrastructure, equipment and collect varying volumes of FS and therefore it is difficult to directly compare them without the AIC value. Firstly, the projected costs for each year were converted into their respective present values (PV) using Equation 7-3. Here the discount rate was applied to allow the present value of each year’s projected expenditure to be calculated. Each year’s present values were then summed together over the 25 year design life.

Equation 7-3: Present Value

$$PV\ (\$) = \frac{X_t}{(1 + \ r_d)^t}$$

where X_t = projected future cost in year t and r_d= discount rate

(The World Bank, 2008)

The total volume of FS emptied each year for each scenario was then calculated based on the number of units and their individual operational capacity. The volumes emptied were then summed over the 25 year design life. The AIC value was then calculated using Equation 7-4 were the total present value of network cost (for each scenario modelled) were divided by the total volume of FS emptied (m^3). The analysis also allowed a breakdown of the overall cost per m^3 of FS to be split into individual components (individual capital, maintenance, wear and tear, labour, fuel and oil and discharge costs) so the associate expenditure variation between each scenario could be seen.

Equation 7-4: Average Incremental Cost

$$AIC = \frac{\sum PV(costs)}{\sum PV(benefits)}$$

where PV (costs) = the total present value cost for project in each year and PV (benefits) is the total volume of FS emptied per year.

(The World Bank, 2008)

All of the calculations were set up in a Microsoft excel spreadsheet. The full set of equations and results are provided in the Appendix F and G.

7.6 Results

The following section will present the results for the FSM scenarios for both Kanyama and Chazanga and the results will be briefly discussed. Table 7-2 presented earlier provides an overview of the scenarios modelled. For both settlements the results of the fixed infrastructure scenario optimisations are firstly discussed followed by the AIC and average fleet requirements for each. The percentage of costs associated with the various network components of each scenario are then presented followed by a breakdown of the proportion of the total costs (AIC) assigned to each cost parameter. The full data set for each network scenario is available in the Appendix G.

7.6.1 Fixed infrastructure and transportation scenarios

The results of the optimisation of the transport network using the spatio-topological model are discussed and the resulting average primary and secondary transportation distances for each scenario and variations are presented in Figure 7-3 and 7-4. For clarification, primary transportation relates to internal community transportation using vacutug or manual cart equipment and secondary transportation relates to external transportation outside of the community using vacuum tanker equipment.

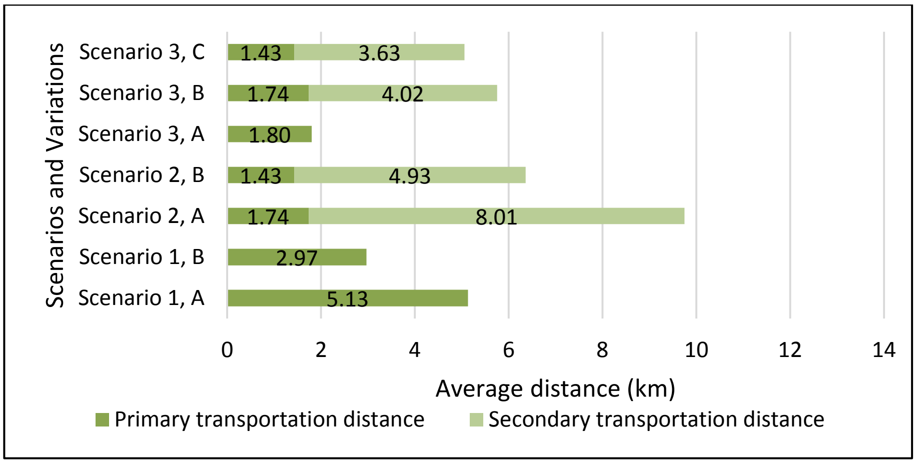


Figure 7-3: Average FS transportation distances required for each scenario and variation in Kanyama after optimisation

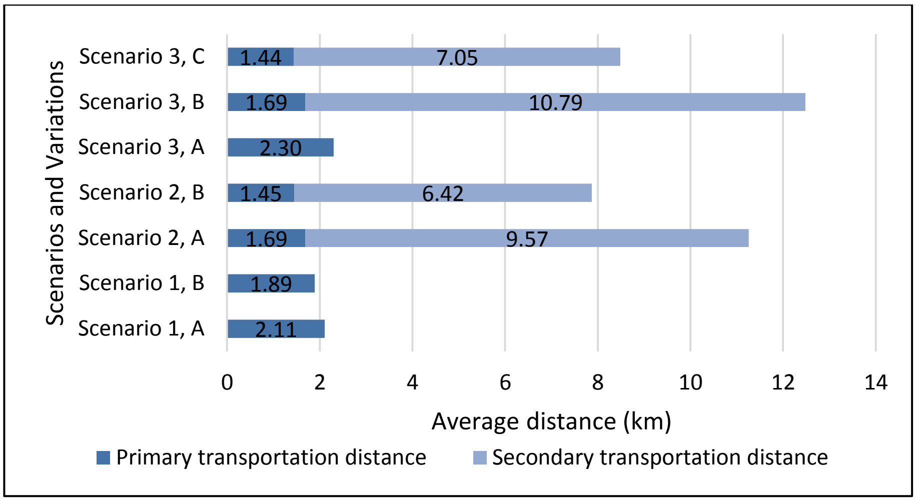


Figure 7-4: Average FS transportation distances required for each scenario and variation in Chazanga after optimisation

The results highlight that for scenario 1 the average primary transportation distance was greater in Kanyama than Chazanga. For scenario 2 the primary transportation distance requirements were similar in Kanyama and Chazanga, however the secondary distance between the selected TS/s and Manchinchi WwTP was further in Chazanga compared to Kanyama. For both settlements scenario 2A was shown to have a relatively long transportation distance associated compared with others. In scenario 3 the SDS was closer to the community in Kanyama and thus the secondary transportation distance requirements were greater than in Chazanga's case. Scenario 3A was shown to require a relatively short FS transportation distance for both settlements compared with other scenarios.

Figure 7-5 below shows the simulated emptying frequency required for containment facilities in Kanyama and Chazanga over the 25 year design period. The frequency increases gradually over the 25 year design period because of population increase which causes the latrines to be used by more people. The emptying frequency for Kanyama was shown to be higher than Chazanga as each latrine had more users.

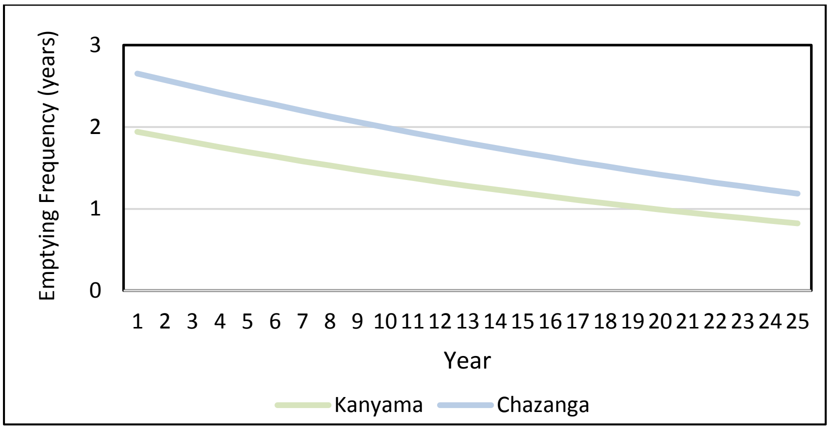


Figure 7-5: Emptying frequency per latrine over 25 years for each settlement

7.6.2 Fixed infrastructure and transportation scenario results for Kanyama

The network for scenario 1 was made up of 65 collection points and 2 possible end points where community level treatment facilities could be located (

Figure 7-6). The results indicate that the average distance from the collection points to end point A (next to the WT) was 5.13 km and to end point B was 2.97 km (Figure 7-4).

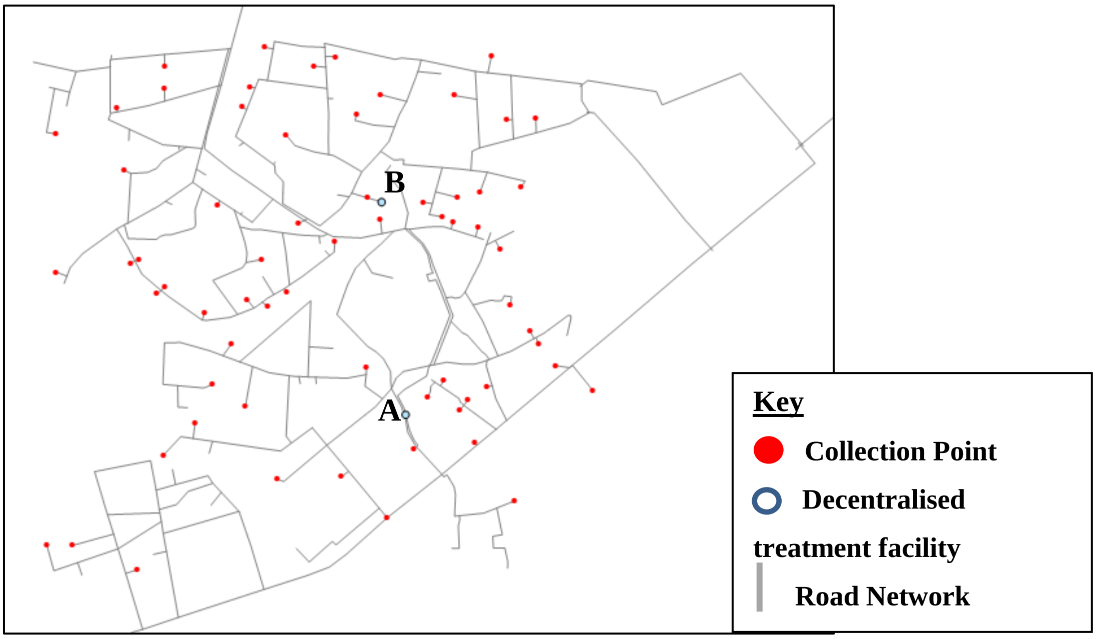


Figure 7-6: Network layout for Kanyama (scenario 1)

For scenario 2 the network was made up of 65 collection points and 6 possible TS locations (Figure 7-7). The complete results from the Network X analysis is provided in Appendix G. The results show that for scenario 2A TS with the I.D code 1668 was optimum with a total travel time of 46 hours required to transport FS from each collection point to the treatment facility via the optimum TS. Table 7-12 highlights the results for scenario 2B and shows that the use of five TSs was optimum in Kanyama. The optimised set of 5 TSs (variation 2B) is shown in Figure 7-7, one of which (TS1668) is also the optimal TS location for the single TS variation (2A). All 5 are located at main road junctions of the edge of Kanyama on route to Manchinchi WwTP (also shown in Figure 7-7), as would be expected.

Table 7-12: Network X model results scenario 2B in Kanyama

TS ID code	Collection points served	Primary Transport Time (mins)	Secondary Transport Time (mins)
1106.	1	22.85	2.38
1668	27	753.05	18.54
2084	2	25.97	4.87
2585	17	903.19	11.90
3759	7	151.07	4.55
Total	54	1856.14	42.24

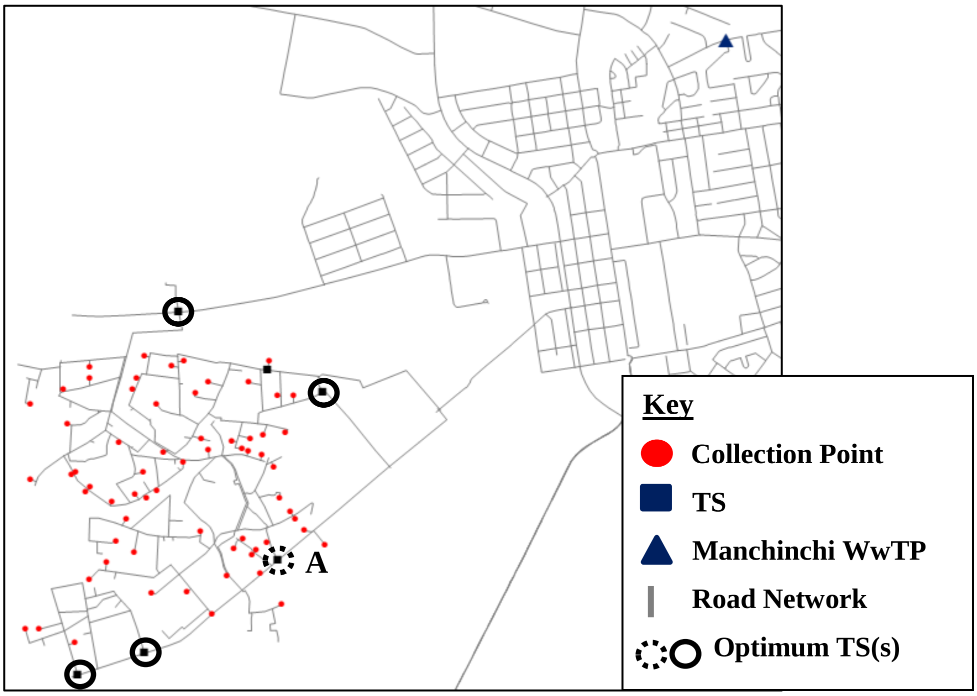


Figure 7-7: Network layout for Kanyama (scenario 2)

For scenario 3, variation A (no TS) the total transport time between the collection points and the SDS came to approximately 47 hours. For variation B (single TS) the same single TS was optimum as for scenario 2 because of the location of the SDS (TS 1668 was optimum). For variation C (multiple TSs) the optimum combination was four TSs (Figure 7-8).

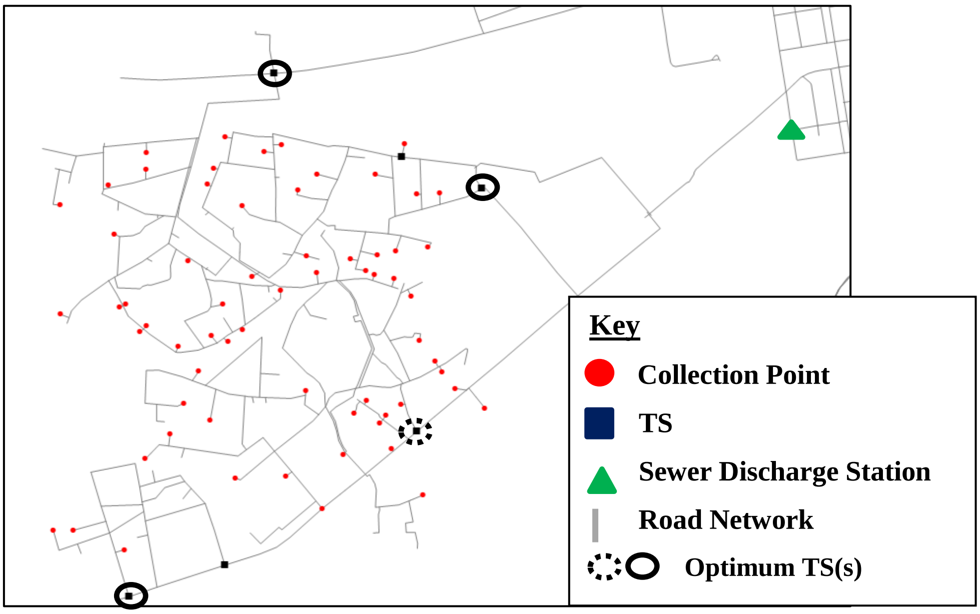


Figure 7-8: Network layout for Kanyama (scenario 3)

Figure 7-9 shows the AIC per m^3 of sludge collected (bar chart) for each fixed infrastructure scenario and variation (primary transportation) and the primary transportation fleet requirements (both manual cart and Vacutugs) at year zero (line graph) for Kanyama.

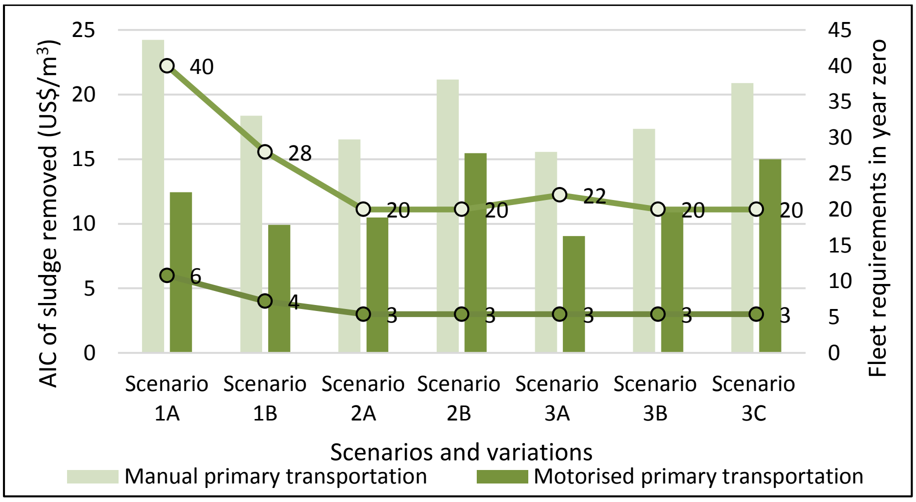


Figure 7-9: AIC and fleet requirements for each scenario and variation in Kanyama

For all the scenarios and variations modelled, the cost per m^3 of sludge collected was lower for those options which utilised motorised primary transportation. The cost difference between using manual and motorised primary transportation varied between 27 and 49%. For AIC per m^3 the lowest costing option overall was scenario 3A. The fleet requirements were shown to be much higher for those options that utilised manual primary transportation equipment compared with motorised. Whilst not shown in Figure 7-9, the fleet requirements for all the scenarios increased gradually over the 25 year design period in line with the increase in emptying frequency (Figure 7-5).

For scenario 1, variation A was shown to be more expensive than variation B for both primary transportation options. This was caused by the average distance between the collection points and the community level treatment facility being 42% further in variation A compared to variation B (Figure 7-3). Figure 7-10 highlights that the majority of the cost for all variations of scenario 1 (apart from variation B utilising motorised primary transportation) were related to the primary transportation component, with a higher proportion of the cost being associated with transportation in those variations which use manual equipment. Figure 7-11 highlights that for those variations that use manual equipment the highest cost component was related to labour costs caused by the higher fleet requirement for these options. In the cases were motorised equipment was used the cost components with the greatest expenditure relate to them were capital costs and operation and maintenance.

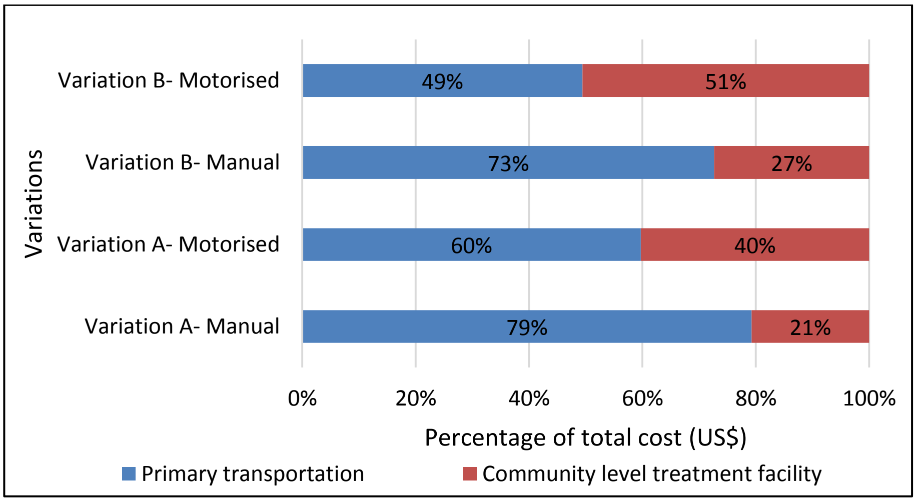


Figure 7-10: Costs associated with components of the network for scenario 1, Kanyama

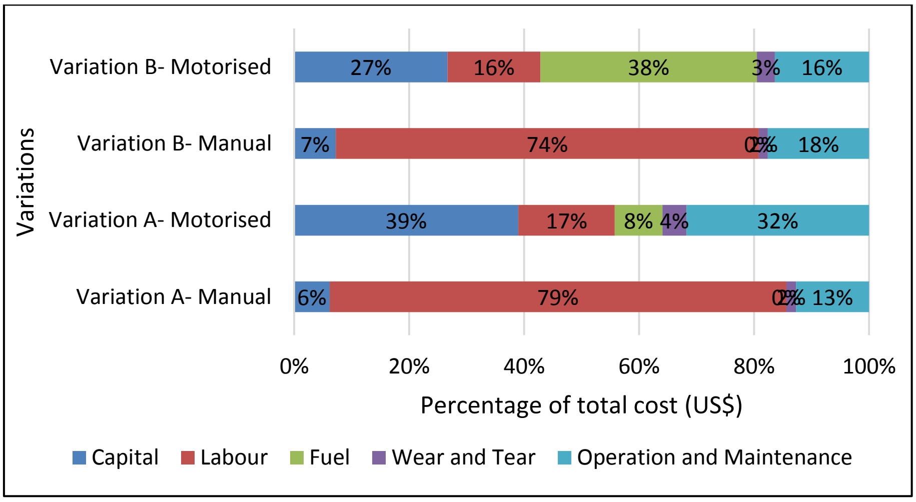


Figure 7-11: Cost breakdown for total AIC cost (per m^3) for scenario 1, Kanyama

For scenario 2, variation B was shown to be more expensive than variation A for both primary transportation options (manual 24% and motorised 34% more expensive). Figure 7-12 highlights that for those variations where manual equipment was used the largest proportion of the costs were associated with primary transportation, while in the motorised cases the highest proportion was related to the discharge fee. Figure 7-13 shows that those variations which used manual equipment had the highest proportion of cost related to labour that was expected due to large fleet requirement (as above). For the scenarios using motorised equipment the greatest proportion of the expenditure relates again to discharge fees. The results indicate that the cost of using multiple TSs was higher than using a single TS (manual= 21% increase and motorised= 32%). This was despite the use of multiple TSs causing a reduction in the transportation distance requirements (by 35%). Therefore, showing that the cost saving related to a reduction in transportation requirements were less than the increased capital and operational costs associated with implementing more TSs.

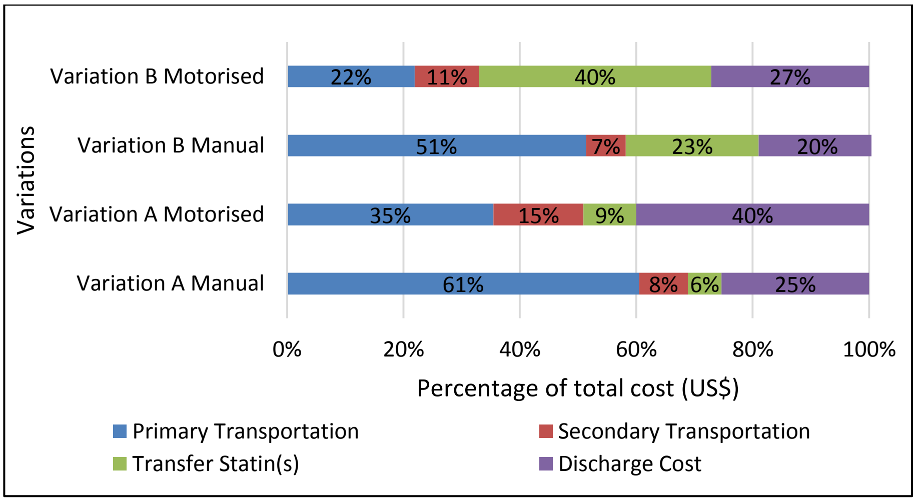


Figure 7-12: Costs associated with components of the network for scenario 2, Kanyama

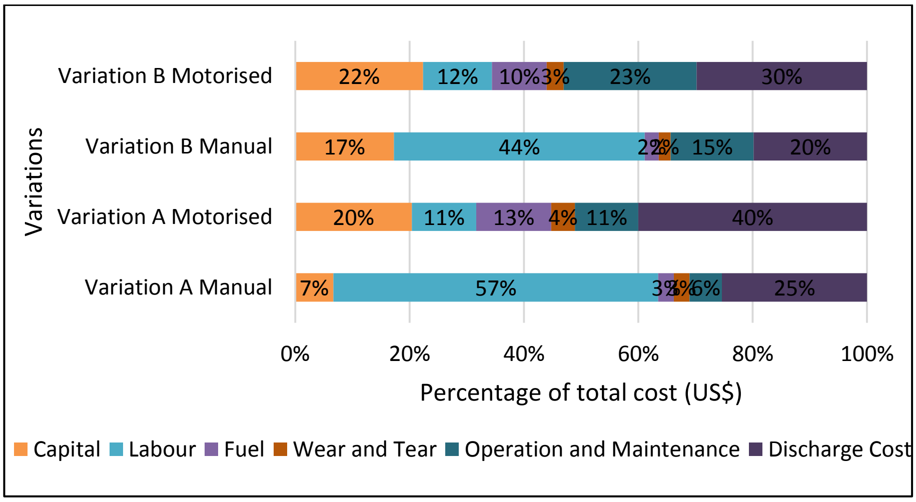


Figure 7-13: Cost breakdown for total AIC cost (per m^3) for scenario 2, Kanyama

For scenario 3, the variation with the lowest overall cost was shown to be scenario A where the FS was collected from source and directly transported to the SDS using primary transportation equipment. However, there was not a large cost difference seen between variation A and B for both manual and motorised options (10% and 18% for AIC/m^3 respectively). The results again indicate that the use of multiple TSs causes the network to be more expensive than when a single TS was used despite a 12% reduction in travel distance being achieved (manual: 15% cost increase, motorised: 25% cost increase). Figure 7-14 highlights that for variation A, when manual equipment was used, the highest proportion of the cost related to primary transportation whereas for the motorised cases it related to the discharge cost. Figure 7-15 indicates that for the manual options the highest proportion of the cost was associated with labour and in the motorised case the highest proportion was related to capital and discharge cost. These findings are also seen for variations B and C. Figure 7-15 shows that the overall proportion of cost associated with fuel (variation B and C) when motorised equipment was used was reduced when multiple TSs were utilised because of the reduction in primary and secondary transport distance.

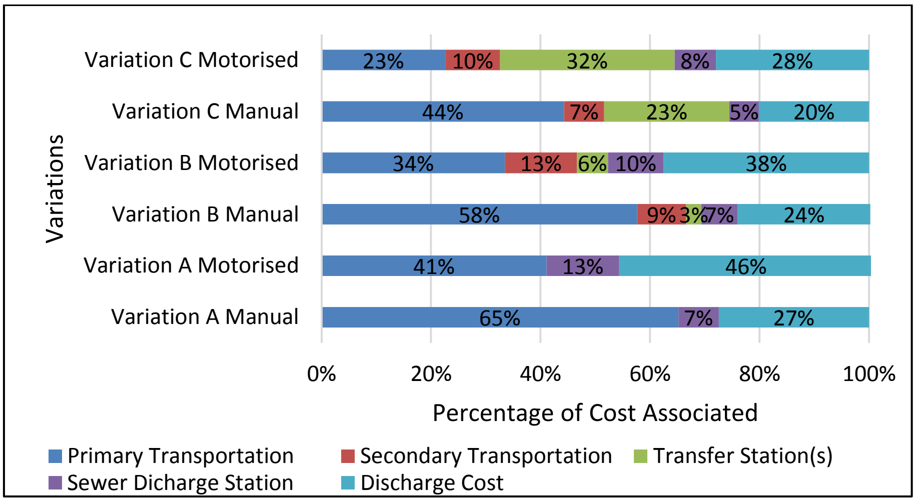


Figure 7-14: Costs associated with components of the network for scenario 3, Kanyama

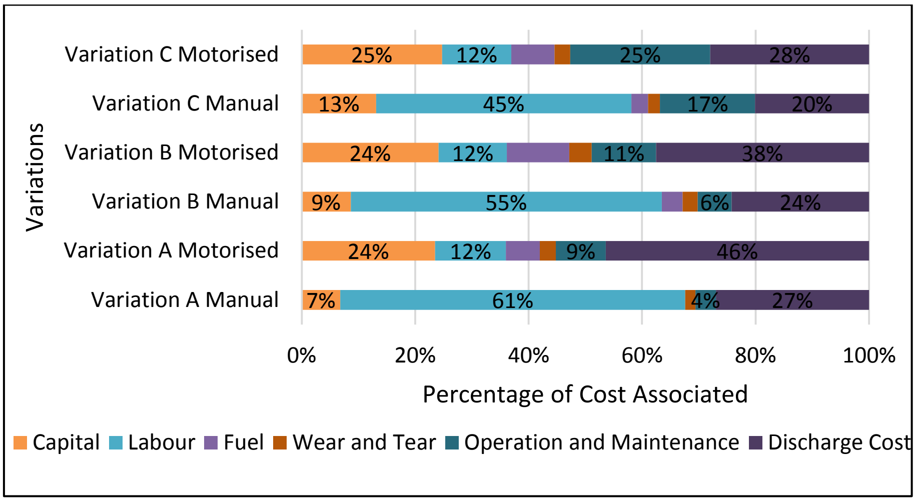


Figure 7-15: Cost breakdown for total AIC cost (per m^3) for scenario 3, Kanyama

7.6.3 Fixed infrastructure and transportation scenario results for Chazanga

The network for scenario 1 was made up of 42 collection points and 2 possible end points (Figure 7-16). The results indicate that the average distance from the collection points to end point A (next to the WT) was 2.11 km and to end point B was 1.89 km (Figure 7-4).

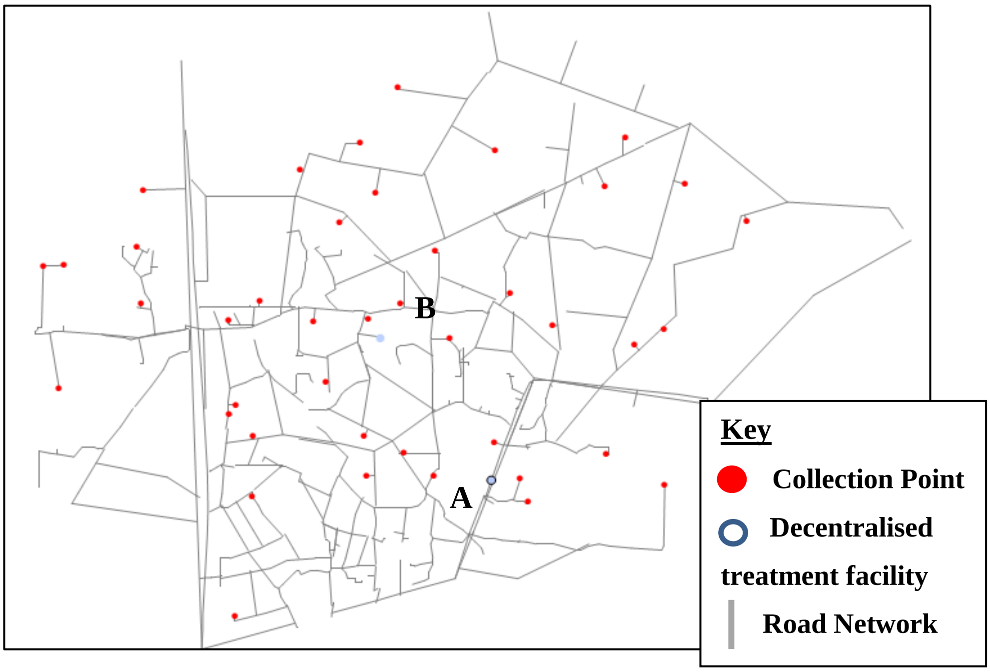


Figure 7-16: Network layout for Chazanga (scenario 1)

For scenario 2, the network was made up of 42 collection points and 12 possible TS locations (Figure 7-17). For scenario 2A, TS with the I.D 4061 was shown to be optimum with a total travel time of 30 hours to empty from each collection point and transport to the WwTP via a single TS. Table 7-13 indicates that four TSs provided the optimum network for scenario 2B.

Table 7-13: Network X model results scenario 2B in Chazanga

TS ID code	Count	Primary Transport Time (mins)	Secondary Transport Time (mins)
1182	8	356.17	5.80
1748	3	47.22	10.79
3548	1	12.58	2.79
4061	30	1045.61	24.62
Total	42	1461.58	44.00

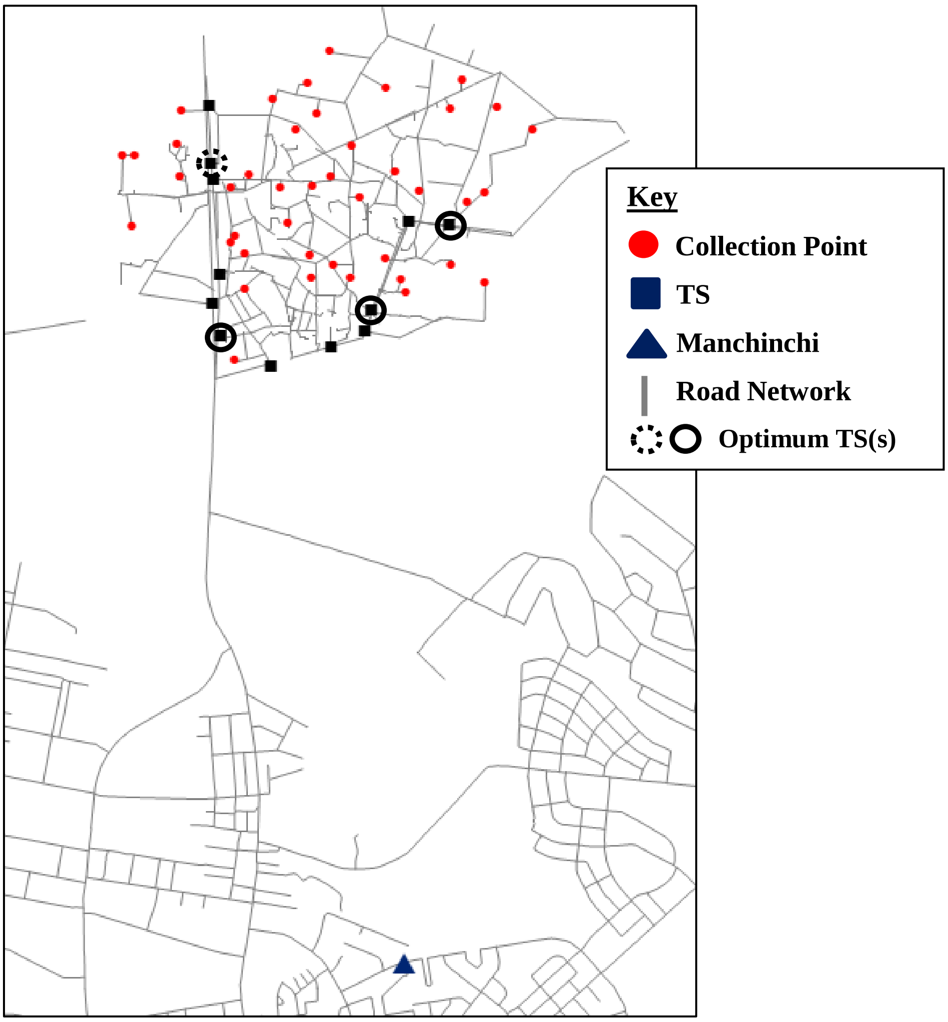


Figure 7-17: Network layout for Chazanga (scenario 2)

For scenario 3A the total travel time between all of the collection points and the SDS came to 39 hours. The same TS(s) were shown to provide the optimised network as in scenario 2 for both variation B and C as highlighted in Figure 7-18. A full set of results can be seen in Appendix G.

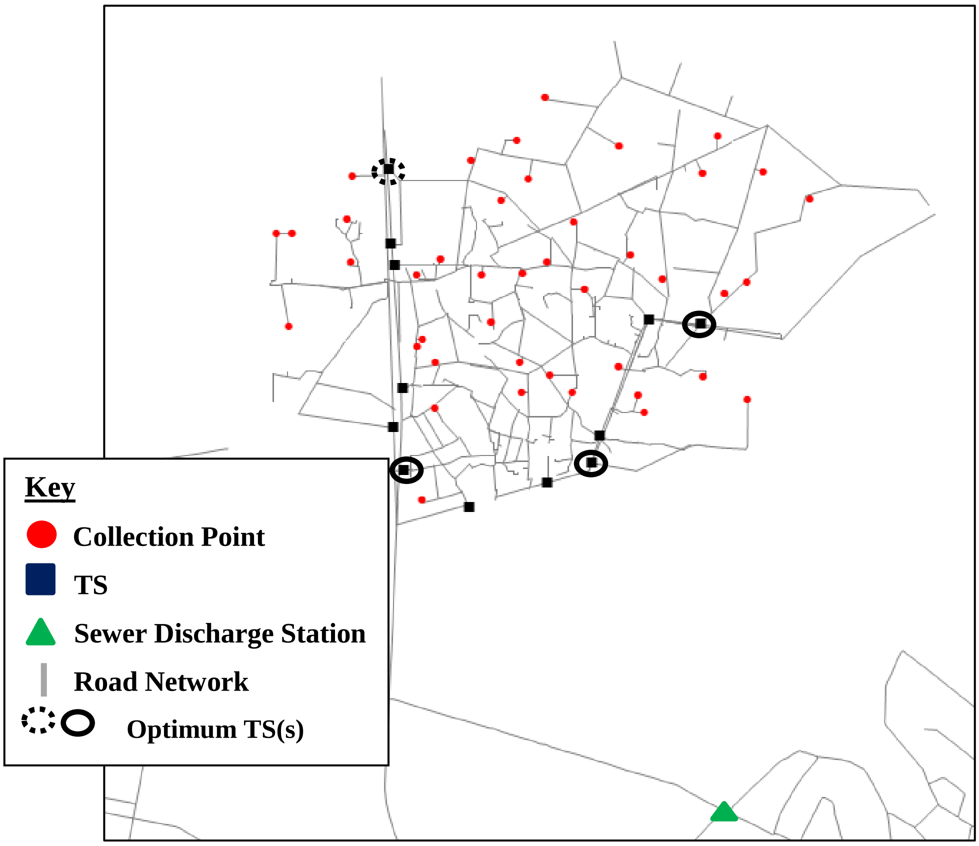


Figure 7-18: Network layout for Chazanga (scenario 3)

Figure 7-19 shows the AIC per m^3 of sludge collected (bar chart) for each fixed infrastructure scenario and variation (primary transportation variation) and the primary transportation fleet requirements (both manual cart and Vacutugs) at year zero (line graph) for Chazanga. Similar to Kanyama, the results show that the AIC/m^3 was less for those options which used motorised equipment compared with manual (difference ranges from 26% to 46%). The network with the lowest cost overall for Chazanga was 1B. The fleet requirements for Chazanga were also shown to be lower than observed for Kanyama and again those variations which used manual equipment had higher fleet requirements than those utilising motorised equipment.

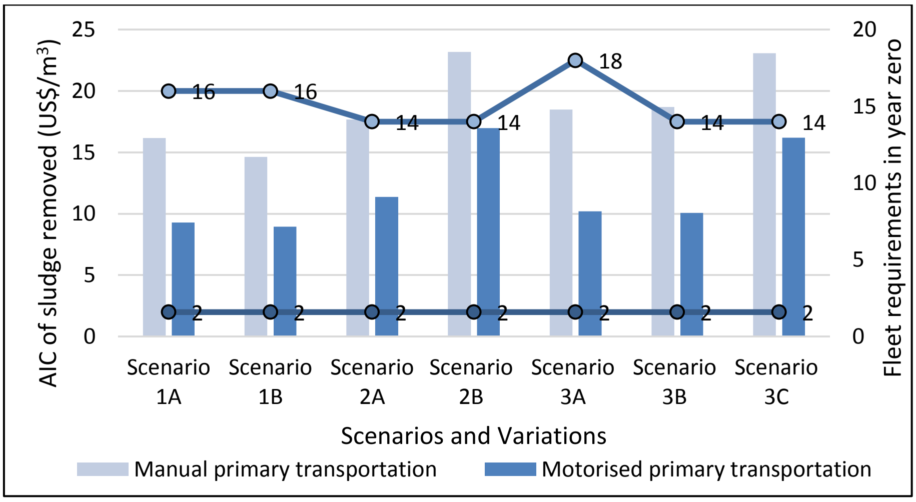


Figure 7-19: AIC and fleet requirements for each scenario and variations in Chazanga

Figure 7-20 highlights that for scenario 1, where manual transportation equipment was used, the majority of costs were associated with primary transportation. Whereas, where motorised equipment was used the community based treatment facility made up the highest proportion of the cost. Figure 7-21 highlights that in the motorised equipment cases the majority of costs were associated with capital and operation and maintenance whilst for the manual options labour had the largest percentage of cost associated.

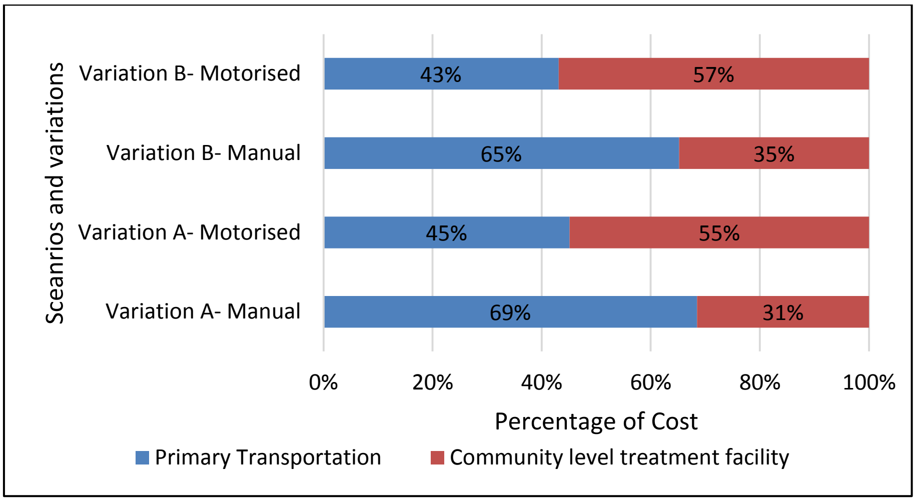


Figure 7-20: Costs associated with components of the network for scenario 1, Chazanga

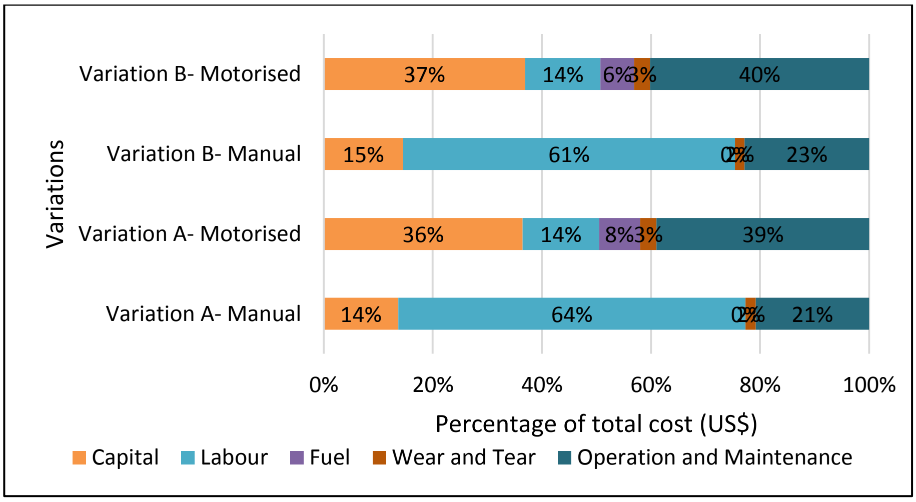


Figure 7-21: Cost breakdown for total AIC cost (per m^3) for scenario 1, Chazanga

For scenario 2, the results show that the use of multiple TSs (2B) increased the overall cost of the network compared with use of a single TS (2A) despite a 30% reduction in transport distance (increase cost by 24% for manual and 33% for motorised). Similar to Kanyama and scenario 1, for those options that used manual equipment the majority of the costs were associated with the primary transportation requirements (Figure 7-22). Whereas for variation B, a much higher proportion related to TS costs. Labour was again shown to make up a high proportion of the cost in the manual cases and discharge costs, capital and operation and maintenance costs for those options that used motorised equipment (Figure 7-23).

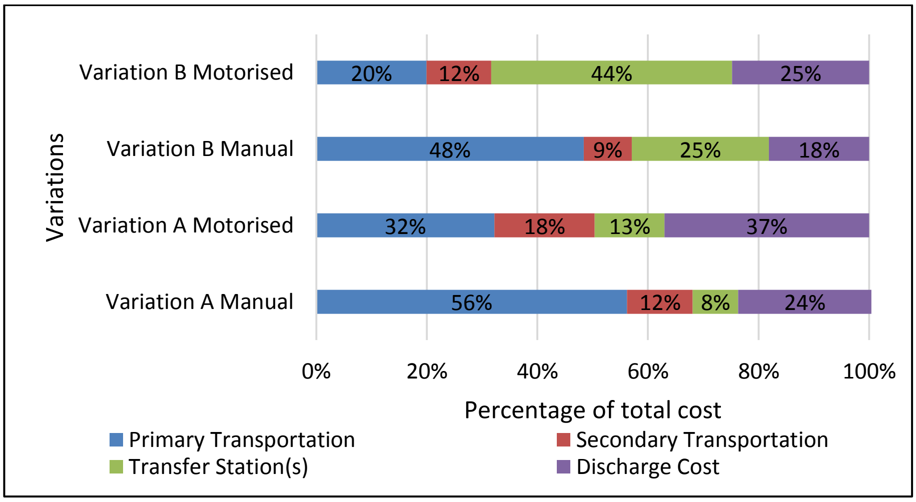


Figure 7-22: Costs associated with components of the network for scenario 2, Chazanga

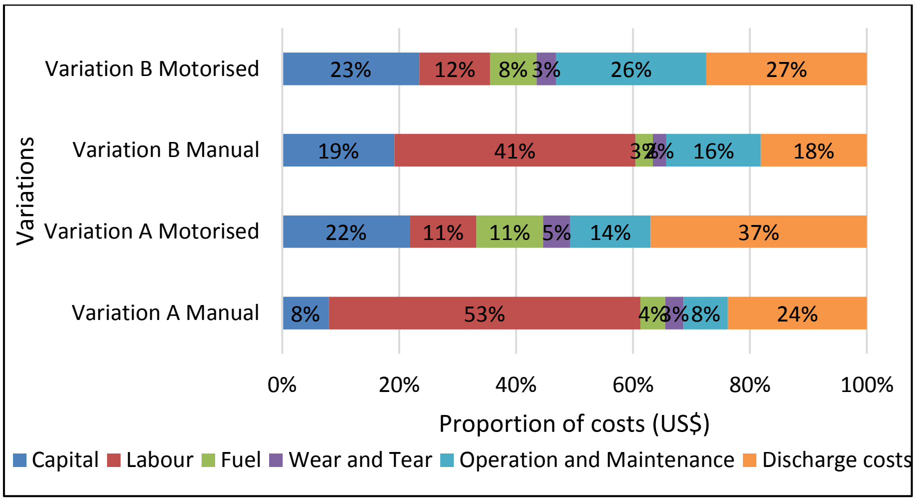


Figure 7-23: Cost breakdown for total AIC cost (per m^3) for scenario 2, Chazanga

Figure 7-19 indicates that there was very little cost difference observed between variation A and variation B for both manual and motorised options (manual: 1% increase, motorised: 1% decrease based on AIC/m^3). For variation C, where multiple TSs were used the network cost was higher than where a single TS was used (manual: 19% increase, motorised: 41% increase), again despite a 32% reduction in transportation distance. Similarly, the highest proportion of cost was related to the primary transportation in those options which utilised manual equipment, whereas for motorised options, the highest cost proportions differed between primary transportation, discharge costs and TSs (Figure 7-24). Labour made up the highest proportion of cost for the manual options and discharge, capital and operation and maintenance costs made up the highest proportions for the motorised options (Figure 7-25).

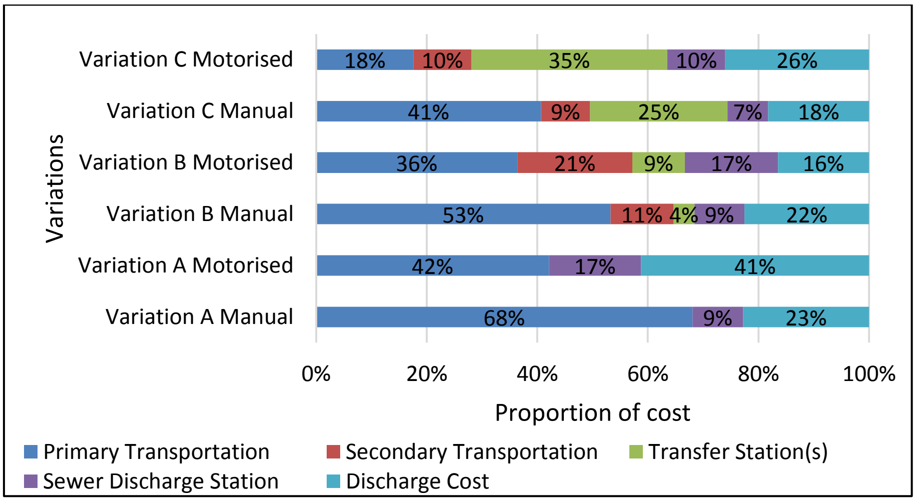


Figure 7-24: Costs associated with network components for scenario 3, Chazanga

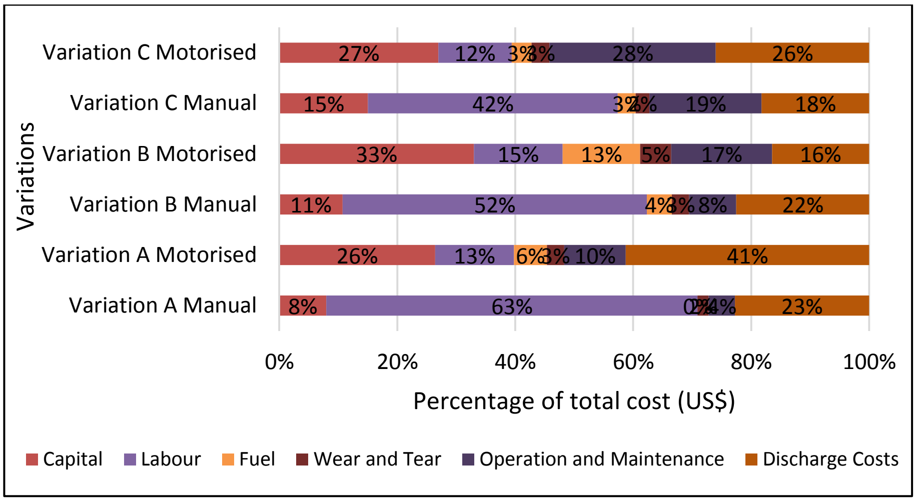


Figure 7-25: Cost breakdown for total AIC cost (per m^3) for scenario 3, Chazanga

Section 7.6.2 and 7.6.2 presented the results achieved for the various fixed infrastructure and transportation scenarios modelled within Kanyama and Chazanga respectively. The results will be discussed in more detail in section 7.7.

7.6.4 Results for containment and emptying frequency optimisation

The results discussed in the following section relate to the optimisation of the containment facility for scenario 3A for Kanyama and scenario 1B for Chazanga (the scenarios with the lowest associated costs- see section 7.3.2). The results achieved for both of the sludge generation rates modelled (60 litres and 550 litres) can be seen in Figure 7-26 and 7-28 below. The bar chart relates to AIC cost per m^{3}of sludge removed and the line graph to the household charge per year required for the project to break even (NPV=0). A full set of results are available in the Appendix G.

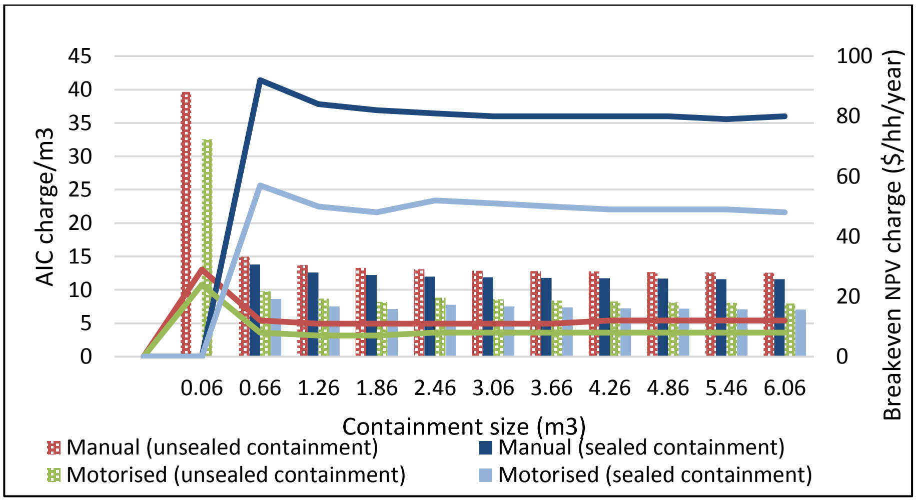


Figure 7-26: Household charge and AIC per m^3 related to varying containment volume for Kanyama (scenario 3A)

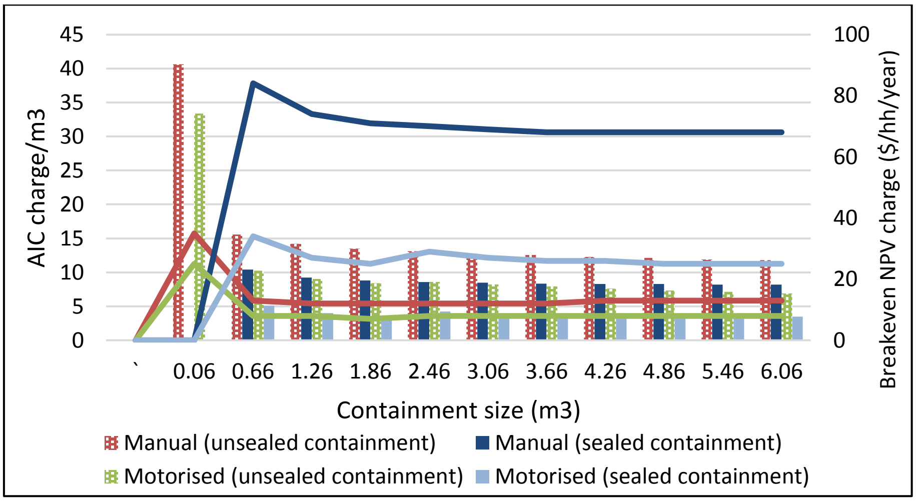


Figure 7-27: Household charge and AIC per m³ related to varying containment volume for Chazanga (scenario 1B)

The results show where manual primary transportation equipment was used the scenarios were more expensive than those where motorised equipment was used, based on AIC per m^3 of sludge removed and breakeven household charge, for all of the optimisation scenarios tested. The results indicate that the FSM system costs the most when the smallest size of container was utilised ($0.06m^3$). In this case a much higher emptying frequency was required and therefore more equipment (fleet) and a larger workforce was shown to be needed. In the highest sludge generation rate cases (550 litres/capita/day noted as sealed containment) and were the smallest containment facility was used ($0.06m^3$), the results were shown to be invalid when using manual transportation equipment because the emptying frequency required was unrealistic.

Overall, the breakeven household charge for unsealed containment systems was shown to be less than the sealed ones. This was to be expected as the sludge generation rate was lower and thus the required emptying frequency was lower causing the associated fleet requirements to also be less. In the case of the sealed containment, the results showed that for year zero over 80 manual carts were needed to achieve the required emptying frequency in Kanyama with this value increasing yearly. For the motorised options a fleet requirements of around 20 Vacutugs was recorded for the same scenario (3A).

The option with the lowest AIC per m^3 of sludge removed was shown to be those that used motorised equipment and a sealed containment facility. For both Kanyama and Chazanga the results indicated that the AIC/m^3 of sludge removed reduced as the size of the container increased which was to be expected as the larger the containment facility the more sludge which required collection per year. The results indicate that the costs overall were less for Chazanga compared with Kanyama (because of lower population).

Table 7-14 highlights that in each community and for each containment design (sealed or unsealed) there was containment volumes which provided the cheapest household charge (NPV=0). The results show that in the case of the fully sealed system (with higher FS accumulation rates) the optimum containment volume required was higher than in the unsealed systems.

Table 7-14: Containment volume which provide cheapest household charge to breakeven

	Filling frequency (m^3/year/capita)	Optimum containment volume (m^3)	
		Kanyama	**Chazanga**
Manual option	0.06 (Unsealed)	1.26-3.66	1.26-3.66
	0.55 (Fully sealed)	5.46	3.66-6.06
Motorised option	0.06 (Unsealed)	1.26 or 1.86	1.86
	0.55 (Fully sealed)	1.86 or 6.06	1.86 or 4.86-6.06

7.7 Discussion

In this section the main findings of the study will be considered and the potential contribution they can make to optimising FSM network planning and implementation in the future.

7.7.1 Primary transportation equipment

Overall the results showed that the options using motorised equipment for primary transportation (and emptying- Vacutugs) were cheaper than those utilising manual equipment. The majority of costs associated with motorised options related to capital costs and discharging to sewer or WwTP. Whilst capital outlay for manual options were smaller, the fleet requirements were much higher.

The motorised options were shown to have higher capital costs when compared with manual ones despite a smaller fleet being required. Vacutugs are not manufactured in Zambia and therefore shipping costs increase the associated capital costs. The cost of using Vacutugs could potentially be highly variable because their cost can be influenced by external factors, such as the availability of new equipment and replacement parts from overseas and the availability of locally trained mechanics to keep the fleet operable. Fuel prices associated with motorised options are also variable and could potentially affect the cost of these options in the future. Despite this high capital cost motorised options where shown to be cheaper overall compared with manual ones.

The manual options required a larger workforce and therefore a large proportion of the associated costs related to labour. More operators and a larger fleet were required in the manual cases to achieve the same emptying capacity as the motorised option. Labour costs are variable as the minimum wage could increase in the future (due to inflation or change in law). Having a larger fleet could also bring further complications as specialist resources may be required related to the logistics, management and storage of equipment.

For those scenarios that incorporated both primary transportation equipment (either manual or motorised) and secondary transportation equipment (vacuum tanker) the majority of the cost was shown to be associated with the primary transportation system. This infers that if cost saving or optimisation were required the focus should be on reducing costs associated with the primary transportation components (i.e. distance travelled, efficiency of emptying, capital cost of equipment, labour and fuel efficiency).

The costs associated with primary transportation are related to the equipment's operational capacities which in turn impacts the size of the fleet required to achieve the emptying frequency needed for each community. Overall, each Vacutug had more volumetric capacity than the manual cart (2000 litres compared with 330 litres * 2 carts for each team). Both options were given identical transport speeds of 2.5 km per hour, though in reality the speed of the motorised transportation option may be quicker or have the potential to become quicker if road and pathway infrastructure was improved. In this model the Vacutug was also more efficient in terms of filling rate (5 minutes) compared with the manual option (30 minutes).

This model was based on an optimised situation where it was assumed that MSW has minimal effect on the emptying process. In the case of Vacutugs, the time required for filling would be greatly increased if MSW had to be removed from the containment facility prior to pumping out and depending on the amount of MSW this may cause the use of this technology to be unfeasible. Whereas, in the case of manual emptying, the process of separating the MSW can occur simultaneously. If no MSW was present in the containment facility, the operators could utilise equipment such as a gulper which would accelerate the process. The dryness of the sludge would also affect the emptying process and what would be technically possible in these communities. In the case of the existing FSM service in Kanyama the presence of MSW and the dryness of the sludge meant manual pit emptying was the optimum solution for this informal settlement.

A final consideration between manual and motorised emptying options relates to the health and safety risk associated with each. The manual option poses health and safety risks to the operators themselves due to their direct contact with FS, however with proper personal protective equipment and training this risk could be significantly reduced. This risk is less prominent in the motorised options as less direct handling of FS occurs. The emptying practice used by manual emptiers to gain access to the FS also carries a risk as the facility can collapse due to its structural integrity being compromised (discussed in section 4.4.2). Such an event would carry environmental risk in addition to the risk to individuals operating the facility. As discussed in section 7.2 manual removal options may not be in line with JMP WASH post 2015 indicators and therefore may not be promoted by the sector.

7.7.2 Fixed infrastructure scenarios

The long term costs associated with three fixed infrastructure scenarios to improve FSM in informal settlements of Lusaka were determined. The results show that overall the scenario with the lowest costs associated for Kanyama was **scenario 3A** which transports FS directly from collection points to the SDS using primary transportation equipment. This result was to be expected as this scenario utilised no secondary transportation system, had some of the shortest transport distances required and used fixed infrastructure with the least cost associated (i.e. no TSs). The scenario with the highest cost associated was 1A which transports FS from the collection points directly to a community level treatment plant at the southern tip of the community. The high cost was because this scenario had the highest transportation distance requirements using only primary transportation equipment. For Chazanga, **Scenario 1B** which transports directly to community level treatment facility using primary transportation equipment had the lowest cost overall because it had the shortest transportation distance requirement, only utilised primary transportation equipment and did not utilise TSs or incorporate sewer charges.

For those scenarios which utilised TSs (scenario 2 A&B and 3 B&C) the results showed that the costs were higher when multiple TSs were utilised rather than a single TS. Despite an overall reduction in the transportation distance being achieved when multiple TSs were used the associated cost saving did not outweigh the cost incurred (capital and operation and maintenance costs) by using more TSs. The results also indicated that scenarios that used TSs may not actually be the lowest cost overall. Therefore, modelling FSM networks which both utilise TSs and those that do not and understanding the merits of both (relates to cost, fleet requirements, distance requirements and associated wear and tear) is an important distinction to make at the planning stage.

The results show that for each of the scenarios that utilised TSs, the average distance between the collection point and TS was between 1.4 and 1.7 km. For those scenarios that did not use TSs the distance transported using primary transportation equipment was much higher (Kanyama: 1.8-5.13 km range and Chazanga 1.69-2.3 km range). One study highlighted that fixed TSs (or end points) should be located a maximum of 0.5 km to 1 km (walking distance) from the latrine (Muller and Rijinsburger, 1992). None of the networks discussed in this study achieved this but there was limited evidence available to support a maximum transportation limit of 1km. Further analysis would be required to confirm this.

7.7.3 Affordability and profitability

Determining the affordability of sanitation options and that the cost of the service is recovered, is important to ensure its sustainability as discussed in Chapter 1. Hutton (2012) reported that thresholds for the affordability of WSS vary considerably ranging between 2 and 6% of overall household income. In this study the African Development Bank's affordability threshold for WSS of 5% of a household's overall income per year was used (Smets, 2012). It was assumed that 0.5% of the household's overall income could be allocated to spending on sanitation services (the same assumption used by Von Münch and Mayumbelo (2007)). The average monthly household income was shown to be US$289/ month (1800 ZMW) in Kanyama and US$ 320/month (2000 ZMW) in Chazanga (based on a conversion rate of 1 ZMW to US $ 0.1602 (XE, 2014)) based on household questionnaires conducted and secondary data sources (Chapter 5) (DTF, 2013)). Therefore, the estimated amount which households could afford to pay for sanitation services was US$1.45 and US$1.60/month/household for Kanyama and Chazanga respectively. Figure 7-28 and 7-30 highlight which scenarios were deemed affordable in each community (based on the monthly household charge required for each scenario to break even).

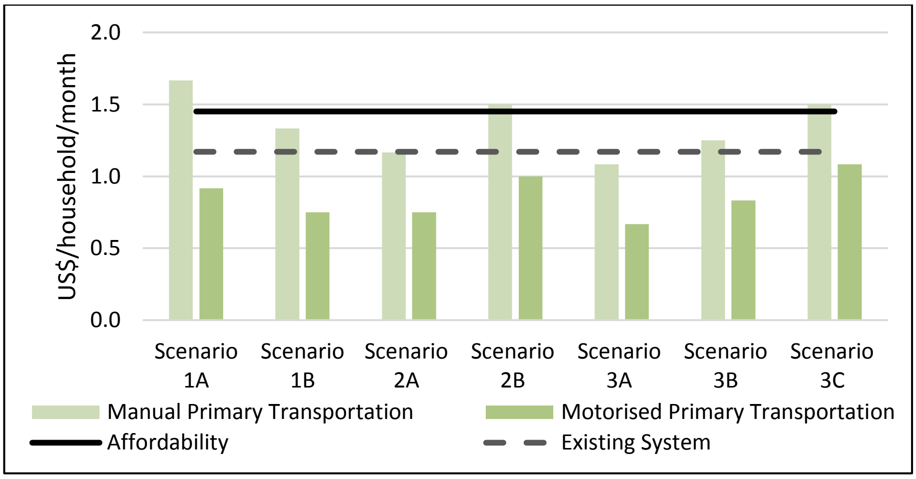


Figure 7-28: Affordability of scenarios and variations in Kanyama

For Kanyama, the majority of options modelled are deemed affordable (only scenario 1A, 2B and 3C using manual primary transportation are not). Figure 7-29 shows that for Chazanga the majority of options were deemed affordable (only scenario 2B and 3C utilising manual primary transportation were not).

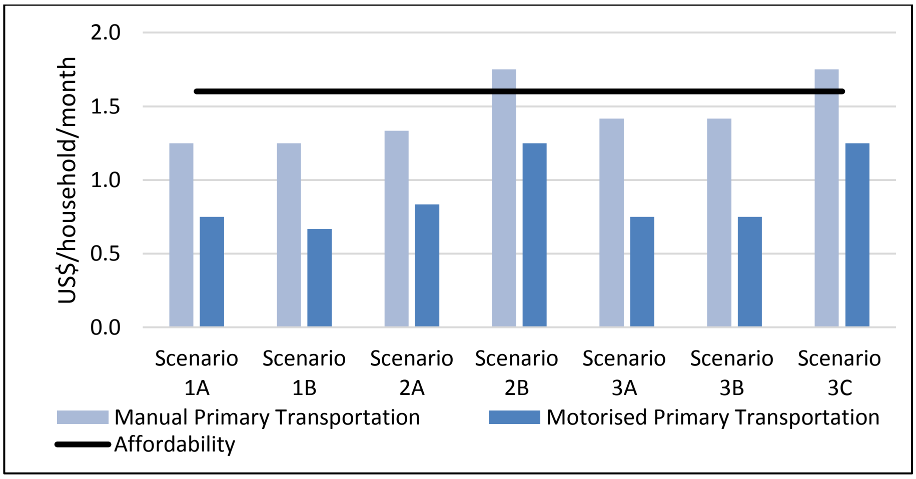


Figure 7-29: Affordability of various scenarios in Chazanga

For both communities the most affordable options were motorised, however a number of the manual options were also deemed affordable. These results indicate that FSM may be affordable for informal settlements in Lusaka. In these settlements manual emptying and primary transportation may be easier to implement as the equipment is locally produced and the methods used are the most similar to those already utilised by informal emptiers. Based on the existing situation in these informal settlements it may make sense to implement a FSM service using manual equipment first and then make incremental improvements to the service so that a transition to motorised technology can take place over time. This may especially be the case if MSW is present in the containment facilities and behavior change campaigns are required to reduce this. However, this would require further detailed analysis and consideration of which technologies are deemed to provide safe management of FS by government or external indicators (i.e. JMP WASH post 2015).

Despite a number of the scenarios being deemed affordable, individual household capacity and ability to pay in reality could affect the success of such service provision. One aspect that requires consideration is the method of payment. People in these settlements are predominantly employed in the informal sector which is characterised by a lack of job security and irregular wages (section 5.4.4) thus there is no guarantee that residents would be able to make regular monthly payment for sanitation services. This is an important issue that would require further examination if such service provision was to be implemented.

It is useful to compare the household charges outlined in this study to those already being charged by the FSM service in Kanyama. In Kanyama, there are three emptying options currently available:

- Small- 12 drums (660 litres) costing ZMW 250 or US$ 47.20
- Medium-24 drums (1320 litres) costing ZMW 380 or US$ 71.70
- Large- 32 drums (1760 litres) ZMK 450 or US$ 84.90

(Mikhael, 2014)

The amount of FS that requires removal by the existing FSM service is estimated based on the accumulation rate of the whole population rather than on the emptying frequency requirements of each latrine. The population serviced is based on the capacity of the treatment facility rather than providing access to the whole population. The service is therefore not governed by the emptying frequency but instead by the volume generated by the targeted population or treatment facility capacity. Approaching the modelling of FSM systems in such a way removes some of the complexity discussed around requiring detailed information on the status of the containment facility which can be complex in informal settlements. However, running the service in this way could make it more difficult to forecast the daily or annual emptying service requirements, which may in turn affect the equipment requirements, promote the delivery of an adhoc emptying service and mean that households can only realistically be charged using a one off service delivery charge (rather than a weekly or monthly charge).

If it assumed that each containment facility (shared by three households) needs to be emptied using the large emptying option every 2 years (based on the frequency requirement calculated for Kanyama in year 0- Figure 7-5) the associated household charge per month for the Kanyama service would equate to US$1.17 per household per month (see Figure 7-28). Based on these calculations Figure 7-28 shows that a number of the scenarios modelled may be cheaper than the existing FSM service in Kanyama. However, further practical application of the modelled scenarios would be needed to verify this. The modelled scenario based on the current situation in Kanyama (scenario 1A) had a higher household charge per month (US$S1.67) than the existing system. This may because the existing service does not provide emptying for the whole population of Kanyama unlike this model.

For a number of the scenarios modelled here there would be potential to make a profit from the scheme if households were charged what was deemed affordable in each community (those that fall under the threshold line). However, the potential profits would be quite small over the 25 year design life. This costing methodology and the results highlight that road based FSM services for informal settlements in Lusaka could be profitable which is consistent with other studies (Chowdry and Kone, 2012).

7.7.4 Containment optimisation

The results achieved indicate that implementing a fully sealed containment system was more expensive than unsealed which allows liquid effluent to permeate into the surrounding ground thus causing a lower sludge generation rate (shown by household charge required for NPV to equal zero). This was caused by the high emptying frequency associated with sealed systems compared to unsealed systems. As the volume of the containment facility grew the emptying frequency reduced, however the emptying equipment requirements and resultant cost did not vary much as the larger containment facilities have a higher volume of FS load to empty per emptying procedure. The model assumed that the containment facility would be emptied once full. Further analysis is needed to establish if emptying the containment facility at varying fixed intervals (not just when full) can reduce the cost of the service further. It should be highlighted that external factors such as customer preference may affect the frequency of emptying.

The results indicated that in all cases the motorised options were cheaper than the manual ones because of the higher fleet requirements. The results for the manual options based on sealed containment facilities showed a fleet requirement (manual carts) of approximately 100 and above (for year zero). Therefore, use of sealed containment using manual primary transportation equipment would not be deemed appropriate for both communities due to the unrealistically high fleet requirement.

The cheapest option overall in terms of breakeven household charge was shown to be an unsealed containment facility using motorised transportation equipment. The results indicated that there was a small difference between the cost of using manual and motorised equipment (for unsealed containment).

For both options the model revealed that there was an optimum volume of container which enabled the lowest household charge to be achieved. For the manual transportation scenarios that utilised a fully sealed containment facility, a much higher optimum volume range was reported than for unsealed facilities. This was to be expected due to the higher accumulation rate. In the motorised cases, the optimum volume of containment was similar for both sealed and unsealed.

Some of the results showed that the largest containment volumes modelled, were optimum in terms of cost. However, the reality of building a tank with such a large volume and the emptying logistics associated (number of trips to empty because of the volume capacity of the emptying equipment) may mean solutions with containment facilities of smaller volumes are more suitable. Implementing a sealed system may also make motorised options more viable as it would cause the water content of the FS to be higher making it easier to pump and empty.

In terms of affordability the results show that in Kanyama and Chazanga based on a break even household charge of US$ 1.45 and US$1.60 per month respectively, the majority of the unsealed containment scenarios (both manual and motorised) were deemed affordable. Only the smallest containment volume ($0.06m^3$) was not deemed affordable which was to be expected due to its particularly high emptying frequency compared with the other volumes. None of the scenarios modelled for sealed containment were deemed affordable.

Despite higher cost being incurred, in some cases a higher emptying frequency or the need for a fully contained system may be justified on the grounds of resource recovery. When FS is held within the containment facility, natural degradation (through both aerobic and anaerobic processes) occurs. This degradation naturally reduces the volume of the FS (in anaerobic conditions biomass is reduced). However, the nutritional content and methane producing potential of the FS is also reduced (Still and Foxon, 2012). It is interesting to note that a recent study highlighted that the calorific value of FS was not affected by its age thus the energy potential is not compromised by less frequent retrieval (Muspratt *et al.*, 2014). Where resource recovery is a key focus of the SVC, collecting the FS more regularly so that it is fresher (and therefore less degraded) may be key to a system. Due to the fact that a large fraction of nutrients available in FS comes from urine it may be more applicable to use a sealed system (or urine diverting one) so that all the urine can be captured by the containment facility and does not leach away (Kenge *et al.*, 2014). Also in areas were environmental conditions mean that there is a high public health risk by allowing the liquid fraction of the waste to leach into the ground then a sealed containment system may be one of the only technical solutions available.

These results indicate that the design of the containment technology can affect the overall cost of an FSM system. It has been shown how modelling can be used to establish the optimum design of containment facilities to minimise overall household charge. The importance of the containment element of the SVC has been highlighted and the impact it can have financially and logistically on the rest of the FSM network. In the case of informal settlements in Lusaka, the analysis reinforced the imperative need to improve the containment facilities in use and to encourage their replacement, so that the safe containment of FS and optimisation of the facility can be achieved.

7.7.5 Cost analysis methodology

A cost analysis based on results obtained in this study using the scenario based methodology will be compared with existing cost models.

The results of the breakeven household charges and value for AIC showed that those options that utilise manual internal transportation system were between 27-49% more expensive than the motorised options. In one real life case study in Dhaka it was reported that using Vacutugs was approximately three times more expensive for a user than using manual emptying (Opel and Bashar, 2013). However, only 1% of the overall service coverage used Vacutugs and therefore the cost of such service was divided among a small proportion of the population compared with 100% of the population used in this study. The results of this study may indicate that economies of scale (i.e. service coverage to the highest number of households possible) ensures the lowest service cost.

There are few studies that provide an indication of the real world costs of implementing manual or motorised FSM services. In particular, for manual pit emptying there was limited data to compare the values achieved from this study, most likely due to manual emptying often being an informal practice. Opel and Bashar (2013) indicated that in Dhaka, Bangladesh it costs households US$17.26 to have their pit latrines emptied using Vacutugs. Whilst in Dar es Salaam, Tanzania it was quoted as costing between US $12-20 to empty each full latrine using a Vacutug (Smet, 2007). However, it should be noted that both services were subsidised. The results from this study indicate (based on a two year emptying frequency) that it would cost households $16-26 and $16-30 to have their pit latrine emptied in Kanyama and Chazanga respectively.

It is difficult to compare these costs directly with ones achieved in this study because there are differences in how the analyses were completed. Costs are heavily dependent on location and the date of the analysis as this will affect the input parameters (von Münch, 2008). This study was based on 2014 prices from Lusaka whereas the referenced studies are all from different times and locations. Another possible reason for differences in costs was that this analysis includes costs associated with the required fixed infrastructure and secondary transportation. Often existing FSM costing methodologies do not determine the full cost recovery of the service and secondary collection therefore the charges determined are likely to be higher for this analysis. Finally, the use of a formal minimal wage within this study may be another reason why the overall cost was higher in comparison to other studies which may have used lower informal wages which are usually earned by pit emptiers.

There are a number of examples in literature of road based FSM projects not achieving full cost recovery (Parkinson and Quader, 2008; Yousuf and Mahmud, 2011). Both of these studies highlighted that the income received covered the O&M costs but were not enough to repay the capital investments made. One reason for this may be due to the emphasis being on initial associated costs only and not the long term costs which could make such schemes unlikely to achieve full cost recovery. In contrast, the cost analysis methodology developed in this chapter focused on ensuring that long term cost recovery requirements over a 25 year design period were identified. Achieving full cost recovery for any WSS project is vital for success and in Zambia it forms one of the seven WSS sector principles adopted by the Government of Zambia (GRZ, 1994). This methodology also allows for a breakdown of associated costs to be produced which could be useful in identifying where costs can be cut. Finally, the methodology presents a high level of detail and includes consideration of factors such as population growth and inflation, allowing the creation of more accurate costing forecasts. Therefore, the cost analysis methodology that has been developed in this study could be considerably more accurate as it is more comprehensive in its approach.

7.7.6 Non-technical factors

Within this section there will be some consideration of the non-technical factors which may influence decisions over which scenarios or variations are the most applicable for each location. In the majority of the scenarios modelled, some form of fixed infrastructure was required to be built within the community itself. For example, in the case of scenario 1, land would need to be allocated or purchased so that the community level treatment facility could be built. Due to the nature of informal settlements and in some cases because of their illegal status, the acquiring of land can be difficult and is often done in a non-formalised or illegal ways (Rakodi and Leduka, 2006; UN Habitat, 2008). This could cause problems or limitations for any of the scenarios which require fixed infrastructure to be built within such communities.

Both the manual and motorised transportation options have fleet equipment (manual larger than motorised) which would require management and possibly storage. In terms of storage, space may be required for the equipment, meaning more land and secure spaces may be needed. Specialist skills may also be required to manage such a transportation fleet: e.g. skills in logistics, operation and maintenance and specialist mechanics skills which may not be currently available within these communities.

In the case of scenario 1 the treatment facility was located within the community itself. If the community themselves or an existing organisation located within the community was to operate and manage the system then it would need to be ensured that they had the required technical, financial and managerial capacity, support and power to do so successfully. If an external agency was to operate the system then problems of ownership, trust and political pressures (discussed in Chapter 5) would need to be overcome so that such a technology could be successfully implemented and managed.

In scenario 2 and 3 it was assumed that the secondary transportation component (vacuum tanker) would be managed by an external organisation, possibly one currently operating in Lusaka. The success of any of these FSM scenarios depends on ensuring each component is functioning correctly, including: the scheduling of emptying; volume of emptying; and location of dumping. Lessons can be learnt from previously implemented MSW systems in informal settlements of Lusaka which predominantly failed because of the nonfunctioning secondary waste collection (from community skip to landfill) which was managed by LCC (see Chapter 5). During KIIs, the main reason given for the failure of the SWM collection was financial issues. CBOs set up to provide the primary collection had limited financial capacity or support to undertake this role and secondary waste collectors were not paid to collect MSW from the communities.

Consideration for the most suitable way to recoup payments from households would also be needed. A sanitation levy fee is included in LWSC customer's water tariff (Chapter 4) which for tenants is included in monthly rent. For the Kanyama emptying service a one off payment is made at the time the emptying service is provided. Both types of charging have varying positives and negatives. Charging customers a service fee means that they need to have access to a large sum of money every time they require their containment facility to be emptied. However, possible complications caused by determining mechanisms to charge households on a regular basis and the issue of mispayments are reduced in this option. Alternatively, if households are charged more frequently the cost to the customer is spread out over a longer period and can be collected along with other monthly service fees that currently exist (i.e. rent, electricity and water) which for some customers may be more suitable.

It was observed that currently household behavior and cultural beliefs result in MSW being present within pit latrines. For an optimised FSM system to exist the impacts of cultural beliefs needs to be better understood and a focus on behavior change would be required to stop MSW from entering the pit. The design requirements for a functioning SWM system would need addressing alongside the development of any FSM service delivery. In particular, the existing practice of using the pit latrines for menstrual hygiene management would need addressing to achieve a reduction in MSW presence within the pit latrines.

One final component that would be vital to ensure the success of such systems is the buy-in and support of high level institutions and actors as well as more grassroots level stakeholders (WTs, CBOs, households) (discussed in Chapter 5 and 6). An enabling environment needs to be created which supports the development and implementation of FSM services in informal settlements.

7.8 Limitations

There are several limitations within this study concerning the input parameters, data availability, processing and the cost analysis methods which are discussed in the following section. It should be noted that this cost analysis is based on two specific informal settlements in Lusaka and therefore the numerical results have limited applicability to other locations globally.

7.8.1 Input parameters

The input parameters used in this study are open to errors as the majority of them were determined through secondary reporting rather than direct primary observations or measurements. To establish such data, a large scale longitudinal study would have had to have been completed, however the capital and manpower to do so were not available as part of this study. However, where possible the parameters were gathered from reliable sources and verified through triangulation with other literature or through direct observation during field visits to Lusaka. In relation to the pit latrine volume and accumulation rate, scarce data availability resulted in a fixed estimate being used. The parameters related to speed of the transportation equipment (manual cart, Vacutug and vacuum tanker) and fuel requirements are also variable. They are dependent on road conditions, traffic, accessibility of the pit latrines, capacity of equipment and topography of the road network. These factors have not been considered in detail in this study. Future practical application of this model, primary data collection of factors affecting accumulation rate, the transportation system and the fixed infrastructure costs would need to be collected in the field.

The dumping fees which forms part of scenario 2 and 3 could also be variable and changes to this fee may have implications to costings. From discussions had with representatives from LWSC and NGOs it was not clear whether the current fees cover the true cost of treatment of the sludge or whether this fee is subsidised and therefore further discussion and investigation around this issue would be required.

The input parameters may also have been affected by the rebasing of the Zambian currency which occurred during the period of this study (2012). This meant that some of the reports referenced had figures based on the old currency and some on the new. To try and overcome this a standard conversion rate to US dollars was used throughout the study for both currencies.

Poor data availability, especially related to the existing road network within informal settlements, was also a limitation. Network scenario optimisations were based on geospatial networks which were built from the available road network data. Although some data was available, a large quantity of the network had to be built manually which may introduce human errors (i.e. roads missing or networks not being connected together). Due to time and manpower constraints there were issues with the development of the spatio-topological models for both communities. In a few instances roads were not present or nodes and edges were not connected properly causing the model to run into error in some instances. In this model all pathways were given equal weight with no preference given to specific pathways. In reality, there would be primary and secondary routes used within these communities. Identifying these would improve the accuracy of the model as they would provide a more realistic overview of the transportation flow. In terms of the data requirements, the best solution would be for detailed primary mapping and transportation data to be collected from the required areas (whether formally or using methods such as crowd source mapping (Map Kibera Project, 2010) so that accurate data of the road network was available to be used for the network optimisation exercise.

The modelling did not consider the maximum or optimum transport distance for the primary transportation technologies. Literature indicates that manual and motorised transportation options should not travel more than 1 km (see section 7.6.2). This should be considered further to enable a maximum transportation distance to be identified for future models. This study only focused on two primary emptying/transportation technologies and in reality it would be beneficial to investigate alternative technologies to ensure the most appropriate (both technical, economically and non-technically) was implemented. It would also be beneficial to develop long term costings for other types of sanitation technology systems (i.e. beyond road based FSM) so that a direct comparison between various technological solutions could be made.

There are several components which were not included in this study which would affect the cost of the project and the ease of its implementation. These are;

- Purchasing any land required (i.e. for TSs, SDS, storage of fleet and the community level treatment facility)
- Cost to alter or rebuild containment facility
- Cost associated with management (i.e. higher wages, overheads or office)

- The depreciation values for any of the fixed assets (equipment) modelled (i.e. emptying equipment, buildings and pumps)
- The costs associated with the final component of disposal or reuse of FS

The presence and effect of MSW was also a component which would require further analysis. Due to limited data availability about the amount of MSW present in the containment facilities and the effect this material has on the emptying process (time in particular) the impact of MSW on the various models being studied was not taken into consideration.

Inaccuracies in the input parameters would lead to mistakes in the overall results. A simple sensitivity analysis (when input parameters changed by + or - 20%) for scenario 3A for Kanyama and 1B for Chazanga is presented to give an insight into which input parameters were the most critical to ensure accuracy of the overall cost analysis (Figure 7-30 and 7-31).

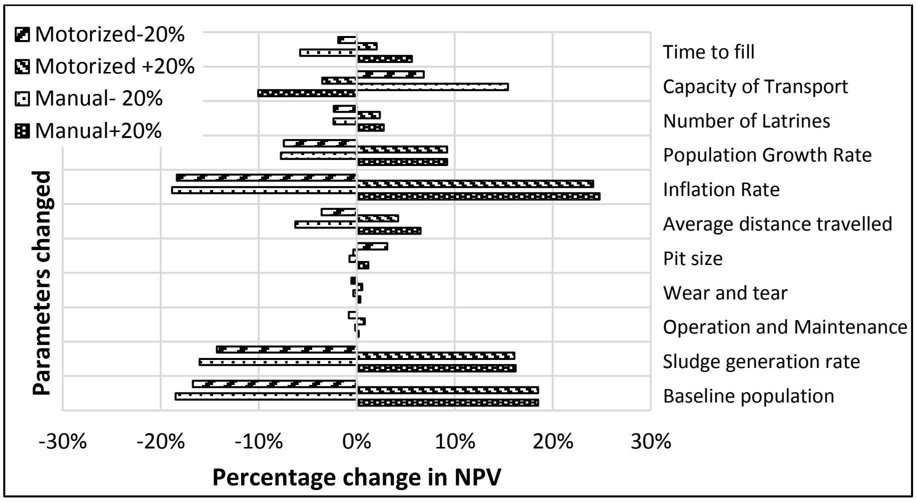


Figure 7-30: Sensitivity analysis of percentage change in overall NPV for Kanyama scenario 3A

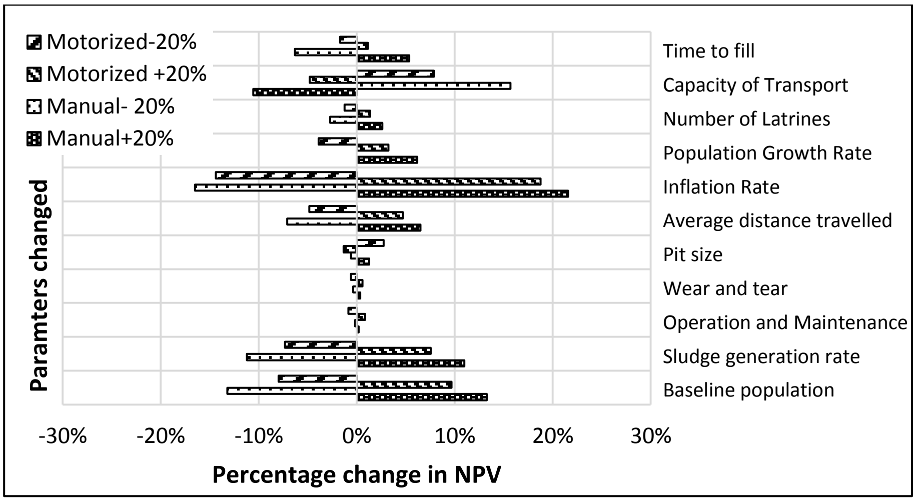


Figure 7-31: Sensitivity analysis to show percentage change in overall NPV for Chazanga scenario 1B

The results indicate that the input parameters for baseline population, sludge generation, inflation rate and capacity (volume) of transport are the most important which if inaccurate would distort the overall cost results significantly (compared with others). Average distance travelled, population growth rate, the number of latrines and the time it takes to fill the transportation equipment were shown to have a marginal effect on the overall cost of the scenarios. The remaining input parameters of pit size, wear and tear costs and operation and maintenance costs were shown to have the smallest effects on the overall cost.

The sensitivity analysis and its results provide a useful indication to which of the systems components should be focused on to help reduce the overall cost. This is a helpful distinction to make in resource scare situations, like those observed in Lusaka and can help planners decide where to investment time and resources to achieve the largest return. For example, which components should data be accurately collected for and which components should be optimally designed.

7.8.2 Cost analysis methodology

There are some limitations with the methods used themselves as NPV and AIC provide very crude and simplistic methods of conducting long term financial analysis. Both methods fail to account for important financial aspects (uncertainties) such as rising fuel prices, government incentives, currency devaluation and the effect of subsidies or tax breaks (von Münch, 2008). Variations in the rate of inflation and population growth were not taken into consideration as a set value was used for the whole 25 years. The sensitivity analysis above shows changes in these inputs would impact greatly on the overall cost of the modelled scenarios. The methodology did not include any contingency for extra costs (i.e. interest fees) which may be incurred if loans were taken out to finance the required initial capital investments. Despite these limitations the cost analysis methodology does provide a useful tool for the planning and costing up of various FSM infrastructure scenarios and allows this technical solution to become a more viable alternative to conventional technologies.

7.8.3 Main assumptions

There are a number of simplifications and assumptions that were made during this cost analysis process. It was firstly assumed that the end points selected for scenario 2 and scenario 3 (sewerage system and Manchinchi WwTP) would be technically feasible. This was based on the assumption that both Manchinchi WwTP and the existing sewerage network would be upgraded and extended in the future, as stated in the sanitation master plan and by members of senior management at LWSC indicated (during KIIs- Chapter 6). In reality, a detailed analysis and trial of the technical feasibility and suitability of these end points would be required. In particular to ensure the end points could cope with the additional volumetric load, that overloading (solids, COD or nitrogen) of the WwTP did not occur and to ensure the discharge of high solid FS via SDS did not cause blockages or problems in the downstream sewerage network.

Another assumption made was that the future population growth would only affect the population density (i.e. number of people per household) and not the physical growth of each settlement. This is unrealistic as population growth would lead to a combination of increasing population density and growth (sprawl), causing an increase in the number of households and subsequently pit latrines. This would cause an increase in the cost of all the scenarios modelled as the primary transportation equipment would need to remove FS from more collection points (thus causing more distance to be transported). However, it was hard to predict accurately how population growth would occur considering the informal nature of these settlements and therefore this assumption was deemed appropriate for this analysis.

The cost analysis also assumed that the whole community in both informal settlements would require access to the FSM service. This assumption seemed reasonable as the residents in both settlements were shown to use onsite containment facilities that would require emptying at some stage and very few of them indicated that they currently use the existing formal emptying services available within the city (Chapter 4 and 5).

7.9 Conclusions and Recommendations

In this chapter long term cost estimations have been produced for various FSM service scenarios which could be implemented in two informal settlements in Lusaka, Zambia. The costings produced were based on three different fixed infrastructure scenarios involving the use of both manual or motorised removal and primary transportation technologies (Vacutug and manual carts). The chapter specifically addresses the need for improved decision support tools to be developed. The main outcomes to this study were; the development of costing methodologies for FSM provision, the successful use of a novel spatio-topological method in network transportation, modelling and resulting identification of optimum FSM networks, identification of factors affecting cost and highlighting the impacts of containment facility design. These are summarised below.

Firstly, the optimisation of the transportation component using the developed spatio-topological methodology was successfully completed for the two selected informal settlements. The optimisation helped to ensure that minimum time transportation networks were selected for analysis, thus, ensuring that the costing analysis was completed for the most efficient transportation networks from the outset. This provides a useful tool in terms of city wide planning as it helps to compare and identify the least cost scenarios (in terms of the transportation component) prior to completing an in-depth cost analysis.

Through employing a variety of fixed infrastructure scenarios, optimum FSM networks for the 2 locations, based on cost, were identified. For Kanyama this was scenario 3A which transported FS from collection points directly to a SDS using primary transportation (Vacutug or manual cart). The most expensive FSM options overall were those that utilised multiple TSs (2B and 3C) and those requiring large average distances to be travelled to a community level treatment facility located near the WT (1A). For Chazanga the lowest costing scenario was 1B which transported FS from collection points to a centrally located community level treatment facility using primary transportation. For Chazanga those scenarios which utilise multiple TSs were the most expensive (2B and 3C). The comparison of the various fixed infrastructure scenarios is also useful for planning as it allows possible options to firstly be identified and then compared against each other in terms of costs. The feasibility of each option can then be further assessed once the financial viability has been exposed.

Results indicate that utilising manual equipment was more expensive than using motorised equipment in all of the scenarios modelled. The reasons for this being the high fleet and labour requirements associated with using the manual option. However, motorised emptying was shown to have a higher cost associated with components which were more variable, such as capital, shipping costs, fuel and oil. In all scenarios the results indicated that a large proportion of the cost was associated with the primary transportation technology (manual cart or Vacutug) and, therefore, if cost saving was required, the focus should be on this part of the network.

There was shown to be a higher cost associated with scenarios that utilised multiple TSs over those that use a single TS. The use of multiple TSs was shown to reduce the overall transportation distance required but the cost of implementing multiple TSs (capital and operational costs) was shown to be higher than the cost saving made by this reduction. In the case of scenario 3 the results showed that the variations that did not utilise TSs were cheaper than those that did.

Comparing the method of payment proposed in this model (household charge per month) with the existing FSM service in Kanyama (one off service charge) highlighted the need to establish the best mechanism for payment within informal settlements. Where the standardisation of containment facilities does not exist and therefore predictions of emptying frequency are difficult, costing and planning methodologies which focus on the accumulation rate of the population (rather than individual household emptying frequencies) may be the best option. However, by not focusing on upgrading, replacing, standardising or modelling the containment facility it may become more difficult to predict service delivery needs (i.e. emptying frequency, equipment, staff requirements) and establish a regular payment mechanism to facilitate consistent service delivery.

The cost associated with the scenarios were shown to be sensitive to various input parameters. It was highlighted that accurate transportation network data was an important parameter as the average transportation distance (between collection point and end point) had an effect on the overall cost. Variations in population, sludge generation rates, inflation rate and primary transportation volumetric capacity were shown to cause the largest variations in the total cost of the least cost FSM scenario for each settlement. This type of sensitivity analysis is useful in helping to identify where investment (i.e. time and financial resources) is most valuable to ensure the optimum system (in terms of cost) is achieved.

Optimisation of the containment component was successful in highlighting how containment design can affect the resulting sludge generation rates, emptying frequency and the overall cost of the whole FSM system. The results showed that the costs of a fully sealed system were higher than those that allowed percolation into the ground. This exercise also highlighted that there was an optimum volume and design of container, were the lowest household charge for the project to breakeven was achieved. The analysis emphasised the need for the containment facilities to be modified or rebuilt in Lusaka’s informal settlements, due to their effect on public health and the environment and the impact on the whole SVC. This method could prove useful for the sanitation field (especially for FSM planning) as it highlights the importance of optimising the containment component, the effect optimisation has on FSM service delivery and the downstream SVC components to ensure that the least cost system is implemented.

The road based FSM scenarios modelled in this study were shown to be affordable for the majority of cases for both settlements. It was highlighted that in the case of Kanyama the reason why scenarios were unaffordable was because FS was being transported long distances using inefficient primary transportation technologies (manual cart or Vacutug) or there was high costs associated with implementing the required fixed infrastructure (i.e. multiple TSs). Therefore, optimising the use of internal transportation systems was again highlighted as a key factor to ensure the least cost and most affordable FSM solutions are implemented.

A further extension of this analysis would be to develop the long term costs associated using other transportation technologies and other types of sanitation systems so that a direct comparison between them could be made. It would also be beneficial to complete this cost analysis in a number of further locations (inside and outside Lusaka) and to compare it to real world FSM services. This would help establish the financial sustainability of road based FSM in a more generalised context as well as to confirm the accuracy and usability of such a model. It would also be beneficial to ensure that all parameters are obtained via primary data collection and specific research is conducted to ensure the accuracy of the input parameters.

In summary, these findings help to support the notion that road based FSM systems could provide a financially sustainable and affordable solution to help improve the sanitation situation in informal settlements in Lusaka. A novel spatio-topological methodology was used to optimise the potential fixed infrastructure scenarios so that least-time transportation networks could be identified prior to further analysis. The results produced were then used to develop a robust long term cost analysis of various feasible FSM scenarios for two informal settlements in Lusaka. Notwithstanding the studies' identified limitations, the results could be used to help support planning for FSM implementation in Lusaka by providing detail on the financial and logistical requirements for FSM which could be directly compared with other types of available solutions (i.e. conventional sewerage). Beyond Lusaka, this chapter addresses the need within the sector for more decision support tools and costing methodologies to be available to support planning for FSM service delivery and provides further evidence that FSM can provide a sustainable and viable technological solution to the sanitation crisis.

The following chapter draws on findings from previous chapters to identify the vital role the SVC plays in ensuring sustainable FSM and resource recovery from FS.

Chapter 8. The Role of the Sanitation Value Chain in Ensuring Sustainable Faecal Sludge Management and Resource Recovery from Faecal Sludge

8.1 Introduction

In recent years, the reuse and recovery of potential resources present in FS have been identified as a key requirement to ensure that sustainable solutions for urban sanitation provision can be achieved (Murray and Ray, 2010; Kennedy-Walker *et al.*, 2014a). Reuse has become a dominant theme within the sanitation sector as discussed in Chapter 3. To date, most research and studies related to FSM have focused exclusively on how households can gain access to toilets or the back-end components of the SVC; namely treatment and reuse (Eales, 2005; Chowdry and Kone, 2012). This chapter draws on evidence collected in previous chapters to identify what role each component of the SVC has in ensuring sustainable FSM and resource recovery from FS.

8.2 Methodology

This chapter draws upon evidence gathered from primary and secondary data collected from Lusaka which has been discussed in detail within the four previous chapters. Within the household level questionnaires undertaken in the three selected informal settlements (Chapter 5), a number of questions were used to establish the current status of the component**s** of the SVC at the household level and to explore households' knowledge and perceptions of reuse. The semi-structured interviews conducted with the community and city level stakeholders (Chapter 5 and 6) included enquiries into the current status of the SVC and whether informants perceived FS reuse as a viable option for Zambia. Observations and discoveries made from working within the wider EPSRC consortium were also drawn upon to develop this chapter (section 2.2). Secondary data provided further information and supported primary findings on the current status of the SVC.

8.3 The Importance of Each Component of the Sanitation Value Chain

In the following section, each component of the SVC is discussed, highlighting the respective roles in supporting the back-end components of treatment and reuse and promoting sustainable FSM service delivery.

8.3.1 Containment

The containment component of the SVC relates to the household level facilities such as pit latrines and septic tanks which are constructed to contain FS. In terms of safe FSM the containment facility should look to safely contain FS and provide adequate access so that safe and easy removal of FS from the facility can occur.

The household questionnaires undertaken in three of the informal settlements in Lusaka revealed that the current level of access to sanitation is low and the majority of containment facilities used were not containing excreta safely based on the ECF criteria set (section 5.4.1). The type of construction, the number of users, the volume of the facilities and the presence of inert material were the main factors observed which directly affect the emptying frequency of these facilities. Observations and household questionnaire responses indicated there were no standard pit latrine sizes (volumes) in use and the size achieved was largely dependent on the underlying geology at each site and how much could be dug out. The majority of facilities were shown to be constructed as unlined and bottomless so the liquid fraction of the facilities contents could percolate into surrounding ground (depending on percolation ability and saturation level of surrounding soil). There was also observed to be a presence of MSW in facilities (section 7.2.1) which reduces the volume available to contain FS within the facility. The number of users for each facility was also shown to vary throughout the community, however for this study (Chapter 7) the numbers were averaged out over the whole settlement. All of these factors were shown to make predicting the emptying frequency of each facility very difficult which in turn has a knock on effect for the implementation of a FSM service. In reality, it would be vital to conduct detailed analysis of all of these aspects so that the situation for each individual facility could be recorded rather than averaging out over the whole community, as these components directly affect each facility’s emptying frequency and FSM service delivery requirements.

Understanding the hydrogeology of each area was shown to be particularly important. The contamination risk of groundwater in informal settlements in Lusaka is high as a result of the geology, the high groundwater table, the location of settlements on low lying marginal lands and the seasonal rainfall patterns (section 4.4.2) (De Waele *et al.*, 2004; Bäumle *et al.*, 2012). These geological factors can directly influence the contents of the containment facilities. They can change the concentration of solids depending on liquid percolation action, causing the accumulation rate to vary. In some instances rainfall even cause the facilities to flood and the contents of the facilities to overflow.

Secondary reports indicated that temperature impacts upon the digestion rate of FS which directly affects the accumulation rate (Foxon *et al.*, 2011; Niwagaba *et al.*, 2014). In Zambia, there are three seasons: this could cause variations in the moisture and temperature within containment facilities and for their contents; cool and dry from May to August, hot and dry from September to November and warm and wet from December to April (Climatic Research Unit 2012). However, this factor was not directly analysed during this research and so further in situ analysis would be required.

All of the factors discussed directly affect the accumulation rate of FS within the containment facilities and thus the emptying frequency. Understanding the impact of these factors is important as they directly impact upon the removal, transportation, treatment and reuse components. The emptying frequency would directly affect the type of reuse or potential end products that can be produced from the FS. For example, as discussed in Chapter 7 fresh faeces has higher methane potential than FS that has been left to naturally degrade within the containment facility. Therefore, if biogas was highlighted as an important end product then ensuring a regular emptying frequency was achieved so the maximum methane potential could be captured from the FS would be vital.

The presence of open based containment facilities in close proximity to shallow boreholes or wells can cause public health risk (Section 4.4.2). During interviews with stakeholders, the flooding of informal settlements was highlighted as a major issue for Lusaka and perceived as the main cause of public health problems. The occurrence of flooding was said to be exasperated by the poor quality of drainage available in these areas. A further public health risk present in these settlements is the potential exposure to helminths which are present in the FS. Whilst this study did not look at helminth concentration in FS, previous studies showed their presence in the host population (section 4.4.1). The risk to public health depends on the level and type of human exposure to helminths and further analysis would be required to assess the real risk. Knowing about the concentration of helminths present in FS at the containment facility level is important as this could directly affect the type of treatment required and the reuse potential from FS if it has to meet certain reuse or disposal standards.

8.3.2 Removal

The removal component of the SVC relates to the emptying of FS from the containment facility and in the case of FSM to a system or technology that will then transport the FS.

The results of Chapter 7 highlighted that the time taken to remove FS from the containment facility impacts on the overall cost of the FSM system (section 7.7.1). During observations of the FSM service in Kanyama, the time required for the removal process varied extensively depending on access to the site, access to the latrines vault and the amount of MSW present in the pit. In the case of Lusaka, results from previous chapters revealed that the containment facilities in use did not provide a situation that supported FSM removal (i.e. access). Current emptying practices can cause the removal process to take a long time and can cause the structure of the latrine to be compromised and collapse (section 4.4.2).

The contents of the containment facilities were shown to directly affect the removal process (and technologies used), in particular the presence of MSW and the solids concentration. The climatic aspects highlighted in section 8.3.1 such as temperature, seasonal rainfall and groundwater level will also impact on the emptiability of the containment facility, due to the fluidity and viscosity of the FS contents. A recent study showed fresh human faeces to exhibit temperature-dependent behaviour, where there is a linear relationship observed between viscosity and temperature (Woolley *et al.*, 2014).

In the case of the FSM service in Kanyama, manual emptying was stated to be the only feasible option for FS removal due to the presence of MSW and high solids concentration (WSUP, 2014). Their presence prevents the use of vacuum based technologies which are more efficient than manual options (i.e. require less time for removal, higher volume capacity and quicker transportation speeds- Chapter 7). In an optimised FSM service the removal time would be made as short as possible so that the greatest number of containment facilities could be emptied per day in the most efficient manner possible. In the case of informal settlements in Lusaka the issues related to access and MSW need addressing so that more efficient (and cheaper) vacuum based technologies can be used (as shown in Chapter 7).

The status of the containment facilities in these informal settlements (i.e. design and volume) causes difficulties for predicting accumulation rates and therefore emptying frequencies. This has a direct impact on the overall FSM service delivery as the amount of equipment, staffing and long-term costs associated cannot be predicted. The back end components of treatment and reuse or disposal are also affected, as the volume and frequency of FS that requires processing is unknown.

The removal procedure itself can cause risks to public health. In the case of informal settlements in Lusaka the current FSM procedure does not ensure the safe containment of FS during emptying as the building of the access hole, manual emptying technique and the clean-up practice often causes contamination of the surrounding environment.

8.3.3 Transport

The main factors that will impact on the transport component are linked to the factors discussed in section 8.3.2 above. The volume of the transportation system used will influence the volume of FS that can be removed. The type of transportation technology (manual or motorised), the technologies' speed, the type of access roads and pathways present (width of road and quality of road (e.g. concreted)) and the service area's topography, will affect the time taken to transport the FS. Another critical factor that will impact on the transportation component is the distance between the containment facility and the endpoint (e.g. treatment facility or TSs). As shown in Chapter 7, it is important to strive to achieve a transportation network or scenario where fuel consumption, fleet size, staffing and wages are kept to a minimum.

8.3.4 Treatment

The treatment component of the SVC relates to the treatment of FS (may consist of a number of treatment processes) so that the effluent achieves a required standard (i.e. a certain level of pathogen concentration). Treatment options for FS are numerous and vary extensively from physical, biological and chemical processes (Nelson and Murray, 2008). Figure 7-1 highlights the wide range of treatment technologies available for FS specifically.

In Lusaka the decentralised anaerobic facility implemented in Kanyama is the only treatment technology available for the treatment of FS from onsite containment facilities (section 4.5.1). Whilst this technology is at the early scale stages of use, it could potentially support the required improved treatment and resource recovery of FS in Lusaka. Whilst Manchinchi WwTP has the ability to receive FS (septage hauling drop off facility) the facility was originally built for the treatment of wastewater from the conventional sewerage system built in the city (section 4.4.1) and not for FS from onsite systems.

Understanding the characteristics and content of the FS influent is an important factor to consider as this can affect the type of treatment that is deemed feasible. In the case of existing treatment facilities in Lusaka, wastewater from conventional sewerage systems will have lower solids concentration than FS from onsite containment systems because the water usage (and requirements) is much higher in conventional systems. This could cause conventional treatment facilities (such as Manchinchi WwTP) to not optimally treat FS from onsite systems as they have not been specifically designed to deal with that type of waste stream. Another important example of this from Lusaka is the effect that the presence of inert material (i.e. MSW or silt) could have on the treatment process. In particular, if it is present in the FS then its removal may be required prior to treatment and this extra process would need to be factored in.

The volume and frequency of FS (determined by the earlier components of containment, removal and transportation) that will require treatment will also influence the optimum type of treatment. The type of end product and end use for the effluent of the treatment process will also influence the type of treatment process selected. Figure 7-1 highlights that various technologies achieve different types of treatment processes: solid/liquid separation; dewatering; and stabilisation/further treatment. The type of treatment selected will therefore directly affect the end product made. The preferred end product and the level of treatment required will also affect the treatment process selected. To ensure the treated effluent achieves the required standard for disposal or reuse, more than one treatment process may be required. The available space and the required retention time (to achieve the necessary treatment standard or desired end product) will dictate the volume of the facility.

For biological treatment systems an understanding of the ambient temperatures that can be achieved are important to consider, as temperature will impact on the digestion process and the retention time required. The availability and level of access to water supply, electricity supply and chemicals may hinder the use of certain physical or chemical treatment processes.

Other factors which need to be considered are the access and availability of required capital and replacement equipment for each potential treatment option and the technical capacity available (in community or externally) to operate and manage the treatment technologies (e.g. skills, knowledge and local materials).

It is important to assess and evaluate the status of any treatment technologies that are currently in use as this will provide a good indication of whether the system currently functions and the capacity that currently exists. The current sanitation situation in Lusaka and specifically for informal settlements would indicate that treatment technologies which require minimal technical expertise and resources (financial, input materials, skills) would be optimum for this location.

8.3.5 Reuse or disposal

The final part of the SVC comprises of either disposal or reuse (recovering a resource) of the treated FS. As highlighted in section 8.1 the sector prioritises recovering resources from FS rather than disposal. Reuse can occur at the treatment stage or following treatment. The main types of reuse seen from FS are: energy harnessed during treatment (i.e. biogas or biofuel); fertiliser and soil conditioner; fuel source; and building materials (Murray and Ray, 2010).

The selected end-use for FS will depend on a number of factors. The chemical and biological characteristics of the FS will impact upon its reuse potential. For example, if the containment facility is infrequently emptied, the FS contained will naturally degrade over time causing its methane yield potential to be greatly reduced (Still and Foxon, 2012). Similarly, the total solids content of FS affects its calorific value and potential as a solid fuel source (Muspratt *et al.*, 2014). Where FS will be reused and applied to land, the principal aim is to recover nutrients. Therefore an understanding of the types and concentrations of nutrients present within the FS is important (from the very beginning of the design stage) to ensure nutrient recovery systems are prioritising the most readily available nutrients.

The type of treatment process selected and the resultant effluent will impact on the potential reuse that can occur. In the case of the anaerobic digester in Kanyama, the by-products of the treatment process being utilised are bio-methane (at the treatment stage) and a bio-fertiliser (WSUP, 2014).

The physical space available will also influence the feasibility of various reuse or disposal processes. If reuse or disposal of FS cannot occur on the same site as treatment, the distance to potential end-points may impact upon the end-use which is selected. In some cases transportation of the treated effluent may not be feasible because of its consistency. In the case of the FSM service in Kanyama, the drying beds are located over a 1km away from the treatment site causing an extra transportation component and cost to the system. Stakeholders who helped design the FSM project in Kanyama indicated that the drying beds were located away from the treatment facility because of issues of space and to improve access to the potential market (buyers). The infrastructural requirements and feasibility of various options, for example pipelines to transport biogas, will also impact upon the potential reuse option selected.

Climate can also significantly impact the effectiveness and applicability of certain reuse processes. For example, those processes that involve elements linked to evaporation, such as drying beds, are affected by temperature, wind and rainfall (Wang *et al.*, 2007). In the case of the FSM service in Kanyama, covered drying beds have been tested to try and improve the drying process and reduce the impact of climatic variables.

The required quality of the end-use product will also impact upon the type of reuse favoured. Legislation and policy can be used to stipulate the quality and standards of effluent that is required (e.g. biosolids or liquid effluent) for disposal or reuse. In Zambia there is currently limited legislation or enforcement of standards (section 4.3.2). This may cause potential risks to public health as unsafe FS effluent (i.e. with high faecal coliform or pathogen concentrations) is reused or disposed of without the appropriate level of treatment.

During discussions with city level stakeholders, political willingness to support reuse and high-level governmental support were shown to be important factors for its promotion. It was identified that in Zambia reuse is not currently promoted within any sector and so it is not a habit commonly practiced by society. Support from higher level institutions was highlighted as a key requirement for the promotion of reuse at the community and household levels. As discussed in section 4.3.2, the newest version of the Environmental Protection Act (GRZ, 2011a) may provide a sign of things to come as the legislation focuses heavily on the need to reuse and recover resources from solid waste.

The economic viability, potential return on investment and the available financial arrangements are key components which may govern the potential success of reuse from FS. In some cases finance may be available from donors, however they may only fund or subsidise specific sanitation interventions and reuse options which they prefer. The economic viability of various reuse options will depend on their potential return on investment which should be modelled prior to implementation. The potential return on investment will be driven by market demand and it should be ensured that there is a market for the end product or a market created prior to production. In Lusaka, modelling of potential reuse options and return on investment had only been completed by the NGO, WSUP (Mikhael and Clouet, 2012). Furthermore, the success of marketing and selling FS biosolids as a fertiliser in Zambia may be inhibited by the current chemical fertiliser subsidy provided by the Government of Zambia to medium and large sized farm holdings (Minde *et al.*, 2008). For the market to be satisfied, demand must be met by the supply and the product needs to be delivered at the agreed quality, volume and frequency. An understanding of the initial components of the SVC is vital for ensuring the volume produced, its frequency and quality can be predicted and guaranteed.

Societal preferences, perceptions and acceptance can also drive which reuse and disposal options are used. Previously implemented Ecosan toilets, which promoted the reuse of FS and urine (separately), were shown to be unsuccessful in a number of informal settlements in Lusaka because of a lack of cultural acceptance (section 4.5) (Nyambe *et al.*, 2010). Responses from household questionnaires in the three selected informal settlements highlighted that there was a clear lack of knowledge of how the safe disposal, treatment and reuse of FS should be conducted. The majority of household respondents indicated that they did not think it was safe to use FS as a fertiliser after treatment (section 5.4.2). Reuse of FS downstream of WwTPs is commonplace, however it was not clear where the sludge is used or whether its use was accepted (section 4.4.1).

As is the case for the urban sanitation planning sector in general, the development of an enabling environment (government support, legal framework, institutional arrangement, training and communication, financial arrangement, information and knowledge management) that supports reuse is required for success (Reymond, 2014). This was shown to be relatively weak in Lusaka at all levels. There was shown to be non-existent government support, limited strategies and political will and a lack of legislation and policy to ensure the safe treatment and disposal of FS. There were limited institutional arrangements at various levels of governance for the safe collection, transportation, treatment and reuse of FS. Training and communication provided about the types or advantages of recovering resources from FS (information sourced from methods used in Chapter 4, 5 and 6) were limited.

8.4 Review of Findings

Table 8-1 below provides a summary of the components discussed in previous sections of this chapter. It is based on findings from primary research, secondary data, observations and findings from the wider EPSRC consortium. The table provides a framework highlighting factors related to each component of the SVC which require attention to ensure sustainable FSM services can be delivered. It also provides evidence that the front-end components require more attention as they directly affect the back-end components. The factors have been broken down into four main ‘effecting’ themes: climatic, practicality, public health and marketability. The importance of each factor has been discussed in the previous sections, using practical examples from Lusaka.

Table 8-1: Framework highlighting factors which effect exploitation of the SVC and FSM service delivery

	Sanitation Value Chain →				
Themes	**Containment**	**Removal**	**Transport**	**Treatment**	**Reuse or Disposal**
Climatic	• Seasonal rainfall • Groundwater level • Temperature	• Seasonal rainfall • Groundwater level • Temperature		• Seasonal rainfall • Temperature	• Seasonal rainfall • Temperature • Wind
Practicality	• Number of users • Design and quality of construction (lined/unlined/ sealed/unsealed) • Facility volume • MSW content • Hydrogeology of surrounding area • Topography of area • Permeability of surrounding ground/soil	• Access by road or pathway • Access to containment vault • MSW content • Total solids concentration (liquid or solid FS) • Process and equipment used for removal (manual/mechanical) • Volume of removal and transport technology • Fleet availability • Staff availability	• Equipment used for transportation (manual/ mechanical) • Volume of transportation technology • Status of access roads and pathways (width, quality and topography) • Speed of transportation equipment • Distance between containment facility and end point (treatment or transfer station) • Fleet availability • Staff availability	• Total solids concentration of FS influent • MSW content • Organic fraction • Volume of FS influent and frequency of loading required • Space available • Volume of treatment facility • Retention time required to achieve required level of treatment • Previous treatment technologies used • Inherent technical capacity and skills of local workforce • Available resources (chemicals, electricity, financial)	• Total solids concentration of FS • Organic fraction • Calorific value • Nutrient content • Type of treatment utilised • Space available • Distance between treatment facility and reuse/ disposal site • Infrastructure available • Effluent quality/ volume required • Legislation and policy for reuse • Support for reuse • Donor preference • Societal preference • Previous interventions (success and failure)
Public Health	• Functionality of facility to contain excreta • Helminth concentration in host population • Risk of contact with pathogens and faecal coliforms through faecal oral transmission routes. • Use of shallow wells	• Access to containment vault and removal process	• Transportation process	• Helminth concentration	• Helminth concentration • End use • Pollutants present in FS
Marketability	• Accumulation rate • End product required • Social acceptance/preference	• Emptying frequency • End product required • Social acceptance/ preference	• Emptying frequency • End product required • Social acceptance/preference	• End product required • Social acceptance/preference	• Market demand • Available supply (volume and quality) • Return on investment or economic viability • Competition • Physical market locations • Incentives in place • Legislation and policy • Social acceptance

8.5 Conclusion

This chapter draws upon the research findings to argue that assessment and optimisation of the whole SVC is required to ensure sustainable FSM services can be implemented and a 'closed-loop' sanitation system can be achieved. With the front end components of the SVC needing as much attention as the back-end ones, as the latter is directly impacted by the former.

Table 8-1 defines the wider range of factors that need to be considered at each component of the SVC to ensure that optimised reuse and FSM service delivery can be achieved. The framework highlights that appreciation of the social factors is just as important as the technical ones. The themes of: climatic, practicality, public health and marketability help to uncover the main overarching influences which require attention at each component. The framework developed is useful for the sanitation sector as a whole as it indicates which elements need consideration, assessment and optimisation before implementation and investment into FSM service delivery. In particular it may provide a useful framework to support the WASH post 2015 proposed agenda, which will require the sector to make drastic changes and move beyond their focus on the containment facilities and reuse to one that ensures the safe management of FS is achieved.

In the case of Lusaka and Zambia, this chapter highlights how more information is required about the current status of each SVC component (i.e. containment, characterisation of FS contents, emptying frequency and the transportation network) and the specific improvements that are needed to be made (i.e. creation of an enabling environment and improved legislation and enforcement). In particular, this chapter outlines the need for investment to be made into the containment component of the SVC as without it the whole system becomes unlocked. These findings coincide with other studies and Chapter 7 which highlight the need for better information to be gathered regarding the status of FSM and in particular on the emptying and transportation components (Chowdry and Kone, 2012; Peal *et al.*, 2014a). In-depth information about the status of each component of the SVC and possible improvements are required to support the planning process and in particular the development of plans which consider the use of alternative sanitation solutions such as FSM. Without such information, FSM will continue to be considered as an unviable or substandard option because details plans cannot be produced which outline the logistical and financial requirements

One of the main drivers for the sectors focus on the back-end components and in particular reuse, is the economic potential it can bring. This chapter shows that any economic benefit created by reuse will be directly dependent on the market demand for the reuse product and whether such a demand can be met by the existing/ potential service chain. Without in-depth understanding and optimisation of the front-end components of the SVC the reuse potential and therefore potential back-end resource recovery cannot be understood and therefore met.

The following chapter looks to present the overall conclusions of this thesis by presenting the findings of the research undertaken in each chapter.

Chapter 9. Conclusion

9.1 Introduction

The overall conclusions for this thesis, which are based on the aim, objectives and research strategy undertaken, are presented in this chapter. The key research findings are discussed for each chapter followed by a discussion of the research limitations. The overall contributions these findings offer for sanitation in Lusaka, Zambia and for the wider sanitation sector are outlined. Finally specific recommendations for future work are defined and a personal reflection is presented.

9.2 Summary of main findings

The overall aim of this thesis was to identify to what extent current urban sanitation planning approaches and practices are suitable frameworks for achieving sustainable FSM in complex informal settlements in Lusaka, Zambia. The research focused on identifying key adaptations to existing planning approaches that are required to ensure the successful implementation of FSM services within these informal settlements. A number of objectives were defined. The main findings from each of the chapters, which addressed individual objectives, are discussed below followed by the overall conclusions.

9.2.1 Conclusions of Chapter 3

Chapter 3 addressed objective 1 which was to review current sanitation planning approaches and highlight dominant processes and foci. A desk based review of existing sanitation planning approaches and their use within the sanitation planning arena, highlighted how the sector had evolved over the last 30 years, with five commonly observed planning concepts emerging (health, sanitation value chain, sanitation ladder, enabling environment and household participation). The review highlighted that there was limited evidence for the use of such approaches and that a lack of an enabling environment was consistently quoted as the cause for failure. The chapter concluded with two main recommendations for the sector; 1) ensure more time is taken to conduct in-depth situational analyses to facilitate a better understanding of the current sanitation and the capability of the existing environment to achieve progress and 2) the need to monitor and evaluate the process of urban sanitation planning more thoroughly, so that evidence of what works best can be uncovered.

9.2.2 Conclusions of Chapter 4

Chapter 4 addressed objective 2 which was to present a situational analysis of the current sanitation situation in informal settlements in Lusaka, based on the evaluation of secondary sources. The evaluation revealed that households in Lusaka have poor sanitation access and low levels of access to FSM. The worst situations were shown to be present in informal settlements where a wide range of factors were shown to be contributing to a lack of improvements being made. A major issue identified was the lack of adequate, clear and targeted strategic plans available that would ensure the coordination of stakeholders and be based on sound evidence of the existing situation, achievable objectives and feasible solutions. Inconsistencies in laws, the legal status of informal settlements, the prioritisation of politically driven legislation and the lack of targeted policies were shown to reinforce inaction. The analysis identified many stakeholders to be involved in sanitation but there was shown to be a lack of clear leadership, roles and responsibilities for those involved. Another issue identified was the lack of institutional presence (physically or otherwise) at the grassroots level implementing targeted responses and initiatives to tackle the poor sanitation situation. The availability and use of limited targeted finance, a lack of developed detailed financial requirements (underpinned by detailed plans) and a dependence on donors and external agencies for the majority of sanitation programmes was also shown to be further hindering progress. This chapter outlined the complexity of the situation surrounding the existing sanitation situation in informal settlements in Lusaka and the major task ahead for ensuring that progress and sustainable development is achieved.

9.2.3 Conclusions of Chapter 5

Objective 3 was addressed in Chapter 5, examining the current status of FSM and presenting key factors which may prevent access to FSM at the household and community level. This chapter went beyond the situational analysis conducted in Chapter 4 and collected primary data from three selected informal settlements in Lusaka through household level questionnaires (N=169) and a series of KIIs (N=14). The methodologies went further than the commonly conducted sanitation situational analysis process and highlighted the benefits of exploring alternative socio-technical factors. Moving away from counting toilets, the questionnaires examined factors which uncovered the ability of each facility to contain FS, the current and potential status of FSM and the level of knowledge that existed at each household. The situation for each of these factors was shown to be poor, caused predominantly by a lack of institutional support, interventions or service delivery. The impact of socially-orientated factors (socio-economic, perception, spatial proximity and social proximity) was also explored. Despite limited significance or association being observed between such factors, the subsequent qualitative information provided useful insight into those factors which may affect development or future service delivery in such settlements. In particular, factors relating to social and spatial networks were shown to directly affect how organisations or services are perceived by households/customers. The need for organisations and services to be physically present, accessible, transparent and reliable were shown to be key influences on observed levels of trust and subsequent acceptance from households. The affordability, cost of services and level of perceived improvement in the situation were shown to be factors that affected households' willingness to pay. At the community level, trust was further shown to be a key cause of development prevention in informal settlements, in particular where it is lacking between institutions and households and between institutions themselves. Other influences such as inhibiting political activity and institutions' lack of power to prevent it; the lack of institutional presence, lack of high-level support and leadership; and the seasonality of interventions were also shown to be hindering progress at the grass roots level. Overall the chapter defined the need for the sector to go beyond current practices to ensure that crucial socio-technical factors are understood so that key dynamics that may lead to implementation failure are identified and overcome at the feasibility and planning stages.

9.2.4 Conclusions of Chapter 6

Objective 4 was reviewed in Chapter 6, which sought to investigate factors at the city level which may prevent access to improved FSM in informal settlements. Conclusions for this chapter were drawn from primary data collected from city level KIIs (N=35). Similar to Chapter 5, this chapter concluded that the situational analysis process needs to do more than simply identify stakeholders and their roles, interests, priorities and incentives by ensuring that socially-orientated dynamics which cause development failures are detected. The findings further highlighted the need for improved situational analysis (and planning) to be conducted in Lusaka based on the fact that the information presented by secondary sources (Chapter 4) was shown to provide limited exposure to the field realities and causes of the poor sanitation (as uncovered by Chapters 5 and 6). The results emphasised that whilst the weakness of the enabling environment in Lusaka inhibited improvement in sanitation in informal settlements, aspects relating to power, politics and history were shown to be more dominant influences on failure. In particular, the un-resisted power exerted by politically driven individuals/groups and dominant institutions that intervene based on their interests, priorities and implications of previous interventions or historic events. These findings coincided with other literature which argues for the need to better understand the influence of politics and power on development.

Overall the findings from Chapters 5 and 6 highlighted the merits of collecting in-depth qualitative information from a wide range of stakeholders and from all decision making domains so that the complexities and dynamics of working in informal settlements can be understood.

9.2.5 Conclusions of Chapter 7

Chapter 7 addressed objective 5 by drawing upon primary and secondary data to develop a methodology which could support planners in Lusaka in their ability to model various FSM scenarios. The results provided the long-term costs for implementing various FSM fixed infrastructure scenarios using different technology variations for two informal settlements in Lusaka. Optimisation of the transportation component of the various scenarios was achieved using a novel spatio-topological methodology. It ensured that the lowest cost FSM service provision could be identified and utilised. The impact of varying the containment facility design on the cost of service delivery was also taken into account. The analysis showed that the accuracy of the input parameters and specifically information regarding the containment facility, emptying frequencies and transportation component were crucial for ensuring the viability of the results. The results indicated that FSM could provide a feasible and affordable solution to improve the existing sanitation situation in informal settlements of Lusaka. Beyond Lusaka the results presented a novel decision-support tool to support FSM service delivery by allowing the financial and logistical requirements for various scenarios to be explored which can be directly compared to other viable technological solutions (i.e. conventional sewerage). This chapter also supports FSM and helps to raise its profile as a sustainable option for the management of FS in informal settlements and beyond.

9.2.6 Conclusions of Chapter 8

Objective 6 was addressed in Chapter 8, which identified how an improvement in the understanding of each component of the SVC is required to promote sustainable FSM implementation and resource recovery from FS. Methods used and findings from the previous chapters were drawn upon to argue that the sanitation sector needs to move away from its current focus on the toilet or the back end components of treatment and reuse. In particular the need to focus more attention on the front-end components because of their direct effect on the back end components was discussed. A framework was developed which supports this argument by presenting the wide range of socio-technical factors which need to considered, assessed, and optimised at each component of the SVC to ensure that sustainable FSM and a closed-looped sanitation system can be achieved. For informal settlements in Lusaka specifically, the analysis showed that there is a critical need to improve the current status of the containment, removal and transportation components so that the public health and environmental risks can be reduced. There was also shown to be a need to improve the treatment and reuse of FS and to evaluate further the performance of anaerobic systems and other available technologies to uncover the resource recovery potential in Lusaka. Beyond Lusaka, the framework was shown to support the proposed WASH post 2015 agenda which will require the sector to focus specifically on the management of FS at each stage of the SVC.

9.2.7 Overall conclusions

The main finding of this study was that changes need to be made to the current approaches to urban sanitation planning so that their appropriateness for implementing FSM services in informal settlements can be assured. This research showed that the dominant influencing factors affecting development in informal settlements in Lusaka, Zambia were different to those discussed and identified as key within planning literature. In particular, it was shown that the true complexities, dynamics and dominant actors affecting improvements in sanitation access and service delivery would not be given enough attention if the existing planning processes and methodologies were used. The realities observed in these informal settings were shown to be far more complex than those defined in secondary sources. At the community and city level, the enabling environment factors were shown to influence the development of the sanitation sector, but the overarching impact of power and politics were shown to be much more inhibiting in the informal setting. Even in a politically and economically stable country such as Zambia a plethora of complex factors were shown to be at play and to be inhibiting development and basic service delivery within informal areas.

The research demonstrated that there is a need to go beyond existing planning approaches and to focus more time and resources at the baseline collection stage. Information collected needs to go further than simple ‘tick-box’ exercises and uncover the true complexities that inhibit progress through the collection of in-depth data collection from all decision making domains. Stakeholder analysis needs to go beyond simply identifying stakeholders, their priorities and interests and focus on influences which govern how they work and interact, especially the role of power and politics. Dominant individuals or collectives who can influence interventions should be incorporated into the development process from the earliest stages so that their power and influence can be used to support sanitation interventions rather than inhibit them.

At all decision making domains, the status of the enabling environment to support sanitation improvements should be properly uncovered and assessed. The research shows that beyond these factors, further qualitative and quantitative information needs to be collected which uncovers socio-technical factors which will affect service delivery, service uptake and development. The need to spend time on the ground, developing a trusting environment, so informants can discuss complex situational realities was also shown to be critical. More specifically in relation to FSM the exploration of technical factors from all levels of decision making that directly affect the management of excreta along the SVC needs to occur. At the household level, assessment of the status of sanitation, beyond just counting toilets, to one were the functionality of facilities to contain FS, the current FSM status and the potential to achieve FSM service delivery is understood, is key. Beyond the household, information about the status of each component of the SVC needs to be collected.

Tools such as the long-term costing methodology and the SVC framework should be used to support planners and those mandated to provide sanitation services. The methodology developed, identified potential infrastructure scenarios, technologies and the long term costs associated with various FSM solutions for two informal settlements in Lusaka. The results of this could be used to develop detailed plans, to compare FSM service delivery with other technological options and to help establish the most suitable options available. The research highlighted the clear need to collect primary data (i.e. costing, mapping, sludge flow diagram) from all decision making domains so that an in-depth understanding of all of the components of the SVC can be established (containment, removal, transportation, treatment and reuse or disposal) to ensure sustainable service delivery, accurate long term associated costs and a closed loop system. The methodologies developed further support FSM and its recognition as a viable technology that can provide reliable service delivery when compared with conventional ones.

Overall the research findings supported the idea that FSM could provide a viable option for the improvement of the existing sanitation situation in informal settlements in Lusaka. However, for such service delivery to be successful appropriate analysis of the existing sanitation situation at all decision making domains at the earliest stages is critical. This is in order for targeted interventions that will enable sustainable services to be delivered and factors which inherently or have previously caused failure, can be overcome.

The research supported the wider EPSRC consortium by identifying and developing methods to support the delivery of FSM service delivery in informal settlements of Lusaka. Key factors were identified which would impact upon the successful implementation of anaerobic treatment technologies and the potential resource recovery from FS. Although the research was specific to the context of informal settlements in Lusaka, the findings were shown to resonate with literature from the wider sanitation and development sector, implying that these findings could be more generally applicable.

9.3 Limitations of the Study

This research has made an important contribution to understanding how urban sanitation planning approaches can be improved for use in informal settlements and for FSM service delivery. Despite this, several limitations of this work are recognised.

Firstly, poor data availability for informal settlements in Lusaka affected the accuracy of the long-term costs for the various FSM scenarios modelled in Chapter 7. Detailed primary data (i.e. in-depth mapping and physical measurements of containment facility) could not be collected because of limited time and resources in the field. Whilst the input parameters used were sourced from the best available secondary data, in reality more accurate figures, based on primary data collection should be used. Simplifications and assumptions made whilst developing this model may also affect the viability of the results. To overcome this limitation a more detailed situational analysis assessment and prediction of future circumstances would be required which focus on aspects as outlined in section 7.7.3.

Secondly, the issue of tenure was not explored in detail within this study. Tenure has been shown by other studies to have a direct effect on sanitation access levels. During the questionnaire trial it was found that householders who rented could not answer the majority of the questionnaire. Data collection was only possible from respondents who were owner occupiers. It would be interesting to include respondents with varying tenure status in such a study as this is likely to impact upon the socially-orientated factors explored.

A third limitation was that no informal manual emptiers or stakeholders collecting and using biosolids produced at Manchinchi WwTP, were interviewed. I was unsuccessful in setting up interviews with these key informants. A different approach may be necessary to achieve access to these groups, as it would take time and the buildup of trust to be able to identify and conduct in-depth research with such stakeholders. Such time was not available within this project. These stakeholders typically operate informally and therefore may not be comfortable in being included in such research which may be deemed to threaten their activity (can be deemed illegal) or businesses. However, these informants would provide further useful insights in the future. Interviews with formal city level emptiers were also not conducted as good quality secondary information was available from a WSUP funded report (Mikhael and Clouet, 2012) and time constraints inhibited these stakeholders from being approached

Fourthly, interviews with local health centres in each selected informal settlement could not be conducted. The in-house ethical approval required to gain access to such institutions could not be achieved during the time in the field. Collecting information from such institutions (minimal access was gained in George settlement) may bring new insights and information which could support the focus of this research and therefore would be deemed important in future research.

The final limitation of this research was that the sample size achieved for the household level questionnaires was limited by constraints on resources and time. Whilst the sample size achieved was big enough to ensure statistical analysis could be conducted on the data (i.e. size of sub groups was appropriate) ensuring a large enough representative sample size would have strengthened the findings of this research further.

By acknowledging these limitations it is realised that possible extensions or complementary studies would be required to add further credibility and reliability to this research.

9.4 Application of the research

This research contributes to knowledge in a number of ways, specifically related to informal settlements in Lusaka but also within the wider sanitation sector. Firstly, it has identified, based on primary evidence, that shortcoming in existing planning approaches exist which may inhibit progress in improving sanitation access in informal settlements and specifically FSM service delivery. The research provides empirical evidence that exploration of socio-technical factors which draw on both qualitative and quantitative data from all decision making domains is key to understanding, acknowledging and overcoming inherent complexities within informal environments. The study supports the need to explore households' level of access to sanitation beyond the JMP criteria (in line with WASH post 2015 recommendations) and provides a method of reporting on sanitation access that includes its ability to contain FS, the household's capacity to make improvements, current FSM practices and technical aspects which may impact upon the success of future FSM service delivery.

The study contributes to the sector by developing a decision support tool which allows for detailed analysis and long term costs associated with various potential FSM scenarios to be modelled. This allows FSM to be compared with more conventional technologies and creates a convincing argument for its place as a 'proper' solution to poor sanitation. The tool also ensures that the modelled scenarios would provide sustainable solutions due to its focus on long-term cost recovery over a 25 year design period. The research presents an argument for the need to focus more attention on understanding and optimising the containment, removal and transportation components of the SVC to ensure sustainable service delivery and resource recovery can be achieved. A framework to support these requirements is presented.

9.5 Recommendations

Recommendations based on the findings of this research are discussed below, firstly those specifically related to Lusaka and then the wider sanitation sector. Finally, recommendations for future work are presented.

9.5.1 Lusaka specific

There are a range of recommendations which relate specifically to Lusaka and informal settlements. The recommendations have been grouped into three domains at which decisions are made, namely country, city and community/households.

Recommendations made at country level domain include:

The creation of a new department within the MOLGH to take a lead role on sanitation provision in informal settlements. High level support is needed at a ministerial level to ensure that the sanitation needs of informal settlements are addressed on a country wide scale. Such a department could lead on improving co-ordination between the wide range of national and international agencies involved in sanitation to align activities, thereby achieving progress. In particular, the activities of the MOH, as a dominant Ministry currently working within the sector and in informal settlements, needs to be more closely aligned to the activities of MOLGH and to encourage the introduction of preventative health measures.

Legislative changes, either through the creation of new or modification of existing legislation, to ensure that the specific sanitation needs of informal settlements are addressed. In particular, the WSS Act should be modified or new legislation created to outline requirements and define institutional roles and responsibilities in the provision of sanitation in informal settlements. Current legal inconsistencies regarding the legality of informal settlements needs to be resolved and where possible settlements should be made legal so that the essential sanitation service provision required can be supported. NWASCO, is well placed to take a leadership role to regulate sanitation provision in informal settlement and support local commercial utilities to improve sanitation provision.

National policy needs to be modified to incorporate effective strategies for sanitation provision in informal settlements. Strategies need to focus on alternative technical solutions, such as FSM, to address the sanitation needs of the majority of the population who are served by onsite sanitation systems. Such strategies should not only deal with the containment technology but also define how the safe collection, transportation, treatment and reuse of FS can be achieved. Any strategies developed should be based on detailed evaluations of what works (pilots) or has previously worked in Zambia (discussed below). NWASCO should create standards for onsite sanitation technologies and support their distribution and take-up at the country, city, community and household levels.

Creation of legislation to support the safe disposal and reuse of faecal sludge. The absence of legislation governing the disposal and reuse of FS is a serious omission. Legislation is needed to support the regulation of the back end components of the SVC. This in turn will also support public health protection from the currently unregulated use of sewage sludge and encourage the safe management of FS along the SVC.

Existing national development plans and sanitation programmes needs to be drastically improved to provide meaningful targets and strategies to support progress. Both the 6th National Development Plan and NUWSS 2011-2030 require an overhaul to provide clarity as to how their visions for the future can be achieved in reality. In particular, existing programmes and plans need to include more detail as to how the sanitation problems encountered in informal settlements are going to be addressed. Country wide baseline data collection and situational analysis needs to be undertaken to support the development of evidence based plans. Whilst such data collection and analysis may not be conducted by country level institutions, such institutions should support and monitor activities conducted by local city level institutions.

Increasing the allocation of national budget to the specific financing of urban sanitation. An increase in national budget, from the current minimal amount, specifically targeted at sanitation will help go some way to increasing attention on the sanitation needs of the country. In particular, financing of sanitation interventions which address the needs of the populations living in informal settlements should be made (in particular FSM). For the sanitation sector to develop sustainably there needs to be a move away from the current dependency on donor funding to one where internal funds are allocated, and where possible, targeted at investments which aim to achieve a return on government investments. DTF have a critical role to play in convincing commercial utilities to allocate more funds to sanitation, specifically in informal settlements, and in supporting them to develop and test the use of novel financing mechanisms aimed at increasing householders' willingness to pay thereby recovering investment costs.

Completion of an in-depth historic review of WSS. This will help to establish what has worked or failed in the past and how external activities have impacted on sanitation provision. Information should be collected from a wide range of stakeholders, from all decision making domains and stages of the SVC. It should also include a review of historic national events, for example, changes in organisation setups, political structures and legislation and outline the effect on service provision.

Improved long-term monitoring and evaluation of sanitation interventions is required. New interventions should be better monitored and evaluated both in the short term and long term and lessons learnt should feed into national/city level plans and strategies. A regulatory or advisory agency should be created at the national and local level to support/ enforce the monitoring and evaluation of interventions. The creation of such an agency would also help coordinate activities of the various stakeholders working in the sector, such as donors and NGOs, so that efforts are further streamlined.

Recommendations at city level domain include:

Coordination of city level institutions focusing on wider problems of housing and service provision. Better coordination of LCC, LWSC and the city level MOH needs to be achieved to address the problems of housing and basic service provision (including sanitation and SWM) in informal settlements. LWSC should lead interventions related to sanitation; however, plans and programmes should be coordinated within the wider development of such settlements. It should be noted that both LWSC and LCC need strengthening in terms of their financial and staffing capacity to support the sanitation agenda for informal settlements.

FSM service delivery needs to be implemented in informal settlements in Lusaka. FSM service delivery needs to be extended to informal settlements in Lusaka to address the sanitation needs of those currently served my onsite containment facilities. FSM was shown by this analysis, to have the potential to provide an affordable and appropriate solution to the sanitation problems that currently exist in informal settlements. Households need to be supported by city level institutions (i.e. LCC and LWSC) to either modify or newly construct containment facilities that ensure the safe containment of FS (specifically in areas of high groundwater and vulnerability) and address the requirements for downstream management of FS (i.e. emptying and transportation). Transportation equipment that can access facilities in informal settlements (smaller and more manoeuvrable) needs to be introduced. Specifically designed treatment facilities that are required to treat the volume of FS produced in Lusaka need to be constructed. Appropriate solutions to either reuse or safely dispose of FS also need to be introduced.

Programmes which promote improvements in hygiene practices and current FS and MWS disposal behaviours need to be introduced alongside technical interventions.

Creation of Lusaka wide sanitation plans. Integrated city wide plans need to be developed which define solutions for all areas of Lusaka, including informal settlements. LWSC should move away from being reliant on donor agencies to prescribe solutions as they do currently, to a position where LWSC produce detailed plans developed in collaboration with other leading agencies, institutions and stakeholders from all decision making domains. Plans should be based on strong primary data collected from the ground (see below) and strategically outline the most feasible solutions (based on financial, technical and social indicators) for each individual area. Whilst theoretical planning approaches (Chapter 3) could provide useful guiding frameworks; this analysis shows that the collection of reliable in-depth baseline data is critical to supporting the planning process. The long term costing and spatio-topological methodology developed in this thesis could be used to directly compare FSM service delivery to other technical options in terms of its financial, logistical and technical requirements. The use of sensitivity analysis, such as used in this thesis, could be used to help define where finance and resources are best targeted.

Collection of baseline data from informal settlements to help support the creation of targeted plans and programmes. LWSC need to collect accurate data from the ground to facilitate the development of long term cost projections for various technical options at each component of the SVC. Where appropriate, pilots should be conducted and the success of intervention rigorously monitored and evaluated. Information including household sizes, current sanitation access (type, size and functionality), accumulation rates and existing FSM practices are needed to define the current sanitation situation. Mapping data of household plot locations, containment locations, existing roads and pathways and possible sites for sanitation infrastructure is also required to ensure spatial attributions are considered within developed plans. Information about associated capital, operational and maintenance costs for various technical options is also required. Whilst the collection of such information from a city the size of Lusaka may be costly, participatory methods, such as crowd source mapping, could be used to reduce data collection costs and could also provide a way of empowering community members.

Completion of an institutional analysis of Lusaka. Information should be collected from a wide range of stakeholders from household, community, city and country level domains. The analysis needs to identify, depict and analyse the actual situation in relation to sanitation provision and appreciate the role and influence of dominant institutions, complex existing social dynamics and the influence of both formal and informal actors (i.e. politicians). To do so, time needs to be invested in creating a trusting environment where stakeholders are able to openly discuss the multifaceted reality.

The role of power and politics on the development of informal settlements should be more formally investigated and defined. Politically driven stakeholders at all domains need to be engaged fully in all planning and development processes so that they can be convinced of the benefits of supporting the development and implementation of improved service provision in informal settlements. Personnel with political expertise who are able to understand the Lusaka context, should be included as members of the planning team to help define how complexities of power and politics can be better understood and utilised advantageously.

Recommendations at the community level domain include:

Creation of institutions or collaboration of existing organisations to ensure presence at the community level. Institutions that are focused on the provision and delivery of sanitation service delivery, support community capacity building and promote improved hygiene and behaviour change activities, need to be established in informal settlements. They are needed to create a line of communication between higher level institutions and households and to create positive household perceptions of higher level institutions. New institutions could either be created in the community through LWSC, or, existing CBOs could be targeted. In the case of existing organisations, the conditions/dynamics of how they function need to be explored first. Such institutions could be used to lead the collection and continual updating of baseline information from each community and feed this information up to relevant city or national level organisation.

Transferring knowledge and building capacity within communities to support development. Newly created community level institutions (recommendation above) have the potential to play a powerful role in capacity building and knowledge transfer to households. Knowledge about requirements for safe containment of FS, FSM practices, hygiene and SWM practices are likely to be well received (based on the findings of Chapter 5). There is a need to increase households' political awareness so that they are clear of the roles and responsibilities of institutions and politicians and understand better who is responsible or able to provide basic services.

The effect of social dynamics (socio-economic, perceptions, social proximity and social network) need to be further explored to support successful service delivery. Further qualitative and in-depth household level data needs to be collected from informal settlements to provide a better understanding of the impact of social factors on service provision and their development.

Further exploration of household willingness to pay for sanitation is needed. Whilst this analysis indicated that householders may be willing to pay for sanitation, further analysis is needed to establish willingness to pay for different types of service delivery, potential for recuperation and which aspects of the sanitation process, householders are willing to pay for (i.e. containment, transportation, treatment and reuse etc.)

9.5.2 For the wider sector

For the wider sanitation sector the following recommendations are made:

More time and resources need to be given to the situational analysis component of the planning process. Whilst theoretical urban sanitation planning approaches (Chapter 3) can provide guiding principles for city level planners, an in-depth situational analysis that is able to obtain detail about the reality of the environment is key within the overall planning process. Without an in-depth situational analysis being conducted, plans will prescribe interventions which will not be optimal for the existing environment or at worst not be possible to implement. In particular, the effect of power and politics needs to be more formally recognised by the sanitation sector and incorporated explicitly within urban planning approaches. Personnel with political expertise who are able to understand the local context, should always be included within any planning team to help understand the power and politics operating and to assist in the development of strategies to utilise these forces advantageously.

Plans for informal settlements need to be part of strategic city-wide plans. Any sanitation intervention needs to be based on properly formulated strategic city-wide plans which have considered through modelling, the long-term cost and feasibility of a wide range of technologies. Plans developed should incorporate the whole population and thus include options for informal areas and formal areas and should accommodate other development objectives (i.e. of other organisation or institutions).

More tools and practical examples of interventions need to be developed to support the position of FSM. In particular, the development of tools which support the optimisation of the containment, removal and transportation components of the SVC (such as developed in Chapter 7) are vital. For FSM to be become an intrinsic technical solution the sector needs to go further in developing tools that support its implementation in reality. More practical examples of FSM service delivery are needed and reporting of both successes and failures are needed so that lessons can be learnt sector wide.

The collection of detailed digital maps and databases which outline the existing formal and informal sanitation infrastructure along the SVC, need to be encouraged. It is crucial that plans developed are based on accurate information from the ground which is both available and kept updated; particularly with regard to household location, containment locations, containment volumes, containment accumulation rate, emptying frequencies, road and pathway locations, fixed infrastructure locations (TSs, treatment) and used disposal or end use locations.

Accurate financial information on the capital, operation and maintenance costs associated with various technological solutions need to collected and kept up to date. Access to this information will support the process of long term cost analysis and planning. If a database of such information is developed, data collection resource requirements will be reduced in the long term as the information will be readily available when planning or costing analysis is to be conducted. Other information such as inflation rates and population growth rates are also useful to have.

The effect of social factors on sanitation access needs to be taken more seriously sector wide. The effect of socially-orientated factors such as; socio-economic, perceptions, spatial proximity and social proximity need to be explored more integrally within the wider WASH sector. Qualitative data should be collected from all decision making domains to provide useful insights into socially orientated influencing factors. Where resources mean that large resource intensive data collection cannot be established, qualitative focused exploratory methods should be used to explore such factors.

The collection and storage of information should be improved sector wide. All institutional information collected should be stored centrally in-country so that it is easily accessible and open source for all to use. This should include situational analysis, historic reviews and information which focuses on the monitoring and evaluation of development interventions. Having access to such information will support the planning process by ensuring information regarding previous interventions (both successful and not) are readily available to review. The process of monitoring and evaluation interventions should be better supported sector wide and information should be more openly available.

9.5.3 Suggestions for future work

An extension of this research would be to test the methodologies in different cities and urban environments (i.e. beyond informal settlements). This would help to refine the conclusions of this study and provide evidence of its wider applicability to the sector.

The research highlights the need to conduct detailed baseline mapping and information collection (i.e. infrastructure and transport network) of all settlements within each city. TO assist this, tools (such as databases) could be developed to support cities (through technical support, capacity building and resource allocation) in order that the collection, storage and requisite updating of such data can be achieved. Where resources may be limited, methods such as crowd source mapping techniques be considered. Further research could also be conducted to develop tools and methods to support the process of monitoring and evaluation to achieve evidence based learning which potentially could lead to improvements on the ground.

Further work could be undertaken to improve the spatio-topological method used within this study. In particular, the model could be updated so that the transportation network used in the model simulates the real life situation more closely. For example, road categories (i.e. primary, secondary and tertiary) could be assigned to each road individually in order for the transportation routes used in reality, to be identified in the model.

The research conducted could be expanded by supporting the use of the developed methodologies by planners (or related institutions) in cities within developing countries. The use of such tools could be monitored and the transition from theory to practice be assessed so that evaluations of whether such tools could directly improve and support the field realities of urban sanitation.

The research found that socially-orientated factors appeared to have the potential to impact on sanitation access, households' capacity to improve sanitation access and the success of achieving sustainable service delivery. The role of these factors in achieving sustainable sanitation provision should be explored further. A greater understanding of these factors could lead to the development of guidelines outlining how such factors should and could be incorporated into existing planning approaches and practices.

Further work could also be undertaken to explore how power and politics can have an inhibiting effect on service development overall. Greater understanding of these factors is needed not only for sanitation provision but for basic service delivery in such complex environment, in order to counteract the negative inhibiting effect. The inclusion of members of the planning team who have political expertise should be further explored to acknowledge the advantages of such a set up further.

9.6 Personal Reflection

I would like to take this opportunity to outline some personal reflections related to this research. The research highlighted the wealth of planning approaches and guidelines available in the sector. However limited evidence of their use suggests that they are used infrequently within the sector. This coincided with findings from Lusaka where stakeholders were not even aware of such approaches. Moving forward, the sector needs to do more to ensure that planning approaches are used by planners in the field. Basic information, such as maps and records defining the location of plots, households, institutions and associated infrastructure, level of existing service delivery, tax revenue, roads and pathways within informal settlements and the wider city are not even available. This situation looks to be commonplace in developing countries (and even in developed) where even the basic of technical information is unavailable. The sector needs to strive to ensure that at least the basics are done right. The problems in Lusaka have been known and discussed about for many years. We as a sector must now turn discussions into action before another 30 years passes without any changes being seen.

Another issue surrounds the fact that reuse is the panacea within the sector. Whilst the importance of this component is clear, as discussed in multiple sections of this thesis, by only assigning resources to this component, interventions will be destined to fail as each component of the SVC has equal importance in my view.

The social and political context within which development is undertaken needs to be better understood. Everything we engineer affects people and is being implemented into highly politicised contexts (this is not just the case for developing countries). In particular there is a need to engage at a political level as there has been a tendency to avoid including politics at a formal and informal level due to the perceived enormity of the challenge. Institutions, journals and organisations that focus on social science discuss these issues and the need for change. However, more needs to be done to ensure these factors are entrenched and taken seriously within the field of development and in particular engineering.

Chapter 10. Appendices

Appendix A: Primary data summary

Appendix B: Photographs of surveyed settlements

Appendix C: Questionnaire and interview guides

Appendix D: Sampling frames

Appendix E: Ideal sample size

Appendix F: FSM parameter and calculation index

Appendix G: FSM model results

Appendix H: Achievements during PhD

Appendix A: Primary data summary

Overall 169 households on a total of 169 plots were surveyed. Surveys were conducted in three peri-urban areas of Lusaka.

Table 10-1: Questionnaires conducted per settlement

Name	Sample
Kanyama	58 households
Chazanga	54 households
George	57 households

Semi-structured interviews were conducted with representatives from city and country level organisations (N=35) involved in urban sanitation and solid waste management and community level representatives (N=10) from community based organisations and service providers. Four focus groups were conducted with community level stakeholders. Interviews were conducted during two visits to Zambia. The first in January-April 2013 and the second in December 2013.

Table 10-2: KII conducted at city and country level domains between January-April 2013

Participant	Role	Method	Number
Water and Sanitation for Urban Poor	Manager	Semi-structured interview	1
Water and Sanitation Association of Zambia	Administrative Officer	Semi-structured interview	2
National Water Supply and Sanitation Council	Manager	Semi-structured interview	3
University of Zambia	Lecturer	Semi-structured interview	4
University of Zambia	Lecturer	Semi-structured interview	5
Institute for Eco-Strategies and Toxicology	Scientist	Semi-structured interview	6
Devolution Trust Fund	Engineer	Semi-structured interview	7
Rankin Engineering	Engineer	Semi-structured interview	8
Lusaka City Council	Environmental Officer	Semi-structured interview	9
Ministry of Health	Environmental Officer	Semi-structured interview	10
Lusaka Water and Sewerage Company	Manager	Semi-structured interview	11
World Bank	Water and Sanitation Specialists (x2)	Semi-structured interview	12
CARE International	Manager	Semi-structured interview	13
Water and Sanitation for Urban Poor	Manager	Semi-structured interview	14

Ministry of Heath	Manager	Semi-structured interview	15
University of Zambia	Lecturer	Semi-structured interview	16
Lusaka City Council	Senior Environmental Officer	Semi-structured interview	17
Lusaka City Council, Town Planning Department	Manager	Semi-structured interview	18
Lusaka City Council, Town Planning Department	Planner	Semi-structured interview	19
Lusaka City Council	Pubic Heath Inspector	Semi-structured interview	20
Lusaka City Council	Manager	Semi-structured interview	21
Lusaka Water and Sewerage	Engineer	Semi-structured interview	22
Ministry Of Local Government and Housing	Senior Engineer	Semi-structured interview	23
Lusaka Water and Sewerage Company	Engineer	Semi-structured interview	24
Lusaka Water and Sewerage Company	Community Officer	Semi-structured interview	25
Lusaka City Council	Engineer	Semi-structured interview	26
Water and Sanitation Association of Zambia	Engineer	Semi-structured interview	27
Office of the President	Commissioner	Semi-structured interview	28
Zambia Environmental Management Agency	Inspector	Semi-structured interview	29

Table 10-3: KII conducted at community level domain between January-April 2013

Participant	Role	Method	Number
Kanyama Community Based Enterprises	Solid Waste Management Representatives	Focus group	1
Kanyama Water Trust	Manager	Semi-structured interview	2
Kanyama Ward Development Committee and Lusaka City Council	Local Representatives	Semi-structured interview	3
Chazanga Ward Development Committee	Chairperson	Semi-structured interview	4
George Lusaka Water and Sewerage Company	Staff members (x4)	Semi-structured interview	5
George Water committee	Chairperson	Semi-structured interview	6
Chazanga Water Trust	Manager	Semi-structured interview	7

Table 10-4: KII conducted at city and country level domains in December 2013

Name	Role	Method	Number
Lusaka Water and Sewerage Company	Manager	Semi-structured interview	1
University of Bergen, Norway	PhD Candidate in Department of Comparative Politics	Semi-structured interview	2
World Bank	Water and Sanitation Specialist	Semi-structured interview	3
Water and Sanitation for Urban Poor	Manager	Semi-structured interview	4
Lusaka Water and Sewerage Company	Manager	Semi-structured interview	5
Lusaka Water and Sewerage Company	Engineer	Semi-structured interview	6

Table 10-5: KII conducted at community level domain in December 2013

Name	Role	Method	Number
Zambian Wash Advocacy Group	Team members (x4)	Semi-structured interview	1
Kanyama Ward Development Committee	Members (x4)	Focus group	2
Kanyama Faecal Sludge Management Team	Pit Emptier	Semi-structured interview	3
Chazanga Water Committee	Members (x5)	Focus group	4
George Water Committee	Members (x5)	Focus group	5
George Ward Development Committee	Leader	Semi-structured interview	6
George Health Clinic	Public Health Officer	Semi-structured interview	7

Appendix B: Photographs from surveyed settlements[10]

Figure 10-1: Formalised Pit Emptying Service in Kanyama

Figure 10-2: Typical pit latrine design- picture taken in Kanyama

[10] All pictures taken by Ruth Kennedy-Walker

Figure 10-3: Alternative pit latrine- picture taken in Chazanga

Figure 10-4: Alternative pit latrine design- picture taken in George

Figure 10-5: Drainage channel constructed in Kanyama

Figure 10-6: Pooling of water adjacent to a pit latrine observed in George

Figure 10-7: Typical septic tank design observed- picture taken in Kanyama

Figure 10-8: Typical waste pit used by households- picture taken in George

Figure 10-9: Major pathway- picture taken in George

Figure 10-10: Water kiosk- picture taken in George

Figure 10-11: Open space in Kanyama

Figure 10-12: Stabilisation ponds following Manchinchi WwTP

Appendix C: Questionnaire and interview guides

Household Questionnaire

Date: ____/____/____ **Questionnaire Number:** | | |

Time: ____________ **Zone Number:** | |

Location: ____________ **Household Number:** ____________

Language: ____________ **Initials:** ____________

Introduction made ☐

Authorisation gained ☐

1 Personal questions

1.1 Gender

1. Female
2. Male

1.2 Are you head of the household or spouse?

1. Head of household
2. Spouse

1.3What level of education have you achieved?

1. Grades 1-5
2. Grades 5-7
3. Grades 8-9
4. Grades 10-12
5. Trade school
6. College

1.4 What is your current occupation?
If you do not work what is the current occupation of those who live in the household?

Detail:

2 Household Details

2.1 How many people live in this household?

1. Adults
2. Children

2.2 Do you own or rent your house?

1. Own
2. Rent

2.3 How long have you lived in your current household?

2.4 Where did you live before this household? (Please give approximate distance)

Detail:

2.5 Is anyone in this household a member of any community organisations? Please give detail.

1. Yes
2. No

Detail: (Probe for sanitation related activities)

2.6 Have you at any time been involved in any activities related to sanitation? Including questionnaires, focus groups and organisations. Please give detail.

1. Yes
2. No

Detail: (Probe for sanitation related activities)

3 Sanitation Service Provision

3.1 Where is the toilet facility your household usually uses located?

1. Own plot
2. Neighbours plot
3. Communal Area
4. No access

3.2 Other than your household, who else uses this toilet facility?

1. Your household only (please go to question 3.4)
2. Neighbours (please go to question 3.3)
3. Public (please go to question 3.3)
4. Other (please go to question 3.3)

3.3 How many households use this toilet facility?

3.4 What kind of toilet facility do members of your household usually use?

1. Open Defecation
2. Plastic bag
3. Pit Latrine (Please go to 3.5)
4. Pour flush latrine to septic tank
5. Pour flush to sewer
6. Ecosan Toilet
7. Other

3.5 If you have a pit, what happens when the pit latrine is full?

1. Engage people to empty
2. Build a new pit
3. Abandon and use neighbours
4. Abandon and use local facilities
5. Use flying toilet
6. Other

3.6 Who provided your toilet facility?

1. Myself
2. Landlord
3. Other
4. Don't Know (Please give reasons why below)

Reasons:

3.7 Do you know how this toilet facility was constructed?

1. Yes (Please detail)
2. No
3. Don't Know

Detail: **(technology type, materials, construction materials, construction techniques, who constructed, diagram)**

3.8 Did you have a choice about the type of toilet facility that was constructed?

1. Yes ***(please give detail as to why you chose this type of facility.)***
2. No
3. Don't Know

Detail:

3.9 Who do you think is responsible for providing a toilet facility for your household? Please give reasons for answer.

1. Myself
2. Landlord
3. Other
4. Don't Know (Please give reasons why below)

Reasons:

3.10 Do you know of any laws or bylaws (LCC or LWSC) related to peoples access to a toilet facility? Please give details.

1. Yes
2. No
3. Don't Know

Details:

3.11 Do you think lack of access to adequate sanitation can cause the following things? (please tick)			
	1. Yes	2. No	Don't Know
1. Contamination to drinking water			
Please explain:			
2. Health issues	1. Yes)	2. No)	3. DN)
Please explain:			
3. Reduction in life expectancy	1. Yes)	2. No)	3. DN)
Please explain:			
4. Increased health care costs	1. Yes)	2. No)	3. DN)
Please explain:			
5. Increases number of days lost at work/school	1. Yes)	2. No)	3. DN)
Please explain:			
6. Reduction in available household expenditure	1. Yes)	2. No)	3. DN)
Please explain:			
7. Reduction in Property Value	1. Yes)	2. No)	3. DN)
Please explain:			
8. Harms the environment	1. Yes)	2. No)	3. DN)
Please explain:			

3.12 Do you know what happens to the human waste once it enters your toilet facility? Please explain. Do you know how human waste is treated? Please explain.

1. Yes (Please explain below)
2. No
3. Don't Know

Explanation given:

3.13 Do you know how human waste is treated? Please explain.

1. Yes (Please explain below)
2. No
3. Don't Know

Explanation given:

3.14 Is the treatment of human waste important? Please give reasons for your answer.

1. Yes
2. No
3. Don't Know

Reasons:

3.15 Do you think it is safe to use human waste as a fertiliser after it has been treated? Please give reasons for your answer.

1. Yes
2. No
3. Don't Know

Reasons:

3.16 What is your current access to garbage disposal?

1. Household collection
2. Use pit
3. No access
4. Other

3.17 Are you currently experiencing any difficulties with your garbage (solid waste) disposal? Please give detail.

1. Yes
2. No
3. Don't Know

Detail Given:

4 Attitudes

4.1 Please indicate your agreement with the following statements using the scale provided (1= strongly disagree; 2= disagree; 3=neutral; 4= agree; 5= strongly agree) Please give detail.		
		Score
1.	I am happy with my household's current access to a toilet facility.	
2.	I am happy with the quality of water access service that the Water Trust provides me with.	

3.	The local government should do more to provide my household with access to a toilet facility.	
4.	Households should not be responsible for providing their own toilet facility.	
5.	Nobody understands my sanitation access needs.	
6.	I would like to have more knowledge about how to design and construct my toilet facility.	
7.	The community should do more to provide my household with access to a toilet facility.	
8.	The Water Trust is responsible for providing my household with access to sanitation.	
9.	I would like to be part of a community group whose focus is to find ways to improve sanitation access within my community.	
10.	I am happy to pay for an improved toilet facility.	

4.2 Do you have any further comments you would like to make about the sanitation situation in your community?

5 More personal questions

5.1 What is your age?	

5.2 What is your household approximate weekly income?	

5.3 How much do you currently pay for these service provisions (per month)?		
1.	Access to Health Services	
2.	Access to Education	
3.	Access to Energy	
4.	Access to Sanitation	
5.	Access to Water	
6.	Access to Solid Waste Management	

6 Observations

6.1 Title of GPS point taken for house	
6.2 GPS reading of house	**S:**
	E:
6.3 Title of GPS point taken for toilet (if away from household)	
6.4 GPS reading of toilet	**S:**
	E:

6.5 Observations with regard to sanitation facility (please tick)	
1. Clean facility in obvious use	
2. Odour-free facility	
3. No flies or other vectors	
4. No feacal matter lingering	
5. hand-washing facility in obvious use	
6. Lid on latrine	
7. 24-hr access to facility year-round	
8. Facility offering privacy, personal safety and shelter	
9. Facility is able to use for women, men, children, elderly, handicapped	
Please detail: technology type in use (Type, material, roof, general appearance, access via road and access to vault)	

6.6 Observations with regard to surrounding environment (please tick)	
1. Environment surrounding household is clean	
2. No garbage surrounding the household	
3. No flooding apparent	
4. Road access available to household	
5. Collection system for household garbage	
6. Easy to undertake pit emptying (i.e. pit is easily accessible)	

<u>THE END</u>

Community level semi-structured interview guide

1. Introduction, Gender, Age, Occupation, Time in Post, Education
2. What services do you think are of the highest priority to Households in this community?
3. Do you think sanitation is important?
4. Which part of provision do you think is most important (toilet, emptying, treatment or reuse?)
5. Do you think access to sanitation is currently adequate?
6. What do you think access to adequate sanitation means?
7. What is your involvement in sanitation in this community?
8. How do the community get involved in sanitation provision activities? Can this be improved? Do they get involved in planning?
9. Do you think community's knowledge about sanitation technologies has an impact in achieving access?
10. Whose responsibility is it to provide access to sanitation in these communities?
11. Are there any laws which ensure these services are provided?
12. Who do you think should pay for improved access?
13. How do you think communities can be encouraged to pay for improved access?
14. Do you think Solid Waste Management activities interact with sanitation? How?
15. Is current access to Solid Waste Management Services adequate? If not, how could it be improved?

Ask about number of zones, cost of technological components in communities and maps of zones

City level semi-structured interview guide

1. Department and Role
2. Involvement in sanitation provision in low- income communities
3. How are sanitation services currently planned and implemented?
4. How are you involved in planning (techniques used, theory participation, post evaluation, Operation and Maintenance, Accountability)
5. What is the role of communities to achieve access to improved sanitation?
6. Do you think this role can be changed?
7. What services do you think are the highest priorities to people in Low Income Communities?
8. If so, why do you think Sanitation is of Low priority?
9. How do you think access to sanitation could be improved? How do you think this could be achieved?
10. Do you think current policy and legislation for sanitation service provision is suitable? How could it be improved?
11. How are sanitation services currently funded?
12. How do you think communities could be encouraged to pay for improvements in sanitation provision?
13. Do you think communities knowledge about sanitation impacts on them achieving access?
14. Do you think the interaction between Sanitation and Solid Waste is important? Do you have any suggestion as to how access to Solid Waste Management could be improved?

Appendix D: Sampling frames

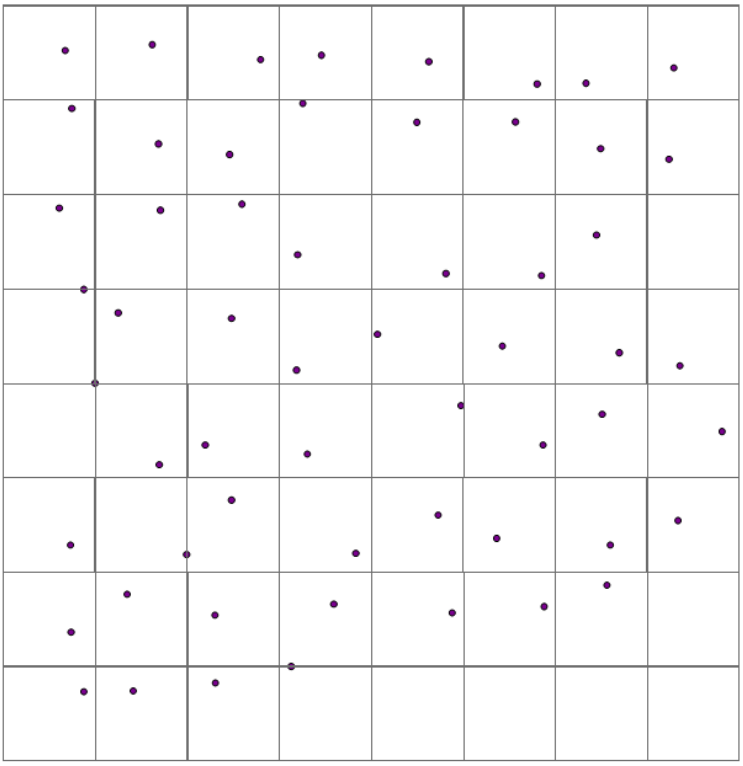


Figure 10-13: Sampling frame for Kanyama

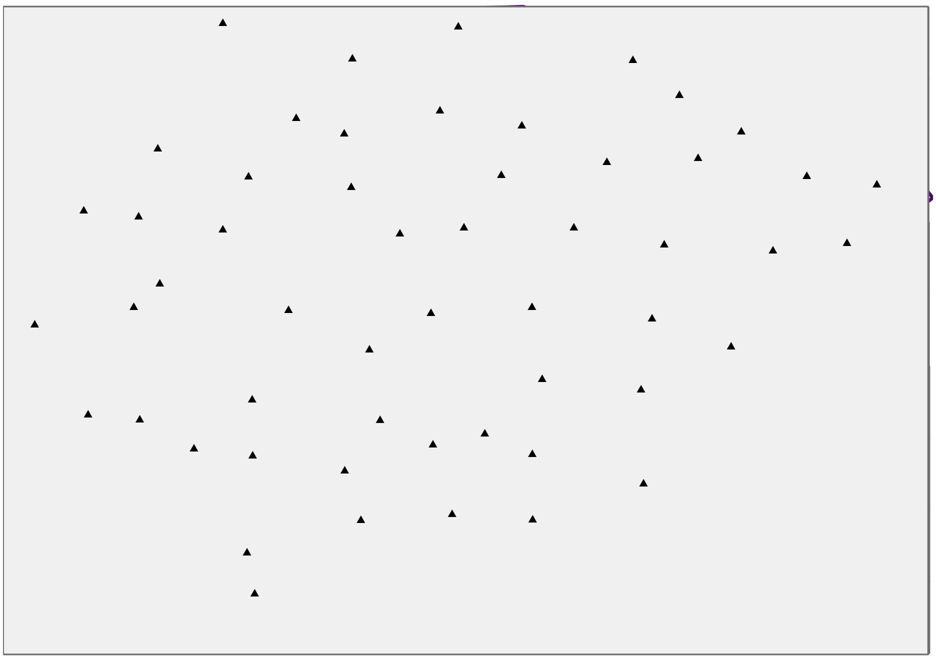


Figure 10-14: Sampling frame for Chazanga

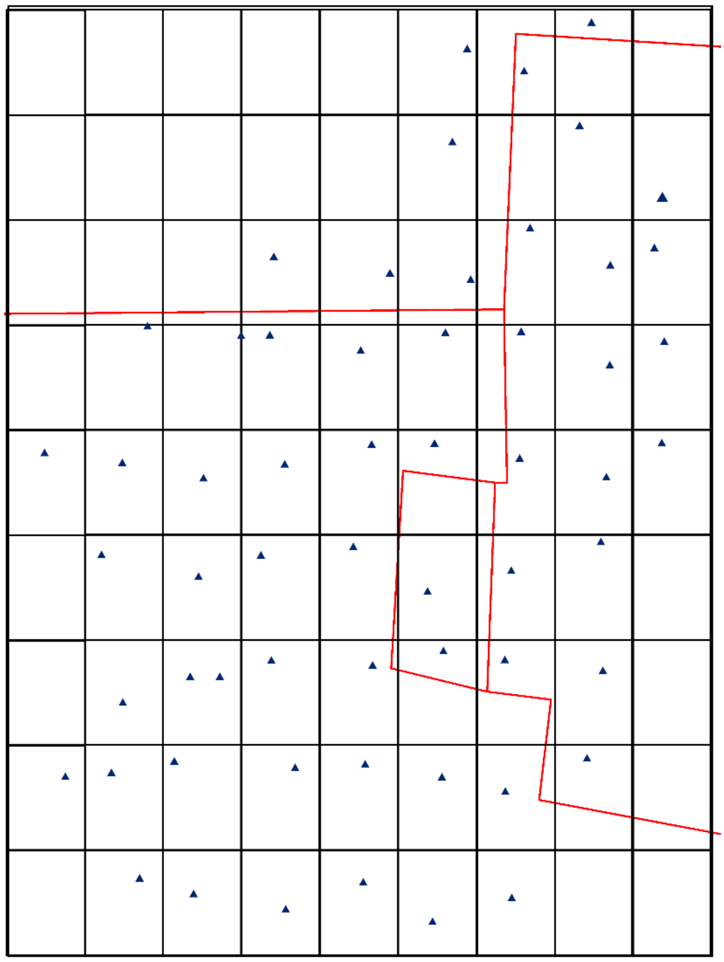


Figure 10-15: Sampling frame for George

Appendix E: Ideal sample size

An estimation of the ideal sample size for this study was established using the following equation:

$$n = \frac{t^2 * p\ (1-p)}{m^2}$$

(WHO, 1986; IFAD, 1999)

n= required sample size

t= confidence level

p= anticipate population proportion

m=margin of error

Due to difficulty in estimating the anticipated population proportion (p) a figure of 0.5 was used (which provides the biggest proportion of sample size). A margin of error of 5% was used. A contingency of 5% was added to the result of the equation above to account for contingences such as non-response or recording error. The table below highlights the required samples for varying confidence levels.

Confidence level	90%	95%	99%
Required sample size	284	403	699

Appendix F: FSM parameter and calculation index

Table 10-6: Complete catalogue of input parameters

Network data	Symbol	Unit	Kanyama Value	Chazanga Value	
Number of collection points	N_c	-	65	42	
Number of TS (single)	T_s		1	1	
Number of TS (multiple)	T_m		5	4	
Collection points to end point Scenario 1A	d_{ce}	km	333.68	88.67	
Collection points to end point Scenario 1B		km	192.89	79.23	
Collection points to end point Scenario 3		km	116.74	116.30	
Collection points to transfer station Scenario 2	d_{ct}	km (single TS)	111.15	70.77	
		km (multi TS)	77.34	60.90	
Collection points to transfer station Scenario 3		km (single TS)	111.15	70.77	
		km (multi TS)	77.29	60.90	
Transfer station to end point Scenario 2	d_{te}	km (single TS)	8.01	9.57	
		km (multi TS)	24.64	25.67	
Transfer station to end point Scenario 3		km (single TS)	4.02	10.79	
		km (multi TS)	14.52	28.21	
Socioeconomic data	**Symbol**	**Unit**	**Kanyama Value**	**Chazanga Value**	
Baseline population	N_p	cap	137,000	86,000	
Number of people per household	$N_{p,h}$	cap	6	6	
Annual population rate	r_g	%/ year	4.2		
Average number of households per facility	$N_{h,f}$	-	3	2	
Minimum Wage	C_w	US$/ day	0.68		
Working Hours	W_h	hours/ day	8		
Working Days	W_d	days/ week	5.5		
Working Weeks	W_w	weeks/ year	45		
Fuel price (petrol)	C_f	US$/ litre	1.48		
Discount Rate	r_d	%/year	12		
Inflation Rate	r_i	%/year	9.5		
Filling rate parameters	**Symbol**	**Unit**	**Kanyama Value**	**Chazanga Value**	
Sludge generation rate	r_s	m^3/cap/year	0.06		
Current pit size	V_p	m^3	2.6		
Transportation equipment data	**Symbol**	**Unit**	**Vacutug (U_v)**	**Vacuum Tanker (U_{vt})**	**Manual Cart (U_{mc})**
Cost per unit of equipment	C_{tr}	US $/ unit	15,000	50,000	800
Shipping costs	C_{str}	US $/ unit	8,000	-	-
Maintenance	C_{mtr}	%/ year	10	10	10
Wear and Tear	C_{wttr}	%/ year	7	7	20
Economic life	L_{tr}	years	4	10	3
Fuel usage	F_1	litres/ km	0.2	0.5	

Vacuum Pump Fuel Usage	F_2	litres/hr	6	10	
Oil usage	F_3	US$/ year	-	-	
Volume	V_{tr}	m^3	2	10	0.33
Speed	**S**	km/ hour	2.5	35	2.5
Number of operators	N_{otr}	-	3	3	4
Time to fill tank	T_f	minutes	10	15	40
Preparation and setting up	T_p	minutes	30	15	30
Transfer station (I_{ts}) parameters	**Symbol**	**Unit**	**Kanyama Value**	**Chazanga Value**	
Cost per unit	C_{ts}	US $/ unit	100,000		
Operation and Maintenance	C_{omts}	%/ year	10		
Economic life	L_{ts}	years	25		
Volume	V_{ts}	m^3	135		
Number of operators	N_{ots}	-	2		
Sewer discharge station (I_{sds}) parameters	**Symbol**	**Unit**	**Kanyama Value**	**Chazanga Value**	
Cost per unit	C_{sds}	US $/ unit	40, 000		
Operation and Maintenance	C_{omsds}	%/year	10		
Economic life	L_{sds}	years	25		
Volume	V_{sds}	m^3	50		
Number of operators	N_{osds}	-	2		
Sewer discharge station (U_p) parameters			**Value**		
Cost per unit (pump)	C_{sdsp}	US $/ unit	40, 000		
Operation and Maintenance	C_{omsdsp}	%/year	10		
Economic life	L_{sdsp}	years	5		
Community level treatment facility (I_{clt}) parameters		**Unit**	**Kanyama Value**	**Chazanga Value**	
Cost per unit	C_{tf}	US $/ unit	600,000	400,000	
Operation and Maintenance	C_{omtf}	%/year	10	10	
Economic life	L_{tf}	years	25	25	
Volume	V_{tf}	m^3	100	60	
Number of operators	N_{otf}	-	2	2	
Disposal costs		**Unit**	**Value**		
Charge	C_d	per m^3 dumped	5.6		

Table 10-7: Calculations to determine baseline cost per unit of transportation equipment

Calculation	Unit	Equation
Total capital cost, C_{CAPtr}	**US \$/unit**	$\mathbf{C_{CAP} = C_{tr} + C_{str}}$
Maintenance cost, C_{maintr}	**US \$/year.unit**	$C_{main} = \frac{C_{mtr}}{100} \times C_{tr}$
Wear and tear cost, C_{weartr}	**US \$/year.unit**	$C_{wear} = \frac{C_{wttr}}{100} \times C_{tr}$
Labour cost, $C_{labourtr}$	**US \$/year.unit**	$C_{labour} = C_w \times N_{otr} \times W_h \times W_d \times W_w$
Fuel and oil cost, C_{fueltr}	**US \$/year.unit**	$C_{fuel} = (C_f \times F_1 \times (d_{ce}/d_{ct}/d_{te}) + (F_2 \times T_f \times N_{trips} \times W_d \times W_w) + F_3$
Total O&M cost, C_{OMtr}	**US \$/year.unit**	$\mathbf{C_{OM} = C_{main} + C_{wear} + C_{labour} + C_{fuel}}$

Table 10-8: Calculations to determine operational capacity per unit of transportation equipment

Calculation	Unit	Equation
Total time per trip, T_{trip}*	hours	$T_{trip} = \frac{(d_{ce}/d_{ct}/d_{te})}{N_c \times S} + \frac{T_f + T_p}{60}$
Number of trips per day, N_{trips}	-	$N_{trips} = \frac{W_h}{T_{trip}}$
Operational capacity, V_{year}	**m^3/year.unit**	$\mathbf{V_{year} = N_{trips} \times W_d \times W_w \times V_{tr}}$

Table 10-9: Calculations to determine population growth and equipment quantities required per settlement

Calculation	Unit	Equation
Population in year t, $N_{p,t}$		$N_{p,t} = N_p \text{ x } (1+(r_g/100))^t$
Total FS generated, V_{FS}	m^3	$\mathbf{V_{FS} = N_{p,t} \text{ x } r_s}$
Total number of transportation equipment units required per year, U_{tr} (U_V, $U_{vt,}$, U_{mc})		$\mathbf{U_{tr} = V_{FS} / V_{year}}$
Total number of transfer stations required per year, U_{ts}		$\mathbf{U_{ts} = T_s \text{ or } T_m}$
New equipment units to be purchased taking into consideration population growth and economic life, U_{new}		$\mathbf{U_{new} = (U_{tr}/U_{ts}/U_p) +}$ **OFFSET** $\mathbf{(L_{tr}/L_{ts}/L_p)}$

Table 10-10: Calculations to determine baseline cost per unit of infrastructure

Calculation	Unit	Equation
Total capital cost, C_{CAPi}	**US \$/unit**	$\mathbf{C_{CAPi} = C_{ts} / C_{sds} + C_{sdsp}/C_{tf}}$
Maintenance cost, C_{maini}	**US \$/year.unit**	$C_{maini} = \frac{C_{omts}/C_{omsds} + C_{omsdsp}/C_{omtf}}{100} \times C_{tr}$
Labour cost, $C_{labouri}$	**US \$/year.unit**	$C_{labouri} = C_w \times (N_{ots}/N_{osds}/N_{otf}) \times W_h \times W_d \times W_w$
Total O&M cost, C_{OMi}	**US \$/year.unit**	$\mathbf{C_{OMi} = C_{maini} + C_{labouri}}$

Table 10-11: Calculations for projected costs for transportation

Year, t	Total number of units required, U_{tr}	Number of new units, U_{new}	Factor for inflation, I	Total CAPEX (US $) for U_V, U_{vt}, U_{mc}	Maintenance cost, M (US $) for U_V, U_{vt}, U_{mc}	Wear and tear cost, W (US $) for U_V, U_{vt}, U_{mc}	Labour cost, Lab (US $) for U_V, U_{vt}, U_{mc}	Fuel and oil cost, FO (US $) for U_V, U_{vt}, U_{mc}	Total OPEX (US $) for U_V, U_{vt}, U_{mc}	Total Expenditure (US $) for U_V, U_{vt}, U_{mc}
(0-24)	U_V, U_{vt}, U_{mc}	U_{tr}	$I = 1+(r_i/100))^t$	$CAPEX_{tr} = C_{CAPtr} \times U_{new\ tr} \times I$	$M_{tr} = C_{maintr} \times U \times I$	$W_{tr} = C_{weartr} \times U \times I$	$Lab_{tr} = C_{labourtr} \times U \times I$	$FO_{tr} = C_{fueltr} \times U \times I$	$OPEX_{tr} = C_{OMtr} \times U \times I$	$= CAPEX_{tr} + OPEX_{tr}$

Table 10-12: Calculations for projected costs for fixed infrastructure

Year, t	Total number of units required, U_i	Number of new units, U_{new}	Factor for inflation, I	Total CAPEX (US $) for I_{ts}, I_{sds}, I_{clt}	Maintenance cost, M (US $) I_{ts}, I_{sds}, I_{clt}	Labour cost, Lab (US $) for I_{ts}, I_{sds}, I_{clt}	Total OPEX (US $) for I_{ts}, I_{sds}, I_{clt}	Total Expenditure (US $) for U_V, I_{ts}, I_{sds}, I_{clt}
(0-24)	I_{ts}, I_{sds}, I_{clt}	U_{ts}/U_p	$I = +(r_i/100))^t$	$CAPEX_i = C_{CAPi} \times U_{new} \times I$	$M_i = C_{maini} \times U \times I$	$Lab_i = C_{labouri} \times U \times I$	$OPEX_i = C_{OMi} \times U \times I$	$= CAPEX_i + OPEX_i$

Table 10-13: Calculations for NPV

Year, t	Total number of units required, U_{tr}	Volume of FS emptied (m^3)	Factor for PV, PVF	PV CAPEX (US $)	PV Maintenance costs (US $)	PV Wear and tear cost (US $)	PV Labour cost (US $)	PV Fuel and oil cost (US $)	PV Total Expenditure (US $)
(0-24)	U_{tr}	$= U \times V_{year}$	$PVF = 1/(1+(r_d/100))^t$	= CAPEX(tr+i) x PVF	= M(tr+i) x PVF	= W(tr+i) x PVF	= Lab(tr+i) x PVF	= FO(tr+i) x PVF	= (CAPEX(tr+i) + OPEX(tr+i)) x PVF

Table 10-14: Calculations for AIC

Year, t	Number of people per latrine*, $N_{p,l}$	FS generated per latrine, $V_{FS,l}$ (m^3)	Time between emptying events, T_e (years)	Emptying Frequency (events per year)
(0-24)	$N_{p,l} = N_{p,h} \times N_{h,l} \times (1+(r_g/100))^t$	$V_{FS,l} = N_{p,l} \times r_s$	$T_e = V_p / V_{FS,l}$	$= 1/T_e$

Table 10-15: Calculations for pit latrine emptying frequency

Year, t	Total Expenditure (US $)	Factor for inflation, I	Total User Charge (US $)	Net Cash Flow, C_t (US $)	Present Value (US $)[2]
(0-24)	= CAPEX(tr+i) + OPEX(tr+i)	$I = (1+(r_i/100))^t$	= variable charge x $(N_p/N_{p,h})$ x I	C_t = Total Expenditure - Total user charge	$= C_t/(1 + r_d)^t$

Appendix G: FSM model results

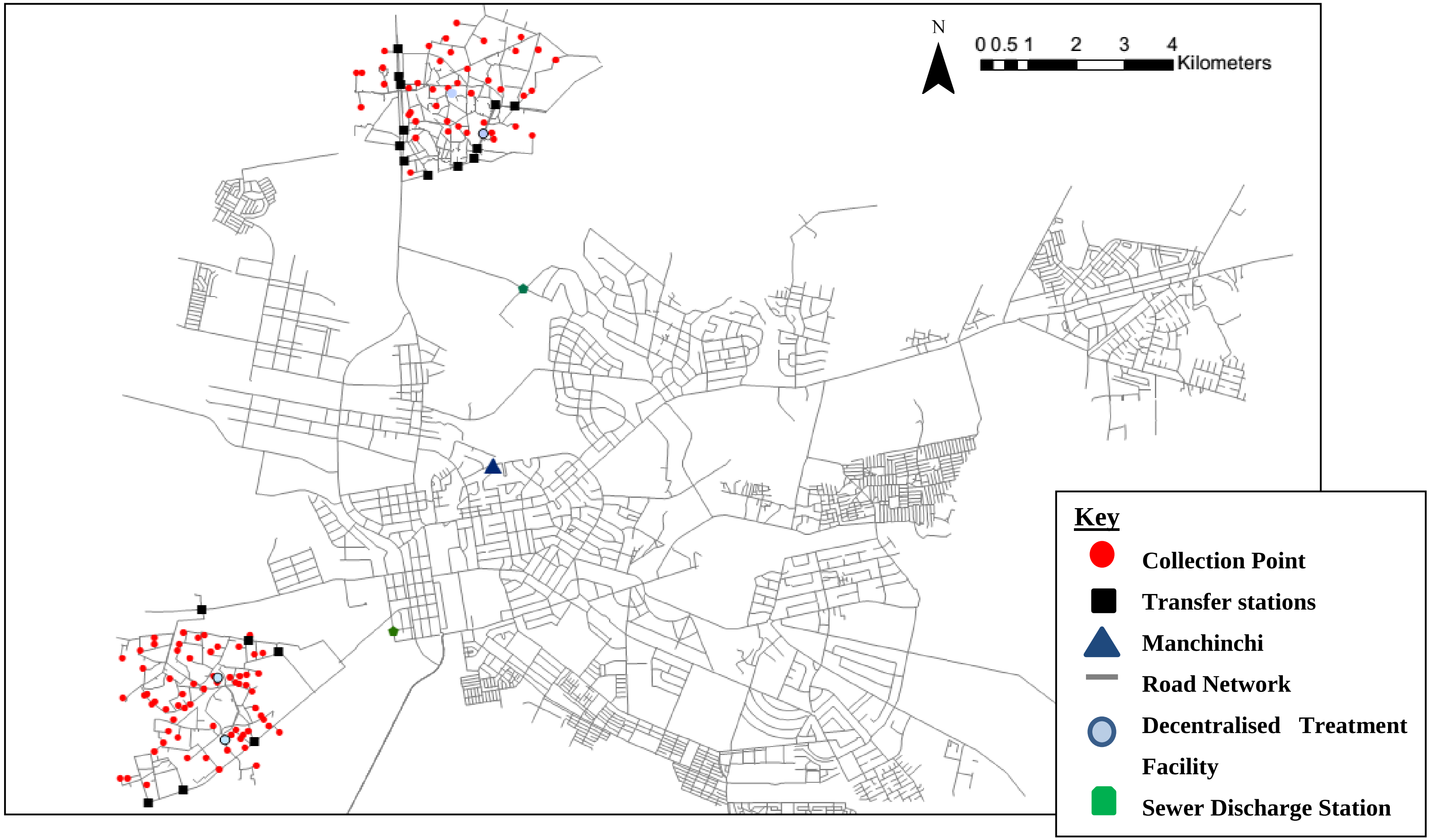


Figure 10-16: Complete transportation network and fixed infrastructure scenarios analysed

Results tables of Network X model results for optimisation

Table 10-16: Network X model results for 'single TS' variation, Kanyama, Scenario 2A

TS ID code	Kanyama Vacutug time (mins)	Lusaka Large Tanker Time (mins)	Weighted sum total time (mins)
2084	3988.9694309	48.7066078	4373.75163252
3759	2715.7792246	13.0003457	2818.48195563
1106	3923.2953509	47.5934878	4299.28390452
2585	2945.9150084	13.9996847	3056.51251753
1668	**2667.6627909**	**13.7351778**	**2776.17069552**
271	3136.5730089	24.0499546	3326.56765024

Table 10-17: Network X model results for 'single TS' variation, Kanyama, Scenario 3A

TS ID code	Kanyama Vacutug time (mins)	Lusaka Large Tanker Time (mins) to SDS	Weighted sum total time (mins)
2084	3988.9694309	41.858875486	4319.65454724
3759	2715.7792246	6.152613386	2764.38487035
1106	3923.2953509	40.745755486	4245.18681924
2585	2945.9150084	8.419554286	3012.42948726
1668	**2667.6627909**	**6.887445486**	**2722.07361024**
271	3136.5730089	17.202222286	3272.47056496

Table 10-18: Network X model results for 'multiple TS' variation, Kanyama, Scenario 3B

TS ID code	Count	Kanyama time	Lusaka time	Total sum weighted time
271	11?	NaN	9.4612222573	NaN
1668	27	753.0514141	9.2980514061	762.349466
2084	3	47.71168	6.2788313229	53.990511
2585	17	903.189683	7.1566211431	910.346304
3759	7	151.0732595	2.1534146851	153.226674

Table 10-19: Network X model results for 'single TS' variation, Chazanga Scenario 2A

TS ID code	Chazanga Vacutug time (mins)	Lusaka Large Tanker Time (mins)	Weighted sum total time (mins)
1888	2143.4205414	30.3300626	2383.02803594
3138	2036.64228632	52.4277237	2450.82130355
2728	2395.3545928	28.2261649	2618.34129551
2447	1857.01977286	64.1951128	2364.16116398
848	2266.1523994	25.1499222	2464.83678478
1748	2112.07139266	71.9408309	2680.40395677
2325	1846.9363401	31.1517772	2093.03537998
1946	2702.5497041	78.8874987	3325.76094383
3548	1946.39679532	55.7891602	2387.1311609
4061	**1698.5224482**	**16.415508**	**1828.2049614**
1182	1753.7578766	14.4936066	1868.25736874
3317	2103.08378852	44.6185316	2455.57018816

Table 10-20: Network X model results for 'single TS' variation, Chazanga, Scenario 3A

TS ID code	Chazanga Vacutug time (mins)	Lusaka Large Tanker Time (mins) to SDS	Weighted sum total time (mins)
1888	2143.420541	32.40368231	2399.409632
3138	2036.642286	54.50134341	2467.202899
2728	2395.354593	30.29978461	2634.722891
2447	1857.019773	66.26873251	2380.54276
848	2266.152399	27.22354191	2481.21838
1748	2112.071393	74.01445061	2696.785552
2325	1846.93634	33.22539691	2109.416976
1946	2702.549704	80.96111841	3342.14254
3548	1946.396795	57.86277991	2403.512757
4061	**1698.522448**	**18.48912771**	**1844.586557**
1182	1753.757877	16.56722631	1884.638964
3317	2103.083789	46.69215131	2471.951784

Table 10-21: Network X model results for 'multiple TS' variation, Chazanga Scenario 3B

TS ID code	Count	Chazanga time	Lusaka time	Total sum weighted time
1182	8	356.1697599	6.626890524	362.79665
1748	3	47.224683	11.10216759	58.326851
3548	1	12.5791474	2.893138996	15.472286
4061	30	1045.608599	27.73369157	1073.34229
		1461.582189	**48.35588868**	**1509.938077**

Compact Disc Contents

Please see attached CD-ROM for copies of all the spreadsheets used for this analysis. Data included for each location, scenario and variation;

- Input variables
- Population growth and emptying equipment quantities
- Emptying frequencies
- Projected costs
- NPV calculations
- AIC calculations
- Containment facility optimisation results

Appendix H: Achievements during PhD

The following presentation and conferences have resulted from work conducted as part of this PhD research.

1. Oral platform and poster presentation given at the IWA Development Congress, Nairobi, Kenya in October 2013.

2. Oral platform and poster presentation given at the WASH Conference 2014, Brisbane, 24 – 28th March 2014.

3. Oral seminar presentation given at SMART Infrastructure facility, University of Wollongong, Australia on the 2nd April 2014.

4. Oral seminar presentation given at Nanyang Technological University, Singapore on the 4th April 2014.

5. Oral presentation given at the SanCoP 15 event on 'Faecal Sludge Management and Wastewater Treatment' on November 4th at Leeds University, UK.

6. Oral presentation given at Faecal Sludge Management II conference in Hanoi, Vietnam, January 2015.

1. UK SanCoP Coordinator

Throughout my PhD (2012-Present) I have held the role as one of three coordinators for the UK Sanitation Community of Practice Network. The UK Sanitation Community of Practice (SanCoP) was created in 2008 and aimed is to strengthen the UK sanitation sector and provide a forum for learning and debate. SanCoP events bring together a wide range of professionals with an interest in sanitation from academic and research institutions, NGOs, public and private organizations. My role includes the planning and organising of meeting (themes, logistics, speakers, attendees) preparation and distribution of agenda/minutes and updating the website and communication outputs. My PhD studies have helped me within this role as my growing expertise in the sector have enabled me to chair debates, present at meeting and to ensure meeting topics have been novel/ in line with the sectors requirements.

2. Intern at the Water and Sanitation Program, World Bank. Jakarta.

From February to June 2014 I completed an internship with the urban sanitation team at WSP in Jakarta. The focus of the internship was to work alongside the in country team who were currently completing an in depth analysis of the current Fecal Sludge Management (FSM) arrangements for three cities in Indonesia. My role was to focus on one of the cities (Balikpapan) and complete a more in-depth situational analysis in line with a global FSM study being conducted by WSP in 5 countries for 2014/2015. The internship allowed me to put what I had learnt during my own PhD Research into practice in a development organization. I felt that technical knowledge, independent thinking and fieldwork experience gained during my PhD research related to urban sanitation and Faecal Sludge Management helped me to complete the internship with success.

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