

Slum Growth and Space Transformation: The Implication on Service Delivery and Environment

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Declaration

I **Kimotho Gathogo** hereby certify that this is my original work and it has not been presented to any other academic or professional institution for scholarly purposes or otherwise.

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Dedication:

This work is dedicated to all the hard working Kenyans living in slum areas who wake up before the break of dawn to walk to work and have to walk back home each evening just to save a few shillings in order to make ends meet.

Keep the fire burning, tomorrow, will be a better day.

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To God be the Glory.

Abstract

This research study investigated slum growth and transformation and the associated implications on the environment and service delivery in Mukuru Settlement between September 2013 and October 2014. The study particularly sought to quantify the spatial growth of the Mukuru slums and establish whether there has been any change in character in the slum ultimately establishing the implications this growth has had on service provision and on the environment. Aerial photographs of 1978 and 1998 were used together with a Quick Bird Satellite image with a 1meter resolution being used to quantify growth and assess change in character. A field survey was then conducted using a sample size of 195 with the household being the target. Data was analysed using SPSS statistics software and ArcGIS spatial analysis software and presented in tables and charts.

The study established that the Mukuru kwa Njenga and Mukuru kwa Reuben slums have grown spatially from zero hectares in 1978 to approximately 125 hectares and approximately 77 hectares by year 2008 respectively. The study also established that there has been a change in character of the settlements which has had a positive impact on service provision with the settlements developing post-1998 having a higher access to services as compared to the settlements that developed pre-1998. In view of these findings, the study made several conclusions. First is that, the Mukuru slums developed from about 1978 with most growth seen between years 1998 to 2008. Second is that there had been a change in character of the settlement and this had a positive impact on access to services in the settlement. Thirdly is that the poor waste disposal was having a major negative impact on Ngong' river. The study therefore recommended that the solution to the identified problems lie in proper planning of the settlement by ensuring proper implementation and enforcement of prerequisite laws. It recommended that youths in these settlements should be empowered and facilitated to be able to assist in delivering some of the services for example garbage collection. The study also recommended advocacy on awareness and behaviour change on waste disposal methods.

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Acronyms

ABM- Agent Based Modelling

APHRC- African Population and Health Research Centre

CBO-Community Based Organizations

CURI- Centre for Urban Research and Innovations

DC- Developing countries

GIS- Geographic Information Systems

GPS- Global Positioning Systems

IIED-International Institute on Environment and Development

IS- Informal Settlements

KNBS- Kenya National Bureau of Statistics

KP-Kenya Power

MPRA- Munich Personal RePEc Archive

NGO-Non-Governmental Organization

OPP-RTI -Orangi Pilot Project-Research and Training Institute

RCMRD- Regional Centre for Mapping of Resources for Development

RS-Remote Sensing

SoK-Survey of Kenya

UN-Habitat- United Nations Human Settlements Programme

UNDP- United Nations Development Programme

UNON- United Nations Office in Nairobi

1.0 Introduction

1.1 Background

Around 3 billion people virtually half of the world's total population-now live in urban settlements. And while cities command an increasingly dominant role in the global economy as centres of both production and consumption, rapid urban growth throughout the developing world is seriously outstripping the capacity of most cities to provide adequate services for their citizens. (Cohen, 2006) National government and local authorities are faced with the serious challenge of guiding the physical growth of urban areas and providing adequate services for the growing urban population. (UN-Habitat, 2008) Due to the inability to match urban population growth and provision of quality housing, it therefore leads to emergence of slums. Slums and informal settlements are growing at an alarming and unprecedented rate in Kenya not only in Nairobi but also in other urban centres in the country. Nairobi, Kenya's capital is the most affected in the country. Rural- Urban migration in search of employment opportunities is the main cause for the high influx of people in the city.

Studies indicate that approximately 60% of the population lives in slums that occupy only 5% of the total land area in Nairobi. This has therefore resulted in straining the available urban services like housing and social infrastructure like clean piped water, electricity and other social amenities and facilities. The environmental effects have affected the ecosystem. The social impacts like resultant crime, drug abuse and prostitution are a major challenge to the social fabric. Mitullah (2003) indicated that between 1971 and 1995, the estimated population of informal settlements in Nairobi increased from 167,000 to some 1,886,000 individuals. The share of informal-settlement village inhabitants rose from one third to an estimated 60 per cent of the total urban population in Nairobi. In an article titled *Patterns of Urbanization and Socio-Economic Development in the Third World: An overview* by Hay (2007), the author notes of two predominant trends. The third world is urbanizing at an ever increasing rate and, although it is still populated largely by rural people, its socio-economic organization is increasingly articulated in urban systems.

The second issue is that urbanization in the Third World has not been accompanied by concomitant economic prosperity as it was in western nations. Quite in the contrary, it has

been paralleled by increasing inequity in income and material amenities. Kenya's annual informal settlements growth rate of 5%, is the highest in the world and it is likely to double in the next thirty years if positive intervention measures are not put in place (UNDP, 2007). Kenya's urban population stood at 34 percent of total population. (UN-Habitat, 2007) The enormous size of urban populations and more significantly, the rapidity with which urban areas have been and are growing in many developing countries have severe social, economic and physical repercussions. (Hove et. al, 2013)

In Kenya, research on the social and economic dynamics has been done in the informal settlements mostly in the capital Nairobi. Most of these researches concentrated on the living conditions in the informal settlements and how they could be improved mainly with respect to housing and service provision. With the advancements in technology allowing for capture of data of a given phenomenon without coming into contact with it using satellite remote sensing, this research study concentrated on one of the poorest informal settlements in Nairobi, Kenya known as the Mukuru slums. They are composed of a number of villages mainly Mukuru kwa Njenga, Mukuru kwa Reuben and Mukuru Kaiyaba. The study concentrated on a temporal period of the last thirty years from about 1978 to 2008 and it investigated two main issues. The first is the changes experienced in the spatial growth of the area occupied by the slum and the probable drivers of that change. The change was quantified in square kilometres. The second issue was to identify and look into the change in character and spatial characteristics of this informal settlement. Moreover, the study was interested in identifying and understanding the resulting impacts of that change with respect to service provision and livelihoods mostly on issues pertaining to availability of services like clean water, electricity, roads and garbage collection.

1.2 Problem Statement

The Mukuru slums in Nairobi's Eastlands area are some of the many informal settlements in Nairobi others include Kibera, Majengo, Mathare and Korogocho amongst others. These informal settlements are characterized by certain aspects, three of which were concentrated upon in this research study. The first one is the issue of service provision. In Nairobi, the County government of Nairobi is mandated with providing services to every inhabitant of the city regardless of whether they live in high income areas, middle income areas or low

income areas. Unfortunately the Mukuru slums are characterized by the lack of basic infrastructure for example roads, clean piped water and sewer systems. Actually a study by the UN-Habitat indicates that only 4% of households in slum areas in Nairobi have access to piped water with a vast majority relying on water kiosks. This has mainly been as a result of failure on the side of the authorities but also the spatial arrangement of the developments in Mukuru slums does not help the situation. Due to the haphazard building of structures, service delivery becomes very complicated since almost any open space is occupied.

This research study assessed the existing situation and the changes over time that have been experienced in the character and spatial patterns of developments in the Mukuru slums and their impacts on development of infrastructure for example water, sanitation and road networks.

This research study used remotely sensed imagery and aerial photographs to identify settlement growth overtime and land use changes. The third issue regards the impacts that the growth of Mukuru slum has had on the environment. With the expansion of the Mukuru slums, this resulted in serious environmental impacts for example regarding the expansion of the slum onto the riparian reserve of the *Ngong'* river that cuts across the slum. Urban and Regional Planners are expected to provide solutions on how to prevent, control and curb growth of informal settlements. This research study has developed a slum growth model that shows how the slum has been growing spatially in the last three decades and at what rates. This will enable planners understand growth dynamics of informal settlements.

The study then proposes changes to the spatial character and arrangement of the slum area that will favour development of infrastructure and delivery of services.

To monitor the growth of informal settlements, planners have been using traditional methods for example census to estimate the population in informal settlements. Area topographic maps have also been used to map these informal settlements. However, due to the rapid changes taking place in this informal settlements, it therefore becomes very difficult to update the data onto the maps thus translating into slow, cumbersome and inefficient decision making on the side of the planner due to lack of sufficient data. Aerial photographs have been in use for long duration now and they are far much better when

compared with topographic maps. So, to solve the problem of acquiring data on the rapidly changing environment of informal settlements then aerial photographs should be acquired frequently. This brings in the challenge of the resultant cost of doing flights to capture data.

Therefore, these traditional methods are not only expensive but very time consuming and are also exposed to subjectivity. With the emergence of the use of Geographic Information Systems (GIS) by municipal authorities, Planners can now be able to map out the informal settlements much more easily and efficiently. This has at least improved on efficiency in planning and decision making. However, the use of remotely sensed imagery provides a rather unique solution towards monitoring the growth of informal settlements. Since remote sensing satellites capture imagery quite frequently depending on the specific satellite. The data used in this research study was from Quick bird sensors with a spatial resolution of 0.6 meters for year 2008 and aerial photographs for the year 1978 and year 1998.

Remote Sensing offers spatially coherent data sets that cover large areas with both high spatial detail and high temporal frequency. These data characteristics are necessary for land-use monitoring, which is an essential element of socio-ecological studies (Mubea & Menz, 2012) and as Rashed et. al in 2005 puts it, “The timely and spatially explicit characteristics of RS data not only provide a means of exploring and testing hypotheses and models about urban areas, but also for constructing new theories that can help in the formation of policy in anticipation of the problems that accompany urbanization processes” This research study incorporates use of remotely sensed imagery into understanding the growth and spatial character of Mukuru slums over a period of thirty years from 1978 to 2008.

1.3 Purpose of the Study

The purpose of this study was to model slum growth and associated implications on environment and service delivery. Growth patterns and characteristics of the Mukuru slums were analysed using base spatial information and data from remote sensing imagery over a temporal period of thirty years. The study also aimed at understanding the urban transformation over the specified period. A case study approach was used with the aim of developing a growth model that will be used to project further growth and spatial patterns

and ultimately to make recommendations on how service provision can be improved in these informal settlements. In this study, slum growth and urban transformation was determined using high resolution satellite imagery and aerial photographs which were then used to identify the impacts on service provision. As any informal settlement grows spatially and demographically it has certain implications on the character of that particular urban setting and also on the required quality and quantity of services and this is what was determined from the study.

1.4 Scope of the Study

This study on the spatial growth of slums, the transformation of urban space due to slum growth and their implications on delivery of services was conducted in two of three slums that form the Mukuru slums namely Mukuru kwa Njenga and Mukuru kwa Reuben. The study was conducted between September 2013 and March 2014. A case study approach was applied whereby remotely sensed imagery and aerial photographs were first used to model the growth of these slums and also to study the transformation of space which was then followed by a field survey in order to make sense of the findings from the modelling.

The field survey concentrated on the socio-dynamics of the population and the level of service provision to these slums. A sample size of one hundred and ninety five households were targeted in the study. A sum total of one hundred and seventy questionnaires were conducted with twenty three questionnaires from one of the villages (MCC) in Mukuru kwa Njenga failing to be conducted due to security and lack of authorization reasons. Two questionnaires were also not traced after the data collection. Data was collected through structured interviews by the main researcher and four assistants whereby household heads were interviewed. The slums were divided into villages and the villages to be used in the study were selected randomly after which a systematic random survey was conducted. The study specifically aimed at determining the effect that slum growth and space transformation has had on service provision and on the environment in slum areas.

1.5 Study Objectives

The main objective of the study was to model slum growth and transformation in Mukuru slums and its implications on access to basic services.

The following were the specific objectives of the study.

- i. To analyse spatio-temporal changes in land use and identify the character change of the Mukuru slum at selected stages of development.
- ii. To identify the implications of such growth and transformation to service provision.
- iii. To identify the implications of such growth and transformation on the environment.
- iv. To suggest planning solutions to the problems identified.

1.6 Study Questions

- i. What has been the spatial growth and change in character of the Mukuru slums in each selected stage of development?
- ii. What have been the implications of such growth on service provision resulting from the growth and transformation of the Mukuru slums?
- iii. What have been the implications of such growth on the environment resulting from the growth and transformation of the Mukuru slums?
- iv. What are the most appropriate solutions to the problem of service provision in the Mukuru slums?

1.7 Research Hypothesis

The study tested the hypothesis that:

Slum growth and transformation does not lead to improved access to basic services.

1.8 Justification and Significance of the Study

1.8.1 Justification of the Study

This research study utilized remotely sensed imagery to study and understand the spatial characteristics and growth dynamics of the study area. Ultimately, a spatial growth model was developed showing the rate of growth of the slum in the period lasting thirty years from 1978 to 2008. The reason for conducting the research over this specific thirty years is due to the fact that literature indicates that the Mukuru slums started developing at about the mid 1980's. In a report by the Muungano Support Trust in 2012 a local non-governmental organization working in the Mukuru slum, the author Jane Wairutu claims that the Mukuru kwa Reuben slum stands on the land previously owned by European settler known as

Reuben. The same is supported in (Howden, 2012) showing that Mukuru was a vast estate belonging to Jack Reuben a British Army Veteran who then established Villa Franca which was divided between a sisal plantation and a depot for the Reuben haulage empire and since the business required labour therefore a labour camp was established. The settlement is said to have been started around 1979 however, it is not clear whether Reuben died or left the farm in the early 1980's thus opening the area to development of shanties.

According to a report by the UN-Habitat in 2007, the urban population of Kenya stood at 34 % of the total population. And considering that most of these people end up in informal settlements Mukuru being one of them as indicated by a report by the UN-Habitat in 2013 titled 'Urban Planning for City Leaders' showing that 50% of the population of Nairobi, Kenya and Mumbai, India live in slums then it is important to understand how informal settlements grow and hopefully at what rates. A UNDP report in 2007 showed that the growth rate of Kenya's informal settlements stood at 5% per annum one of the highest in the world in terms of demographics thus it was important to see if the same translates to spatial growth.

This information will enable urban planners understand the dynamics of slum growth and thus enable them make better decisions that are efficient and at a much lower cost with regard to time and resources required as compared to the traditional methods that have been in use. Quantifying urban growth processes is crucial to monitor urbanization and its impact on the environment over time (Abebe, 2013)

The research study also looked at the spatial character and arrangement of the settlement and how it has changed over the study period. Any changes in the spatial arrangement and character of an area has implications on service provision for example piped water and electricity considering that some of these infrastructure are aligned to the land parcels and houses. After understanding the character of the informal settlement the research study then proposes solutions to the problems identified. A plan that anticipates the effects of future shocks can help a city to withstand them and rebuild itself when necessary. (UN-Habitat, 2013)

1.8.2 Significance of the Study

Research has been conducted on the changes in demographics of informal settlements and also on the living conditions in these informal settlements. Also remote sensing has been used mainly to model land use/land cover change and study of urban sprawl. This research study aimed at applying remote sensing techniques to identify and study urban planning problems resulting from growth of slums. Over and above population growth rates of urban areas identified by different authors from their studies, this research study identified spatial growth rates of informal settlements and quantified this growth over certain temporal periods.

Considering that the Constitution of Kenya, 2010 in the bill of rights outlines that ‘every person has a right to a clean and healthy environment’ it is the obligation of the authorities to ensure that each citizen has access to basic services like clean water, electricity etc. and considering that the environment cannot remain ‘clean and healthy’ if services like solid waste collection and sewer systems are not functional, therefore, this research study after identifying the impacts of slum growth and transformation on service provision will give recommendations on how the provision of service in these slums can be facilitated. This recommendations to the necessary authorities for example County Government of Nairobi can make them into policy thus allowing for enforcement hence helping improve the living conditions in these informal settlements.

The planning profession is tasked with projecting and predicting into the future and identifying different probable outcomes and scenarios. So, this research study mainly dwells on the problem of service delivery in informal settlements and how it can be facilitated even as the slums continue to exist. Considering that a planner is expected to provide solutions to some of these ‘wicked problems’ (Ndegwa, 2001) the study will look at the growth patterns and rates which can then be used by planners to make better planning decisions.

1.9 Assumptions of the Study

The first assumption was that there has been population growth of the city of Nairobi which has translated to population growth in slum areas which then translates to spatial slum

growth. This was happening over the thirty years beginning 1978 to 2008 and that the spatial growth of the slum will continue. The second assumption of the study is that as the slum grew spatially, then there has been transformation of the urban space and that these has resulted in certain implications with regard to service delivery. Finally, there is the assumption that the city population grows including slum growth.

1.10 Definitions of Terms and Variables

This research study mainly had two independent variables and one dependent variable. The independent variables are slum growth and urban space transformation while the dependent variable is basic service provision.

A slum household is hereby defined using the following parameters; access to improved water, access to improved sanitation ,security of tenure (the right to effective protection by the state against arbitrary, unlawful eviction), durability of housing (including living in a non-hazardous location) and sufficient living area (no overcrowding). (UN-Habitat, 2003) Therefore, slum growth refers to the increase in spatial size of the area occupied by slum households over a defined period.

Urban space transformation in this instance can be described as the change over time of the character of the slum area. Rather, this can be described as the change in the spatial arrangement of the slum area. On the other hand, service provision can generally be described as the regular access to basic services like clean water, collection and proper disposal of solid waste and access to sanitation facilities like having a functioning sewer system. The research also involves some key terms including; remote sensing which can be described as the science and art of obtaining useful information about an object, area or phenomena through the analysis of data acquired from a device that is not in contact with the object under study. High resolution satellite data in this case refers to remotely sensed imagery with a spectral resolution of approximately thirty meters and a temporal resolution of about sixteen days.

2.0 Literature Review

A number of factors are driving the growth of cities worldwide. Rural economies in many regions have been hard hit by environmental degradation, military or ethnic conflicts, and the mechanization of agriculture, which has curbed the number of rural jobs. The prospect of better-paying jobs has drawn many people to cities. (Sheehan, 2014)

Kenya is facing an increasing growth of informal settlements in her urban centres. As rapid urbanization takes its toll, so has the development and growth of slums. More than 34% of Kenya's total population lives in urban areas and of this, more than 71% is confined in informal settlements. (UN-Habitat, 2009).

The growth of informal settlements in Nairobi, Kenya has hit unprecedented rates most of which has been in the last two decades. This research aimed at studying the spatial growth patterns, rates and the resulting impacts on service provision and the environment in the Mukuru slums. This chapter reviewed important literature on rapid urbanization and slum growth, the planning implications resulting from this slum growth mainly on service delivery and on the environment, how slums can be monitored using remote sensing tools and also case studies where the same has been applied, how slum monitoring data can be managed and manipulated, ultimately the applicability of all these with regards to planning for interventions consisting of slum mapping, the actors involved and the existing regulations.

2.1 Urbanization and slums

Rapid urbanization has overwhelmed many municipalities' ability to provide serviced land to accommodate the influx of newcomers, but ignoring this problem will not make it go away. In Mumbai (India) and Nairobi (Kenya), 50 per cent of the population lives in slums, notably in Dharavi and Kibera, two of the world's largest slums. (UN-Habitat, 2013) Half the world's population lives in urban areas and by the middle of this century all regions will be predominantly urban, and according to current projections, virtually the whole of the world's population growth over the next 30 years will be concentrated in urban areas (UN-Habitat, 2010). As urbanization occurs, changes in land-use accelerate and land making up the natural resource base such as forests and agricultural land, leading to modification and conversion of existing land-uses. (Mundia et. al, 2010)

Waugh (1990) defines urbanization as a process by which rural areas are transformed into urban areas and which involves the growth of urban populations through the combined effects of migration and natural increase. Migration from rural areas on average accounts for about 60 per cent of the urban population and in exceptional cases, as much as 75 per cent. (Todaro, 2000) With a rapid urbanization growth rate of about 4%, population (in Nairobi) was projected to grow to 5 million by 2015 and to more than 8 million by 2025 (UN-Habitat, 2001). These unprecedented rates of urbanization can be linked to massive migratory movements as well as to natural growth, challenging urban planning and thereby causing environmental problems with far reaching effects. (Mutisya and Yarime, 2011)

Slums also known as informal settlements in Nairobi have existed since the cities inception, the government has failed to respond to the plight of slums dwellers accordingly. (Mitullah, 2003) According to a report by the UN-Habitat in 2003, a slum household can be described using the following parameters; access to improved water, access to improved sanitation ,security of tenure (the right to effective protection by the state against arbitrary, unlawful eviction), durability of housing (including living in a non-hazardous location) and sufficient living area (no overcrowding). In his paper, (Bolay, 2006) describes the phenomenon that “existence of slums worldwide is also a sign that the slum is a crucial element of contemporary urbanization” which has to be understood, including its causes then suggest policy responses to the slum issue. The article goes ahead to bring out the contradictions between housing related practices, social mechanisms and public policies as well as the need to define sustainable solutions which promote the wellbeing of the majority of urban dwellers. (Sietchping, 2005) points out that “one of the key lessons (from his assessment) is that past and current slum policies act and react on existing slums and fail to capture and incorporate preventative and proactive measures that could reduce the spread of future slum growth and ultimately mitigate the effects of unplanned settlements on the majority of urban dwellers in developing countries-DC”.

Emergence of slums results from multiple causes ranging from issues like the ‘oil boom’ in Venezuela resulting in the Barrios in Caracas, the migrant labourers living in Dharavi, one of India’s largest slums. It is worth noticing that recent slum expansion in DC is largely controlled by four additional factors: intra-urban migration, natural population increase,

reclassification and annexation. (UN-Habitat, 2004) However, for the slums in Kenya for example Kibera, rural-urban migration mainly in search for opportunities is the major cause of slum growth. “Kibera is often the first stop for rural migrants who have travelled from their villages to the city to find work.” (Royal Geographical Society, 2014) Another key driver of emergence of slums is the lack of security of tenure on occupied land. (Sietchping, 2005) points out that “It is now well established that the proliferation of slums associated with the lack of security of tenure is changing not only the urban form and structure, but also (and more importantly) is exacerbating poverty, housing problems, inequality and social exclusion in most cities in DC.”

2.2 What form do slums take?

The urban transition began later in Africa than elsewhere, and the continent remains one of the least urbanized of the less-developed regions. A clear majority of African countries, nonetheless, are now characterized by a pace of urban slum formation and expansion that is unprecedented relative to less-developed countries in other areas of the world. Urbanization and urban slum formation and expansion in numerous African countries are now virtually synonymous. (Jorgenson and Rice, 2010) Slums themselves are the physical manifestation of several overlapping forces. On the one hand, they are the manifestation of deep poverty, unrealistic regulatory frameworks, ill-conceived policies, inadequate urban planning, weak institutional capacity and larger macro-economic factors. But on the other hand, slums are a manifestation of the ingenuity and resilience with which extremely disadvantaged populations have organized themselves in the face of these very challenges. (Mehta and Dastur, 2008) The Global Report on Human Settlements (2003) indicates that slums develop in many forms but mainly they are either squatter settlements and/or illegal settlements. “The twofold tenure problem of squatters- that is, that they have neither the owner’s permission nor the permission of the local authorities (while illegal settlements have the owner’s permission) - tends to render life there more tenuous and to discourage investment.” The following graphic images illustrate the characteristics of several slum areas across the world.



Figure 1 An alley in Dar al Salam Suburb, Cairo, Egypt (Johnson, 2013)



Figure 2 Kibera slums, Nairobi, Kenya



Figure 3 Blikkiesdorp and Happy Valley slums in the Western Cape Province, South Africa (Kindra/IRIN, 2012)



Figure 4 Plate of a Jhopadpatti (slum) in Mumbai, India (Unger and Riley, 2007)

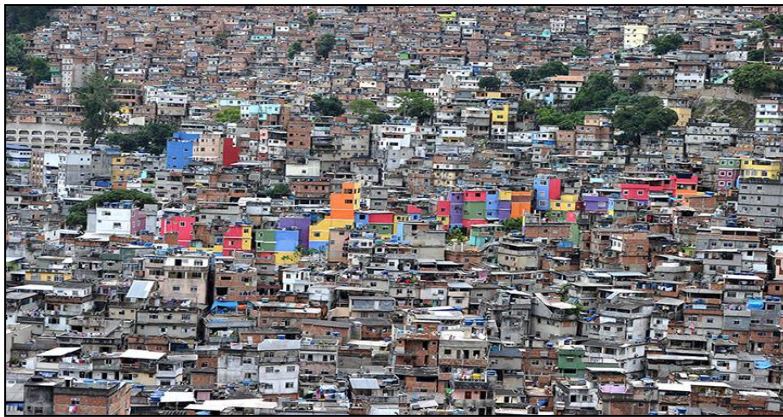


Figure 5 Plate of Rocinha, Brazil (Phillips and McOwan, 2013)

The Kibera slum in Nairobi, Kenya is characterized by tin shacks dwellings. The shacks maybe joined or ‘stand-alone’ albeit with very small spaces in between them. A similar scenario is noticed in informal settlements in South Africa for example in the Blikkiesdorp and Happy Valley slums in the Western Cape Province. (Kindra, 2012) However, slums in other parts of Africa differ in terms of building materials and the element of informality whereby in North Africa for example in Cairo, Egypt the Dar al-Salam suburb has been left to piles of uncollected garbage and dilapidated buildings to the extents that it can only be described as concrete slum. The situation is worsened by the overcrowding in the households and the limited access to services for example power.

In sub-Saharan Africa an estimated 72% of the urban population live in slums, while in North Africa the figure is 28%. (UN-Habitat, 2011)

Further afield, cities for example in the Indian sub-continent are home to multiple informal settlements. As noted elsewhere in this report, 50% of the local inhabitants live in slums in India, notably in the Dharavi slums in Mumbai, India which is one of the largest slums in the world. In South America, quite a number of countries have informal settlements in their cities including in Venezuela, Colombia and Brazil amongst others. In Brazil the slum areas are commonly referred to as favelas. “Rocinha is the biggest favela in South America, home to an estimated 150,000-300,000 people. It has developed from a shantytown into an 'urbanized slum' and boasts hundreds of businesses, banks, restaurants, internet cafes and even its own television channel.” (Phillips and McOwan, 2013)

2.3 Locations of slums

Various reasons are often put forward to explain the emergence and growth of slums in developing countries. For instance, research shows that slums excel in marginal or less valuable urban land such as riverbanks, steep slopes, dumping grounds, abandoned or unexploited plots, along transportation networks, near industrial areas and market places, and in low lying areas or wetlands (Blight & Mbande, 1998: Global Urban Observatory, 2003). Slums are often located in a city's least-desirable locations-situated on steep hillsides, in floodplains, or downstream from industrial polluters-leaving residents vulnerable to disease and natural disasters. (Sheehan, 2014)

Other works suggests that slums seem to be mutually attracted, at least in part, by spiritual or religious activities. Such correlation is also well documented for new urban migrants who prefer to settle in neighbourhoods that share similar socio-cultural backgrounds (Malpezzi & Sa-Adu, 1996). It could therefore be argued that the knowledge of dominant ethnic, cultural and religious groups in existing neighbourhoods or slums could provide useful clues for exploring future expansion and location of slums. Such knowledge is valuable for the spatial prediction of slum growth, especially in cities where ethnic, cultural and religious differences highly influence the location choice of the urban dwellers. (Sietchping, 2005)

Jacobson (2007) writing for the National Geographic claims the following on Dharavi, arguably the largest slum in India and probably the world “Until the late 19th century, this

area of Mumbai (where Dharavi currently stands) was mangrove swamp inhabited by Koli fishermen. When the swamp filled in (with coconut leaves, rotten fish, and human waste), the Kolis were deprived of their fishing grounds but room became available for others. The Kumbhars came from Gujarat to establish a potters' colony. Tamils arrived from the south and opened tanneries. Thousands travelled from Uttar Pradesh to work in the booming textile industry. The result is the most diverse of slums, arguably the most diverse neighbourhood in Mumbai, India's most diverse city.”

In Kenya, slums mostly occupied the poorest quality lands for example the “Mitumba” slums build on the periphery of the Nairobi National Park. In many cases, the only recourse the poor have are riparian reserves, swamps, steep slopes, refilled quarries and garbage dumps. Informal settlements also spill over to service reserves like railway safety zones, land under high voltage power lines and on road reserves. The end result of all these factors is rapid, unstructured and unplanned expansion, conflicting land tenure and property rights, poor quality dwellings, decay of the physical environment, unhealthy living environment, severe social problems, and low socio-economic status for informal settlement occupants that all constitute the common characteristic of an informal settlement. Various measures have constantly been undertaken to improve the conditions of slums in DC, but their effectiveness are often questionable. (Sietchping, 2005)

2.4 Challenges associated with slum growth

2.4.1 Slum Growth and Service Delivery

A staggering 62 per cent of the urban population in sub-Saharan Africa lives in slums, compared to 43 per cent in South Asia. (Abbott, 2000) Nairobi is host to more than 200 informal settlements, where living conditions are among the worst in Africa due to extremely high population densities: reaching 26,000 km² in inner-city slums like Pumwani and Maringo. It is the responsibility of the urban management authorities to ensure that all inhabitants of urban settlements have access to at least basic services like clean water, sanitation systems and proper infrastructure for example roads. However, due to the high population densities and the unplanned settlements, it therefore becomes very difficult to plan and provide for these services. The lack of security of tenure has also partly contributed to the problem since the authorities cannot really plan and provide services in such areas as

those occupied by squatters who are doing so illegally as pointed out by Howden (2012) claiming that some 92 per cent of them (inhabitants of slums) are under threat of eviction. The list of challenges faced by slum dwellers is long, and many of these disadvantages reinforce each other in a vicious cycle. (Mehta and Dastur, 2008)

The problem of inaccessibility to basic services has been noted by the UN-Habitat (2010) stating that “between 40 to 60 per cent of people in unplanned settlements in Eastern Africa lack adequate water and sanitation. Their access to water is only through street vendors.” “Multiple interventions consisting of water supply, sanitation provision and hygiene education in developing countries act to reduce diarrhoeal illness levels. It is possible that their effectiveness could be improved by ensuring water safety in the household.”

During a fire that razed the Mukuru slums in February, 2011 more than fifty people suffered burns as they fled from the intense fire. Emergency crews from the City Council of Nairobi who went to put out the fire that started at 10am were unable to venture into the slum due to lack of access roads, eliciting fury from the dwellers who resorted to stoning the fire personnel and their vehicles before police intervened. (Momanyi, 2011) Due to the haphazard development of houses in the informal settlements, then it becomes very difficult to lay out service provision networks. The lack of provision of services by the authorities creates a gap which has to be filled. This is where ‘slum gangs’ come in and begin providing the lacking services to the locals albeit in a dangerous and risky manner. Illegal connections are made to the nearby power lines and power supplied to the locals.

The Mukuru informal settlement lacks sewerage reticulation and the common system used in the emptying of filled up pit latrines is the manual exhausters at a cost of approximately Kshs. 500 per 150 litres drum. (Wairutu, 2012) This waste is then emptied into the nearest river mainly Ngong’ river. Compounding the problem of disposal of human waste is the sharing of pit latrines by multiple households raising the question of how hygienic it is. The analysis of 1,500 randomly selected toilets in the urban slums of Kampala showed that only 22 percent of households have access to private sanitation facilities; the remaining 78 percent share their toilet with an average of 6 households. There is a clear and strong correlation between number of users and the condition and cleanliness of a toilet stance. Less than 20 percent of private toilets are dirty, whereas 60 percent of sanitation facilities are dirty if they are shared by more than 10

households. (Gunther et. al, 2012) The same study recommended that “...not more than four households (or 20 individuals) should share a toilet stance to ensure long-term hygienic and sustainable use.”

To help alleviate the problem of insufficient toilets, a company known as Sanergy developed compost toilets branded “Fresh life”. Likoko (2013) evaluates the sustainability of the Sanergy toilet model whereby a compost toilet utilizes no water and has a waste receiving tank in which aerobic bacteria break down the waste. The faeces and urine from the toilets are used to provide manure and energy for the market. The study concludes that the Sanergy waste management model can be used as template for achieving the millennium development goals of ensuring all have access to good sanitation. A plate of the “fresh life” toilets is displayed below.



Figure 6 Fresh life toilet (Likoko, 2013)

Garbage is also collected at a fee of Kshs 50 per month. Unfortunately, it is then dumped in one location thus forming a big dumpsite. Due to the lack of piped water, the locals buy water from water vendors at a cost of about Kshs 5-20 for a 20 litre jerry can. (Wairutu, 2012) At times this water comes from boreholes sunk in the slum areas but the bottom line is, its suitability for drinking still remains very difficult to determine.

Sheehan (2014) writing for World watch Institute discusses the issue of cost of services in informal settlements stating that “another long-term cost is the premium residents pay for basic services. The African Population and Health Research Centre recently released a report showing that Nairobi's slum dwellers pay more than residents of wealthy housing estates for water-and, as a result, use less than is adequate to meet health needs. A family needs 100 litres per day for drinking and cleaning, as that much water costs 25 Kenyan shillings (30 cents), it could easily eat up half the income of people.” Therefore, service provision a basic requirement for every urban settlement is really wanting in the Mukuru slums. According to the UN Universal Declaration of Human Rights; General Comment 4, The Right to Adequate Housing (1991), the minimum requirements of decent housing are: legal and secure tenure, availability of services for example safe drinking water, security, comfort etc. Location and affordability amongst others. (UN-Habitat/Cities Alliance, 2011) However, this requirements cannot be met in the living conditions experienced in slum areas.

2.4.2 Slum Growth and Environmental Impacts

Increase in population translates to increase in the production of waste both solid and liquid. Due to the poor or even lack of management of waste in slum areas, the inhabitants of these slum areas tend to dispose off their waste in the areas that they think they will have least impact to themselves for example with regards to smell. These (informal) settlements pose grave threats to the health of their inhabitants, stemming from poor-quality housing, lack of infrastructure and minimal access to refuse collection, health care or other essential services. (Sverdlik, 2011)

Unfortunately, riparian reserves and utility reserves bear the blunt of most of the impacts. Considering that the Ngong’ river cuts across the slum, it gets to carry the most impact on the environment. Immense pressures of urban growth and development confront the river wetland (Ngong’ river). This could be attributed to its proximity to the city’s industrial area and ultra-dense human settlements. (Karisa, 2002) Ferguson (1996) in his paper titled “The environmental impacts and public costs of unguided informal settlement; the case of Montego Bay” observes the following “Informal settlements threaten environmentally sensitive areas (aquifers, forests, wetlands and other bodies of water). Settlements built on

steep slopes greatly increase the costs of infrastructure provision and sometimes threaten residents' safety because of mud and landslides. Thus, informal settlement helps solve the individual household's shelter problem but creates great environmental impacts and public costs, often borne by government.”

The area has been subjected to a lot of pollution and environmental degradation. Solid waste that is dumped anywhere and anyhow is the major contributor. The open drains and open sewerage systems in place also play a big role in the degradation of the environment in Mukuru Kwa Njenga. (CURI, 2012) This therefore illustrates the impact development of a slum has on its surrounding and to those living within it. Top of the list is the impact on the environment followed by the impact on health and sanitation of the inhabitants of this slum areas. As (Jorgensen and Rice, 2010) indicate, research shows that child mortality in low-income urban neighbourhoods can equal or exceed that in rural areas (Garenne, 2003). In Nairobi, Kenya the under-5 mortality rate in slums (151 per 1000 live births) was 2.5 times higher than the average of the city (APHRC, 2002). There is diversity between the slums themselves, with child mortality rates of 254 and 123 per 1000 live births in two different Nairobi slums. This has been seen in other intra-urban studies. In areas with inadequate services (of water supply, sanitation, good health care), morbidity and mortality rates can vary with a factor of 10 -20 or more than better-equipped slum areas of the same city (Bartlett, 2003).

More so, it is not simply the lack of services that presents unique health challenges, but lack of services concurrent with densely populated areas frequently located directly upon or proximate to toxic and hazardous areas of land. . . .poverty, overcrowding, malnutrition, insufficient garbage disposal, lack of adequate water drainage, and unsafe drinking water and sanitation coalesce around the social organization of marginalized populations in urban slums. Such conditions highlight the potential social production of infant and child mortality rates as derived from deep-seated inequalities in society, not simply the influence of individual-level, biomedical factors. (Jorgenson and Rice, 2010) Ferguson (1996) quantifies the costs of providing infrastructure to informal settlements otherwise known as slum upgrading. The author concludes that the costs of providing infrastructure to unplanned informal settlements compares to those of government-produced serviced sites

and ‘the infrastructure is often of poorer quality and with less possibility for cost recovery’ further the author points out that it is ‘improper sanitation that contaminates sources of drinking water (that) appears to be the single greatest environmental and health threat in these centrally located informal settlements.

In their paper titled “Urban expansion and the environmental effects of informal settlements on the outskirts of Xalapa City, Veracruz, Mexico” Benitez et al (2012) analysed the dynamics of population growth and urban expansion in the City of Xalapa, Mexico that leads to growth of informal settlements whereby many of them are actually a threat to forest and farmland conservation. The population census data of 1950, 1960, 1970, 1980, 2000 and 2005 were used to document population growth dynamics and its relationship with the expanding urban area of Xalapa. Spatio-temporal data was entered into a GIS on Arc GIS 9.3 platform and also satellite images from an IKONOS sensor with a spatial resolution of 2 meters were used. The analysis of spatio-temporal changes in vegetation cover and land use serves as a base line to map trends in deforestation, degradation and loss of biodiversity in the region.

The research found that the population of Xalapa had begun to rise sharply in the 1960’s increasing by more than 300% by 1980. Between 1950 and 1980, 100,000 people were reported to have migrated from the rural to urban centres. Between 1980 and 2000, the population nearly doubled with considerable further growth in the outlying settlements of make shift dwellings inhabited by low income groups. In the year 2000 around 40% of the area of Xalapa was occupied by informal settlements most of them in hazardous areas and with respect to land use and its implications on the environment, the results showed that 90% of land had been altered due to human activity with natural vegetation and forests covering just 7.6% of the area (9.3 sq km)

The paper concludes that it’s the environmental logic and social logic that dictates the establishment of informal settlement and the two cannot be dissociated. The process is determined socially by the inhabitant’s low income and environmentally by physical features (topography). Also the demand for urban land will continue to rise due to pressure from migration and natural increase thus more pressure on environment more so forests and agriculturally productive areas. Ultimately, urban planning should safeguard the

collective interest and the prime objective is to preserve quality of life and protect the environment.

2.5 Monitoring Slum Growth

2.5.1 The Use of GIS and Remote Sensing Tools

Remote sensing is the science and art of obtaining useful information about an object, area or phenomena through the analysis of data acquired from a device that is not in contact with the object under study.

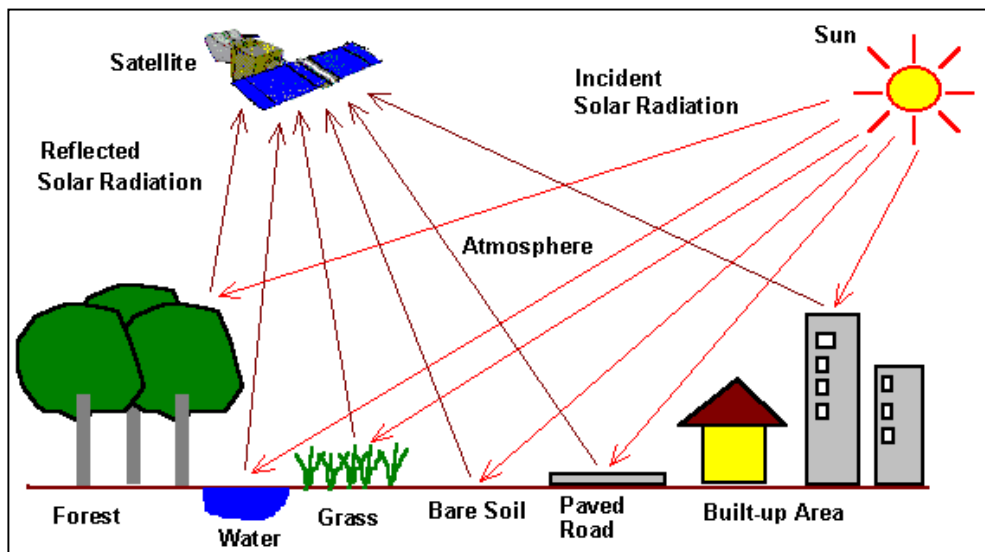


Figure 7 Remote sensing procedure. (Abebe, 2012)

The illustration shows a satellite being used to capture data about vegetation, built-up areas, the earth surface etc. The detection of properties of objects under study is done by using electromagnetic waves.

Urban land use changes have been studied for many years; however, the advent of satellite images and geospatial technologies opened a new dimension for assessing and monitoring land use cover changes. (Tewolde and Cabral, 2011) Remotely sensed imagery allows for analysing data from various years hence it is suitable to carry out monitoring of land use changes in different settings. Remote Sensing offers spatially coherent data sets that cover large areas with both high spatial detail and high temporal frequency. These data characteristics are necessary for land-use monitoring, which is an essential element of socio-ecological studies. (Mubea and Menz, 2012) Remote sensing data comes in different

spatial resolutions and temporal resolutions depending on intended use and accuracy required. However, the higher the spatial resolution, the higher the cost of acquisition.

The main advantage of satellite remote sensing is its repetitive and synoptic coverage that is very much useful for the study of urban areas. It helps to create information base on land use, land cover distribution, urban change detection, monitoring urban growth and urban environmental impact assessment. (Rajeshwari, 2006)

The timely and spatially explicit characteristics of RS data not only provide a means of exploring and testing hypotheses and models about urban areas, but also for constructing new theories that can help in the formation of policy in anticipation of the problems that accompany urbanization processes. (Rashed et.al, 2005)

However, due to the heterogeneity brought about by the rapidly changing urban landscapes, mapping urban areas using remotely sensed imagery is thus complex due to the various surface types involved be it natural or artificial. Studies show that these challenges can be solved by using multi-spectral and multi-temporal data. This study will apply techniques derived from remote sensing to identify study and monitor the growth and spatial patterns of urban informal settlements to the east of the city of Nairobi.

2.5.2 Slum Mapping Case Studies

Before any work can be conducted on an area, the spatial elements first have to be comprehended in order to not only aid in implementation but also in planning the work. This sections looks into previous slum mapping case studies and their outcomes both in Africa and in Asia. The first case study was conducted by Abbott (2000). The aim of the paper was to come up with a new planning methodology to be used in a slum upgrading project in Cape Town, South Africa which had 64 informal settlement clusters as at 1998 with over 70,000 shacks/dwelling units that are times detached although very close to each other. The systematic methodology was first developed and used in Brazil. The method applied was based upon the recognition that informal settlements are multi-functional environments.

The data used was divided into 3 categories namely base data, demographic, social and organization data and ultimately spatial and physical data. The base data collection concentrated on the shack/dwelling as the basic spatial unit rather than the site (parcel).The

research used aerial photographs at a high resolution captured using a helicopter as the source of data for developing vector data comprising of shack data, relief features and existing access routes whereby the images were then warped into position using an affining process with the reference points being taken from a 1996 1:20,000 aerial photograph.

As earlier mentioned the core data set was constructed around the existing dwellings (shacks) while the linkages within the GIS environment were then used to integrate all the other data with the dwellings data set.

The paper concludes that geo-spatial information management is key in establishing a new planning paradigm appropriate to the development of informal settlement. The spatially referenced management system was used to integrate the different components of the upgrading process.

The second case study was conducted by Hassan (2006) in Karachi, Pakistan. It involved the work of a Pakistani NGO OPP-RTI which supports improved provision to sanitation and other services to informal settlements in Karachi, Pakistan. The study area was Orangi town in Karachi. The research noted that Karachi then (2006) required 350,000 housing units per year for its urban areas but the formal sector could only provide approximately 120,000 units thus creating a demand-supply gap hence encouraging development of informal settlements with an estimated 9 million people living in unauthorized/informal settlement.

It points out that the lack of maps showing plot boundaries and existing infrastructure is one of the main challenges facing improving infrastructure and slum upgrading. The Orangi Pilot project research identified 4 major problem areas i.e. sanitation, employment, health and education with sanitation being the most important. The paper notes that documenting and mapping informal settlements is beneficial to development of urban policy, planning and infrastructure investment. With regards to data, they acquired available plans for the study area prepared from aerial surveys. However, the plans were on different scales and were incomplete, also the plans had no contours, levels or land usages marked on them. Proper data was created by conducting “walk through” surveys collecting required data thus enhancing the available data. The paper concludes that “documenting and mapping the informal settlements has a number of important repercussions for urban policy, planning and infrastructure investment as it demonstrates people’s involvement and investment in

development.” The end result is that planning agencies and local governments need to support such initiatives (mapping of informal settlements) hence preventing and minimising duplication of tasks and thus less resources utilized in the process.

The third case study looked into a research conducted by Shekhar (2012) who conducted a study on the use of Quick Bird (remotely sensed) imagery to detect slums in Pune, India using an Object Oriented Approach. The paper looked at urbanization and growth of informal settlements. The researcher noted that in order to improve the conditions in the slums and to carry out slum renewal programs and also to facilitate monitoring of these programs, slum settlements should be recorded to obtain an adequate spatial database. Very high resolution remotely sensed data can be used for this purpose. Due to the heterogeneity of complex urban environments, an attempt was made to detect and discriminate the slums of Pune city by describing typical characteristics of these settlements by using eCognition software.

Analysis of remote sensing data for urban planning and development tasks has been found to be more reliable and less subjective as compared to the traditional methods that demand more labour, money and time. The researcher observed that an Object Oriented Approach offers great potential due to its ability to include spatial, spectral and contextual characteristics similar to human cognitive image interpretation. Ultimately, the findings were that slums will mostly tend to be located near vulnerable areas and close to rivers and transportation lines for example railways and thus the distance to rivers, roads and railways were used to separate and refine the formal built up area. However, the research also points out the difficulty of detecting slums and though the study demonstrated the advantage of VHR data in detecting slums, it still required local knowledge of existing slums and their characteristics.

The three case studies discussed emphasize the importance of mapping and recording slum areas both for planning for slum upgrading purposes and for improving infrastructure in slum areas. The case study research conducted in Pune, India observes that the advantage of using very high resolution data in detecting slums cannot be overlooked however, local knowledge of the existing slum areas is key in developing data for use in planning for the slum areas.

2.5.3 Slum Growth Modelling

This section of the study report looked at what other researchers have observed concerning slum growth modelling. The first paper was by Patel et. al (2012). The aim of the paper was an attempt to build an exploratory ABM called Slumulation, to model slum formation using the existing understanding of urbanization processes, urban morphology, housing markets, and migrants' behaviour within a spatial ABM framework. The Slumulation concept is a spatial agent-based model of a city consisting of agents namely household agents (which make housing location decisions), developer agents (who create housing units on vacated housing sites thus adding to the existing housing stock), politician agents (who provide a subsidy to slum dwellers in a hope to gain votes from them). The environmental aspect provided the second layer in the model consisting of two entities; housing sites and electoral wards.

The model explored questions such as how slums come into existence, expand or disappear, where and when they emerge in a city and which processes may improve housing conditions for the urban poor. The model used a methodology whereby three types of agents that influence emergence or sustenance of slums in a city i.e. households, developers and politicians each of them playing distinct roles were fed into the model. The study attempted to model a city system where several slums form, grow and disappear as a result of human-environment interactions at multiple spatial scales.

The study points out that “majority of previous models that explored slum formation and city growth approached the problem as a static phenomenon (e.g. Alonso, 1964) which has been challenged with the growing realization that urbanization and slum formation are largely dynamic processes” Agent-based modelling (ABM) provided an ideal framework to study such dynamic processes because they focus on individual agent's behaviour and their interactions give rise to a global phenomenon of interest.

The paper points out four main comparisons to other model based approaches for example Cellular Automata. “The first is that explicit modelling of the spatial environment is important as slums emerge in distinct areas. Secondly, slums are a result of human-environment interactions. Thirdly, individual households make locational choices and

lastly, local government plays an important role as it takes city-wide actions such as slum eviction or slum up-gradation to alter the slum conditions or to eradicate them. The models discussed above incorporate one or some of these aspects but none of them incorporates all of them into a single modelling framework.”

The main finding was that slums emerge as a result of human-environment interaction processes. The model also suggested that higher protection of slum-dwellers in the form of subsidies in lieu of slum votes results into slums with high densities. “While peripherization of slums slows down as the formation of new slums decreases, several slums persist on the prime-land for a longer amount of time in the centre. “States the authors.

2.6 Conceptual Framework

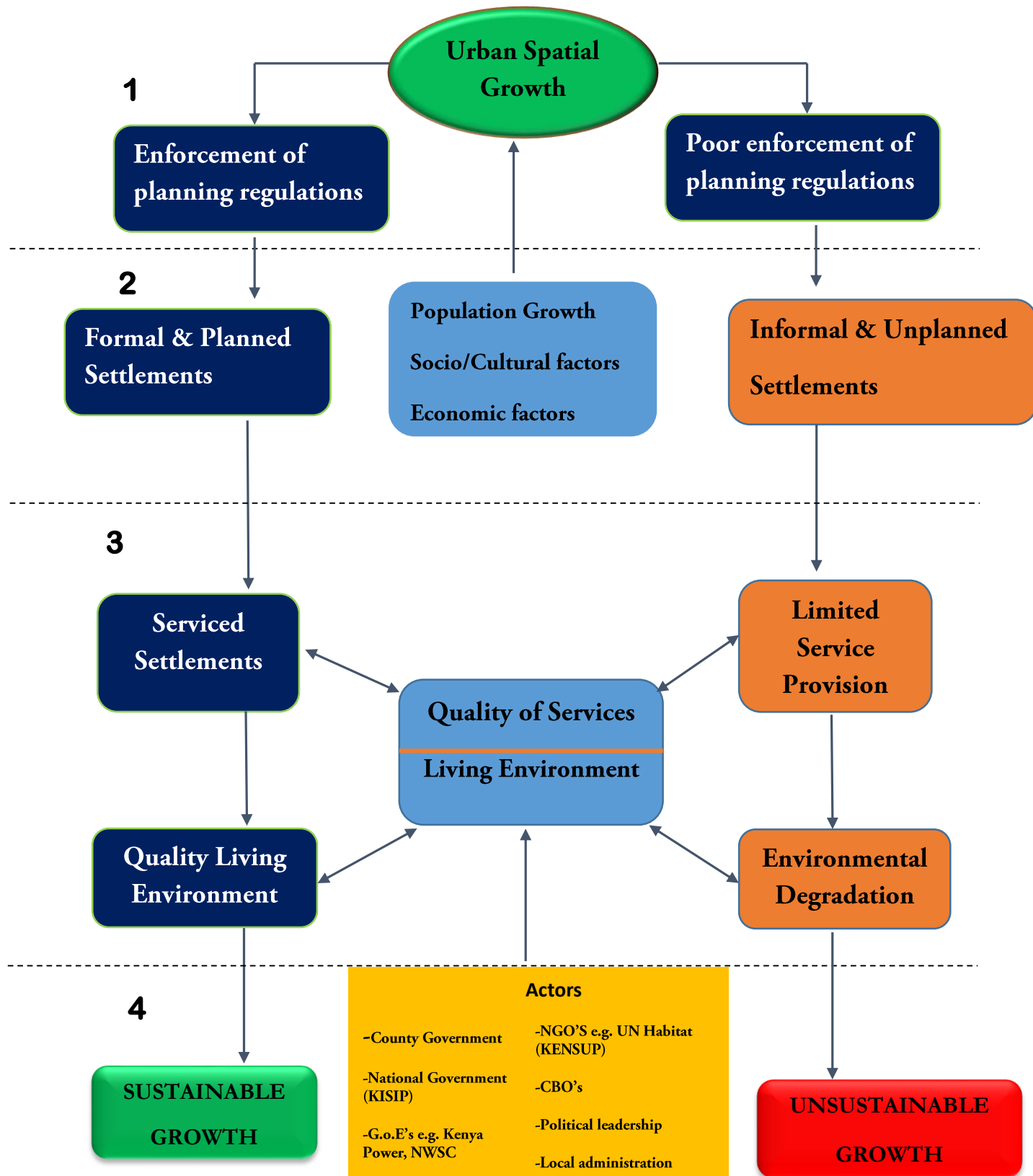


Figure 8 Conceptual framework

The figure 8 is a simple illustration of a conceptual framework of the research study. It shows the linkages of the main aspects of this research study. It has been divided into four main sections. They include (1) urban spatial growth model which has been developed from remotely sensed imagery and aerial photographs from which a slum growth model has been developed showing spatial growth over a specified duration from which the growth rates have been determined. This research study explored how remotely sensed imagery and aerial photographs can be used to develop a growth model of a settlement in the city of Nairobi and also to study the character and form of this informal settlement. Lynch (1981) defines urban form as the spatial arrangement of human activities, which produces spatial flows of persons, goods as well as information. Remotely sensed imagery has been used in previous researches to study changes in land use and land cover for example Rajeshwari (2006) who highlights how remote sensing can be used to study urban sprawl and its growth trends, updating and monitoring using repetitive coverage on the urban environment. Other researchers who have carried out research on growth of urban settlements include Herold et al (2003), Mas et al (2012), Mubea and Menz (2010) and Mundia et al (2010) amongst others.

Growth of informal settlements involves expansion and/or even shrinkage with respect to area and also with respect to spatial characteristics. This comes with its own implications on the environment, service provision and on livelihoods of the inhabitants of these informal settlements as Han et.al (2009) points out “Urban growth is a complex process which involves the spatio-temporal changes of all socio-economic and physical components at different scales”

The conceptual framework in section (2) demonstrates two different scenarios that occur as a result of urban growth whereby this settlement growth is mainly driven by population growth as pointed out by Nordhag (2012) “It is possible that rural-to-urban migration used to fuel urban population growth, but that nowadays it has been replaced in favour of intra-city population growth. Yet it could also be that the mechanisms of urban population growth changes as the urban population extent increases; while the urban focus countries might have begun their urbanization process mainly through rural-to-urban migration, it could nowadays be driven mainly by natural increase” The same has also been supported

by Obudho (1992) stating that “In DC, cities have since grown at such high and uncontrolled rates that a combination of factors now explain why IS are the dominant land use pattern in most urban areas.” How growth of a settlement is managed ultimately decides whether it ends up being sustainable or unsustainable. Sustainable urban growth is as a result of a well-planned, formal settlement that is well serviced with respect to clean and safe drinking water, sewer systems, power and road infrastructure. More so, environmental degradation is held at a minimum. This is illustrated by section (3) of the conceptual framework. A planned settlement is easier to service thus translating to quality services and a good living environment which ultimately means a quality living environment. On the other hand the converse is true whereby an unplanned settlement has limited service provision thus translating to low quality of services and equally a poor living environment due to environmental degradation. The same is supported by McGrahan and Satterthwaite (2014) who argue that “Looking across urban centres in different parts of the world, it is evident that despite the considerable overlaps and variation, the poorest urban populations in the poorest countries tend to have the worst environmental health conditions in and around their homes and also among the lowest levels of greenhouse gas emissions per person.”

Section (4) illustrates the sustainability and unsustainability of settlement growth be it economically, socially and mainly environmentally. A report by the UN-Habitat (2009) on urban planning and informality observes that “Governments and local authorities must, unequivocally, recognize the important role of the informal sector and ensure that urban planning systems respond positively to this phenomenon (growth of informal settlements and sector), including through legislation.” A three step reform process is required for urban planning and governance to effectively respond to informality: first, recognizing the positive role played by urban informal development; second, considering revisions to policies, laws and regulations to facilitate informal sector operations; and third, strengthening the legitimacy and effectiveness of planning and regulatory systems on the basis of more realistic standards. McGrahan and Satterthwaite (2014) note that not all aspects of urbanisation are economically advantageous, however, and urban crowding and congestion also have their costs, particularly if they are not well managed.

3.0 Research methodology

This chapter presents the study area and the data used for the study, methods of data capture and the materials and techniques used to achieve the study objectives. Data required was discussed, source and type of that data, image classification techniques used, change detection methods employed, selection of spatial metrics and a list of software packages used in the research.

3.1 Study Area

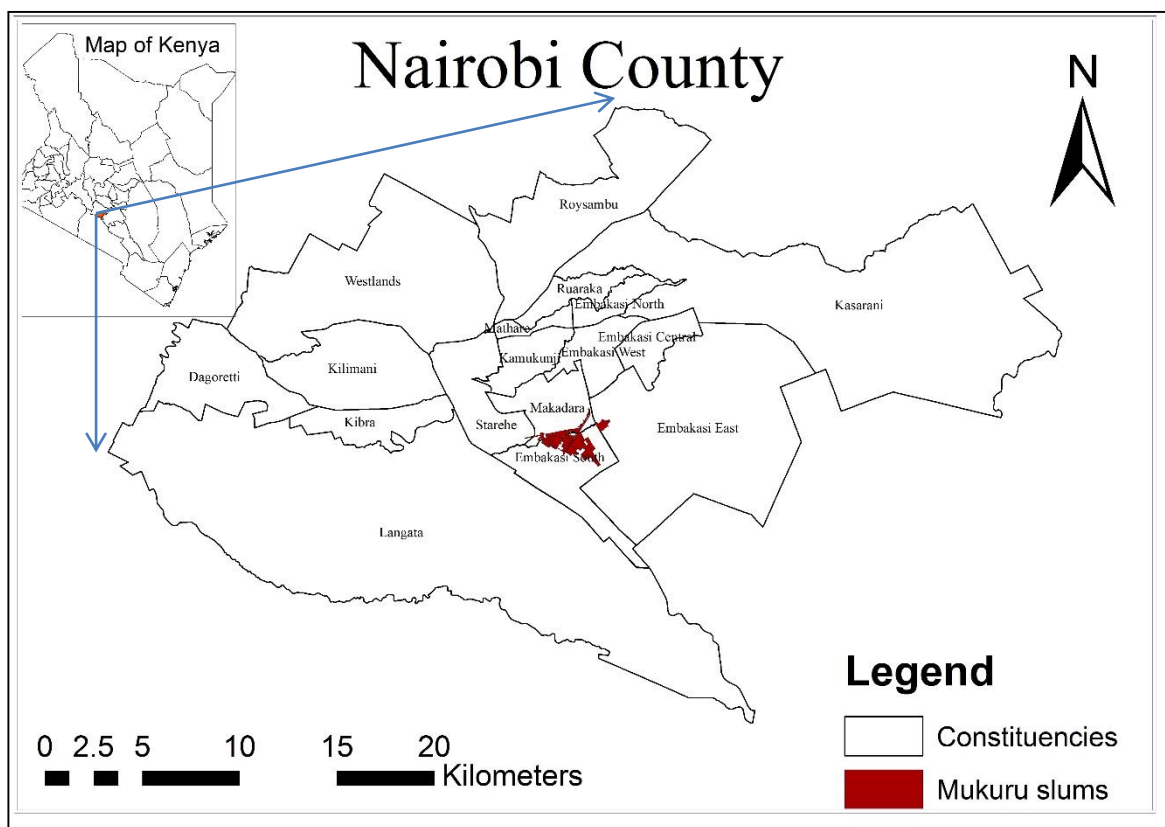


Figure 9 Map of study area.

Mukuru slums lie in Nairobi's east lands area, approximately sixteen kilometres to the south-east of the city as shown in the figure above. Ngong' river-cuts across the slums. The word Mukuru means valley in the local language *Kikuyu* and the slums probably get their name from their situation on the Ngong' river valley.

The railway line also cuts across the informal settlement forming the boundary between Mukuru kwa Reuben and Mukuru kwa Njenga. The slums are then composed of villages with Mukuru kwa Reuben consisting of twelve villages and Mukuru kwa Njenga about villages.

3.2 Research Design

This research design utilized a case study approach whereby two informal settlements in Nairobi, Kenya were selected namely Mukuru kwa Reuben and Mukuru kwa Njenga. The study aimed at investigating certain key elements namely settlement growth, settlement character and their impacts on infrastructure and on the environment. The research was divided into two main stages. Stage one involved analysis of aerial photographs and a remotely sensed Quick bird image. This provided answers for the first two objects targeting a model showing growth of the slum, quantify the change over time of the slum and thirdly to identify any changes in character of the slum. The findings from the first stage of the research provided a basis for the questions to be answered during the field survey. This part of the study targeted understanding the planning impacts the slum growth has had on both service provision and on the environment.

The research study began by first trying to determine whether the settlement had experienced any spatial growth and at what rates over the study period beginning 1978 to 2008. Changes in character were also identified at this stage. These two aspects were determined partly from remotely sensed imagery and aerial photographs. In order to quantify the change over time in land use of the Mukuru slum at selected stages of development, satellite imagery was required, aerial photographs and ground truthing data. A model was developed showing the growth rates during the study period.

The character of a settlement can be described with regards to form, shape, size and orientation. Similarly, satellite imagery and aerial photographs were used to gather this data. Mainly, this was a visual analysis whereby the researcher was interested in understanding whether there had been any change in character in these human settlements. Digitized maps will be used to demonstrate if there has been any change.

Then considering that there has been growth and change in character of the settlement then the researcher was interested in understanding the planning implications these two aspects have had on service provision and on the environment. However, this type of data could not be easily derived from remotely sensed imagery without getting first hand feedback from the inhabitants of the settlement. The researcher was interested the impact such growth and change in character had on availability of amenities and services. A field survey targeting the inhabitants of the settlements, the local administration, and other key informants for example scholars who have conducted studies in the same area. The methods of data collection were by observation, photographs and questionnaires.

From the field study, the researcher gathered data on the year the respondents first moved to the Mukuru slums area, the reason for moving there, issues concerning availability and cost of services for example water and power. Data on availability of toilets and garbage collection was also gathered.

Ultimately, from the findings of the study, the researcher was able to suggest probable planning solutions to the problems identified.

Table 1 Data Needs Matrix.

Objectives	Data Needs	Sources of data	Data collection methods	Data analysis	Data Presentation	Output
To quantify the change over time in land use and the character of the Mukuru slum at selected stages of development.	-Satellite Imagery -Aerial photographs -Ground truthing data	-RCMRD -Survey of Kenya	-Photography -Aerial photographs -Satellite images	-Using ArcGIS to geo-reference, digitize and quantify the land use change	-Tables -Maps	-The model showed the growth rates during the study period. -The maps showed the transformation in shape of structures and character of area over study period.
To identify the implications of such growth and transformation to service provision.	-Availability of amenities and services.	-Field survey -Local administration	-Observations -Photography -Questionnaires -Satellite images	-Spatial analysis tools -SPSS	-Reports -Photographs	-A report on the different planning implications resulting from development of the slum.
To identify the implications of such growth on the environment	-Availability of amenities and services.	-Field survey -Local administration	-Observations -Photography -Questionnaires -Satellite images	-Spatial analysis tools -SPSS	-Reports -Photos	-A report on the different planning implications resulting from development of the slum

3.3 Research Population

The target population consisted of all the inhabitants of the Mukuru kwa Njenga and Mukuru kwa Reuben slums considering that a planning solution has to be provided in order to make their living environment better. A questionnaire was administered to the households. The following is a tabulation of population per village. (KNBS, 2009)

Mukuru kwa Reuben population per village

Table 2 Mukuru kwa Reuben population per village. (KNBS, 2009)

Enumeration area	Total population	Households
Gatope	2915	1187
Kariobangi	1507	647
Bins	2305	964
Mombasa	1331	486
Feed the Children	4504	1774
Simba Cool	1897	736
Rurie	5750	2222
Reuben kijiji Mpya	2343	971
Kosovo	4036	1554
Gateway	4557	1703
Railway	9724	3791
Wesinya	2767	1003
Total	43,636	17,038

Mukuru kwa Njenga population per village

Table 3 Mukuru kwa Njenga population per village. (KNBS, 2009)

Enumeration area	Total population	Households
Sisal	6791	2490
Milimani	4752	1697
Vietnam	14979	5430
Riara	8551	3172
Wape Wape	11631	4665
Zone 48	10901	3686
Moto Moto	8900	3195
MCC	8294	3054
Total	74,799	27,389

3.4 Sampling plan

The case study targeted the villages within the two main slums that make up the Mukuru slums namely Mukuru kwa Njenga and Mukuru kwa Reuben. The unit of analysis used was the house hold. Type of sampling used was simple random sampling whereby the villages to be used for the study were selected, then within the selected villages, systematic random sampling was used when conducting the study along transects. The transects mainly followed the main transportation routes within the study area. The reason behind this is that due to the risk involved into going deep into the slum, keeping to the transects along the transport corridors helped provide some security. Considering that there are two main slums targeted namely Mukuru kwa Reuben and Mukuru kwa Njenga, a total sample size of 195 was targeted as determined from the following computations.

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

Where: n = required sample size,

t = confidence level at 95% (standard value of 1.96),

p = standard deviation of 0.5 and

m = margin of error at 7% (standard value of 0.07)

$$n = \frac{196 \times 0.5(1-0.5)}{0.07^2}$$

$$n = 196$$

(Creative Research Systems, 2003)

However, considering that the size of the target population is known, i.e. 44,427 households, corrections were made in order to determine the exact sample size using the following formula.

$$nn = \frac{n}{1 + [(n-1) \div N]}$$

Where nn = new sample size, N = target population

Therefore, the corrected computed sample size:

$$nn = \frac{196}{1 + [(196-1) \div 44,427]}$$

$$nn = 195$$

Hence the total sample size for this research was 195 households. Considering that the two slums are heterogeneous since one of them is very close to a riparian reserve than the other, then proportionate random sampling was used to determine the number of villages to sample in each of the two slums namely Mukuru kwa Njenga and Mukuru kwa Reuben.

Table 4 Table showing number of villages per slum.

Slum	Total No of villages
Mukuru kwa Reuben	12
Mukuru kwa Njenga	8

As indicated in table 4 above, Mukuru kwa Reuben has a total of 12 villages as compared to 8 villages in Mukuru kwa Njenga. Comparing the household populations of the two slums as shown in table 5, an approximate ratio between the two slums can be determined.

Table 5 Proportionate ratio per slum.

Slum	Household population	Ratio
Mukuru kwa Reuben	17,038	0.4
Mukuru kwa Njenga	27,389	0.6
Total	44,427	1.0

From the computed ratio of 0.4:0.6, the number of villages to target in each slum was determined by multiplying the ratio for each slum by the total number of villages present in that slum.

So, for Mukuru kwa Reuben:

$$0.4 \times 12 = 4.8 \cong 5 \text{ villages}$$

For Mukuru kwa Njenga:

$$0.6 \times 8 = 4.8 \cong 5 \text{ villages}$$

A simple random sampling was then conducted to determine the villages to be targeted during the research in each slum. The following table shows the selected villages for each slum.

Table 6 Villages targeted within Mukuru kwa Reuben.

Enumeration area	Households
Kariobangi	647
Mombasa	486
Rurie	2222
Railway	3791
Wesinya	1003
Total	8,149

Table 7 Villages targeted within Mukuru kwa Njenga.

Enumeration area	Households
Sisal	2490
Milimani	1697
Vietnam	5430
Wape Wape	4665
MCC	3054
Total	17,336

Stratified random sampling was then used to determine the number of questionnaires to administer to each village using the following formula.

$$S = \frac{nn \times a}{A}$$

Where S = sample size within strata, nn = new sample size,

a = number of households per strata,

A = total number of households

Considering that the determined $nn = 195$ and A is 25,485, we can then determine the S (sample size within strata) for each a for which the results are indicated in the following tables.

Table 8 Determined number of questionnaires per village for Mukuru kwa Reuben slum.

Enumeration area	Households per strata	Number of questionnaires per strata
Kariobangi	647	5
Mombasa	486	4
Rurie	2222	17
Railway	3791	29
Wesinya	1003	8
Total	8,149	63

Table 9 Determined number of questionnaires per village for Mukuru kwa Njenga slum.

Enumeration area	Households per strata	Number of questionnaires per strata
Sisal	2490	19
Milimani	1697	13
Vietnam	5430	42
Wape Wape	4665	35
MCC	3054	23
Total	17,336	132

3.5 Data collection methods and instruments

For Primary data, a questionnaire was administered to the heads of households (either male or female). Four research assistants were recruited for the exercise. The questionnaire aimed at gathering data per slum i.e. Mukuru kwa Njenga and Mukuru kwa Reuben. Data for example size of household, year first respondent moved to the slum and their reason for moving to that

slum was also collected. Accessibility to services and the cost of these services for example water, power, roads, sewer lines and garbage collection were also enquired. Ultimately environmental aspects for example distance from River Ngong' were queried in order to determine settlement on the riparian reserve.

For the secondary data, the data was sourced from the Regional Centre for Mapping and Resource Development in Kasarani, Nairobi. Aerial photographs sourced from the Survey of Kenya were used as a source of data during earlier years of the study 1978 and 1998 high resolution imagery mainly from Quick bird images (2008) was used for the latter period of the study (2003-2010). The primary data collected was then analysed using SPSS statistics software whereby statistics such as means and modes were determined. Comparisons on tables, charts and graphs were also made. For the secondary data, the images were geo-referenced, digitized and computations on areas occupied at specific temporal periods deduced.

3.6 Data quality and integrity

The quality and accuracy of the remotely sensed imagery was determined by comparing features captured in the imagery with certain distinct features whose co-ordinates on the ground were known. On the other hand, a pilot study was conducted whilst preparing for the field survey. The pilot study was only conducted in the villages which were not targeted in the main survey that is in Mombasa village for Mukuru kwa Reuben and Zone 48 for Mukuru kwa Njenga. The data from the pilot study guided the researcher in the expected period of study and on whether the questionnaires were actually meeting their intended purpose.

3.7 Data inputting

SPSS and Excel were used for data entry. Cleaning and sorting was done by the researcher then the data entry was done by clerks who had prior experience of SPSS but with supervision by the researcher.

3.8 Data analysis

SPSS and Excel were used for analysis of the data from the questionnaires. ArcGIS 10 was used for analysis of the data derived from the remotely sensed imagery and from the aerial photographs. An urban growth model was then developed. The data collected using the questionnaires and structured interviews were also analysed and certain statistical test determined.

3.9 Data presentation

Findings were presented in form of pie charts, graphs, tables, maps.

3.10 Organization of the thesis

This thesis is structured into five main sections. The first section concentrates on introducing the study whereby a background on the research problem is given. The study objectives are also outlined and research questions also given. The study context has also been discussed whereby the geographical scope and research scope of the study have been discussed.

The second section of the study concentrates on reviews of literature deemed relevant in this study. This has been divided into various sub sections each dealing with the literature concerning that sub section. The first sub section reviews literature on the link between urbanization and growth of slums. The second sub section concentrates on literature discussing land use and land cover change. Drivers of land use/ land cover change and the resulting impacts are discussed. The third sub section reviews literature on the location of slums in different cities across the world. The fourth sub section discussed the challenges that result from development of informal settlements with regards to the impact of slum growth on service delivery and on the environment respectively. The fifth sub section looked at literature discussing applications of GIS and Remote Sensing towards monitoring slum growth and also on slum mapping case studies and ultimately different models of slum growth.

The third section of the research study discusses the research methodology. In this case the research design is discussed and also the key target population in the study. A sampling plan is described including the unit of analysis, type of sampling the units and also the sample size. Data collection methods and instruments used in the study were also described. Issues regarding data quality and integrity were also discussed followed by the soft wares used for data inputting and analysis. The different methods used for data presentation have also been discussed. This is followed by the structure of the thesis and the ethical implications involved.

The fourth section of the study discussed the findings and analysis. The findings were discussed per objective.

The fifth section provided the key findings, conclusions and recommendations derived from the study.

3.11 Ethical implications

The researcher did respect the research participants and their opinions. They were not treated as objects and only important questions were addressed. Any individual's participation was voluntary and was informed prior on the intended research procedure, purpose of research and ultimate use of the findings including non-disclosure of any information that could be traced back to the participant. In order to ensure voluntariness, no reward was offered in exchange for information and no coercion whatsoever was used. In cases where the researcher had to seek assistance of the local administration mainly the chief and the village chairmen, the researcher was careful so as to ensure he does not come out using unjustifiable pressures on the participants.

Due to sensitivity of information, the respondents did not give their name. More so, cell phone numbers were not requested on the research instrument. The research study also ensured that the immature and also the incapacitated may be due to illness were also protected. Ultimately, the data collected during the research study was specifically used only for scholarly purposes.

3.12 Research challenges

The main challenge experienced was on data collection. In the proposal stage the study intended to use only Quickbird Satellite images but this was not possible considering the temporal period under study was from early 1980's whereas there was no very high resolution imagery then. Also regarding seeking authorization to work in a slum area was very difficult. The local chief tried to assist whenever he could but still the chairmen of individual villages still made it difficult. It is for this reason (lack of authorization) that the study was not conducted in one of the villages in Mukuru kwa Njenga namely M.C.C. Security to the researcher team was also a bit problematic.

4.0 Research Findings and Discussions

4.1 Introduction

This study investigated the spatial growth of the Mukuru slums and the associated implications on the environment and on service delivery. This was in light of the changes over time that have been experienced in the character and spatial patterns of developments in the Mukuru slums and their impacts on development of infrastructure for example water, sanitation and road networks and also on the environment with respect to encroachment on the riparian reserve and disposal of garbage. The data collected was analysed using SPSS 20 and ArcGIS 10 soft wares. The year 1998 was selected as the base year. This was due to availability of data on that specific year and considering that the other available data was for year 1978 and 2008 then the middle period year was selected to aid in comparison of the two study periods pre-1998 and post-1998 hence the use of 1998 as the base year.

4.2 Settlement Growth and transformation

The main objective of the research study was to model slum growth and transformation in Mukuru slums and its implications on access to basic services. The first specific objective of the study was to quantify the change over time in land use and identify the character change in the Mukuru slum at selected stages of development. To achieve this objective, aerial photographs of 1978 and 1998 and remotely sensed imagery for year 2008 were used to quantify growth since 1978 up to year 2008. Respondents were also asked which year they first moved to the Mukuru slum area and the probable reason for moving there.

4.2.1 Spatial Element

4.2.1.1 Mukuru Slums 1978

Literature shows that the Mukuru slums began developing as a labour camp for the Reuben haulage empire owned by a British Army Veteran Jack Reuben in the year 1979. (Howden, 2012) The aerial photograph in figure 10 was taken in 1978 and it shows the area currently under the Mukuru slums, the only distinct features are the railway line cutting across the image (digitized using a red line) and the river shown by a blue line on the upper part of the photograph. There is also a stream shown in the lower half of the photograph. To the top of the photograph where the title of the image is are some visible buildings showing the industrial area of Nairobi. There are also two very distinct buildings that have been digitized in red polygons. The buildings are visible in succeeding images. It is visible that the slum had not

begun developing yet considering that there is no visible presence of an informal settlement. The area was still open land and actually this concurs with studied literature that the area under Mukuru slums was initially a sisal farm. (Howden, 2012)

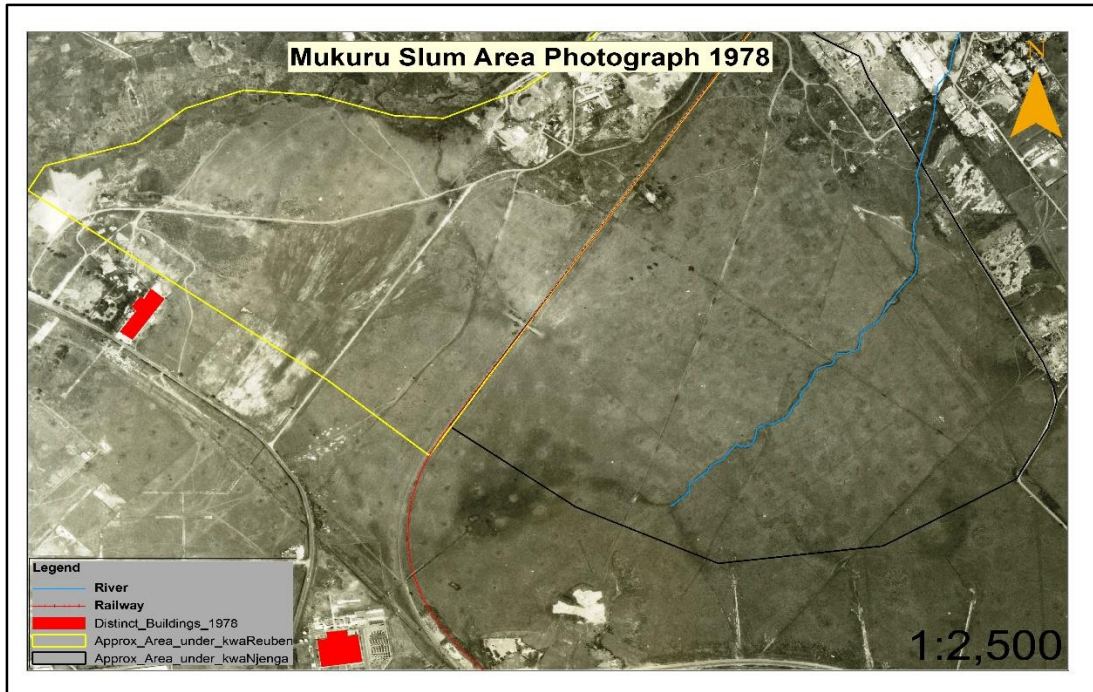


Figure 10 Mukuru slums Aerial Photograph 1978. (Survey of Kenya, 2013)

4.2.1.2 Mukuru Slums 1998

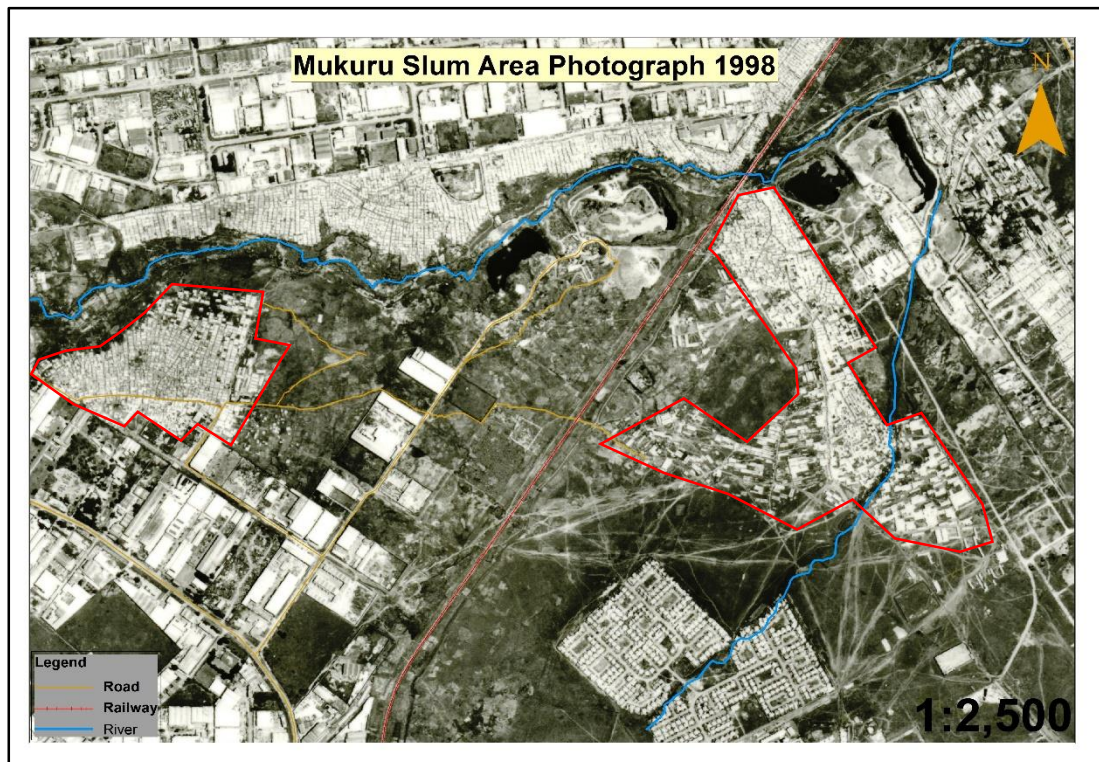


Figure 11 Mukuru slums Aerial Photograph 1998. (Survey of Kenya, 2013)

After twenty years of increasing population since 1978 to 1998, there is evidence of growth of an informal settlement as illustrated in the highlighted area using red on the figure 11.

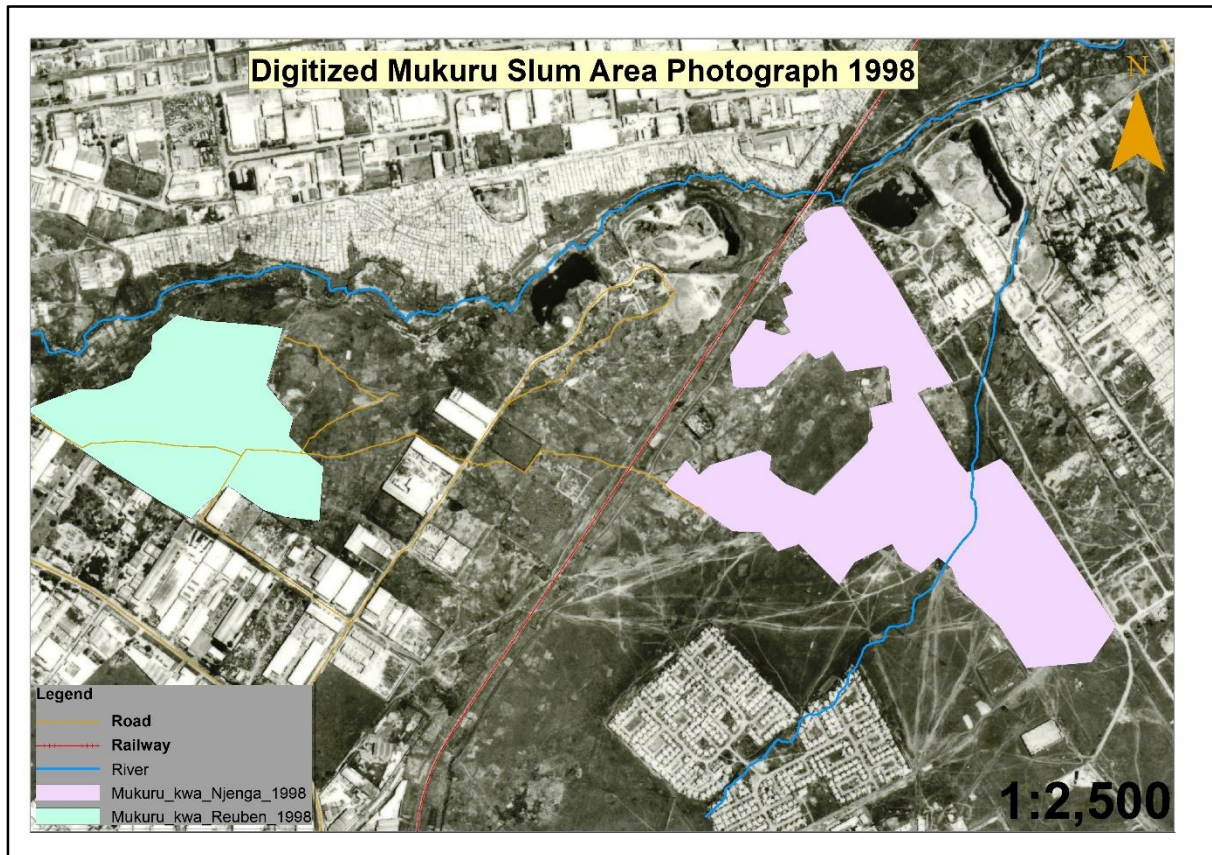


Figure 12 Mukuru slums aerial photograph showing digitized spatial areas for Mukuru kwa Reuben and Mukuru kwa Njenga.

Figure 12 shows the digitized area under Mukuru kwa Njenga and Mukuru kwa Reuben. To the south east of the photograph is the estate currently known as Imara Daima estate and also Villa Franca Estate further bottom of Imara Daima estate. The south west of the photograph shows well planned developments mostly of ware houses and industries. There is still quite some open unoccupied land mostly at the centre of the photograph. This photograph of the *Mukuru* slums area taken in 1998 while compared with that of the same area taken in 1978 shows quite some spatial growth over the 20 year temporal period. The actual spatial growth for both years has been compared in table 10.

4.2.1.3 Mukuru Slums 2008

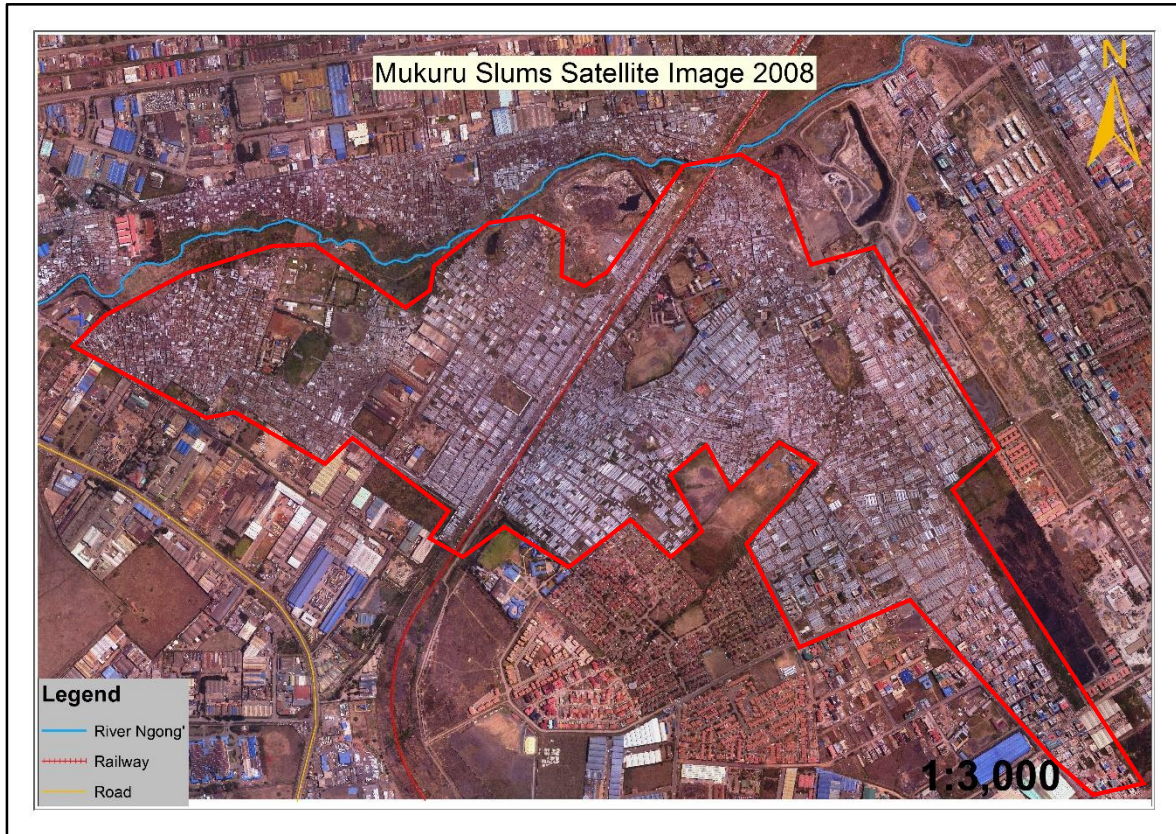


Figure 13 Satellite image of 2008 showing area covered by Mukuru slums.

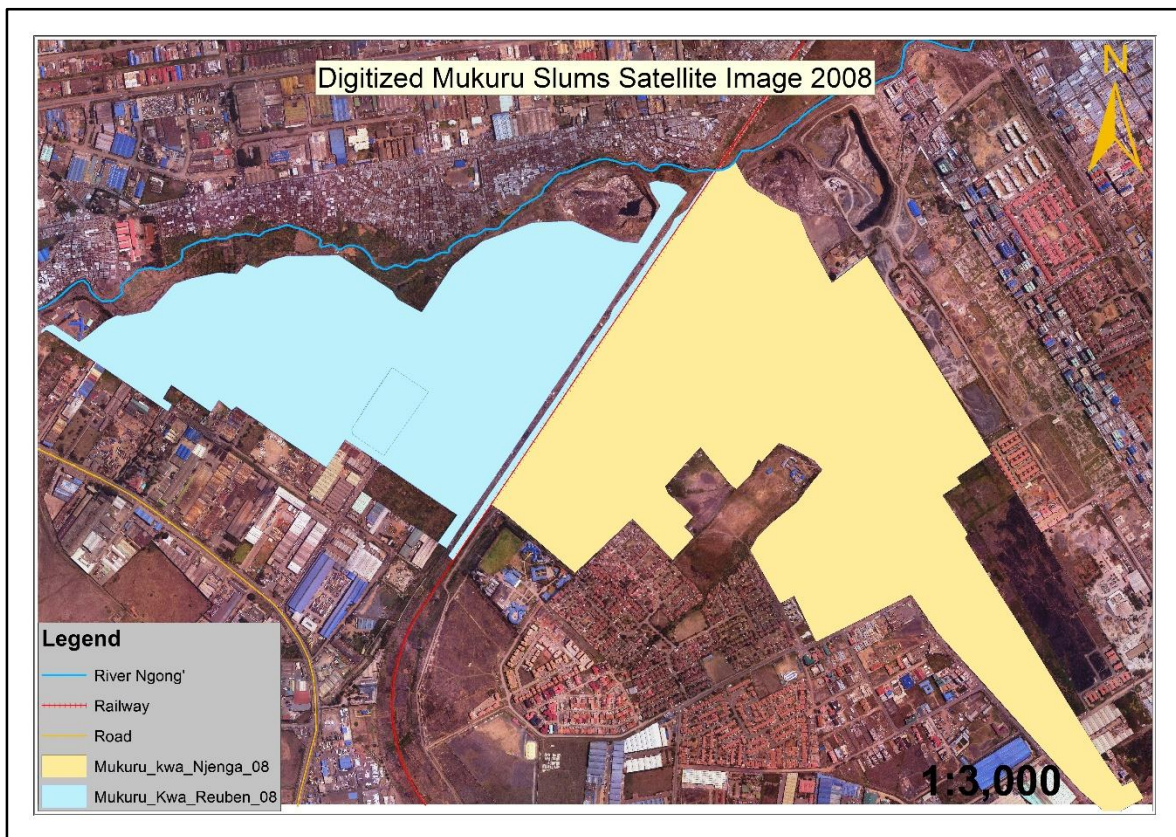


Figure 14 Digitized image of Mukuru slums.

Figure 13 shows a Quick bird satellite image for 2008 showing the study area roughly highlighted in red. The image also shows River Ngong’ on the upper half of the image. The railway line cuts across the Mukuru slums and provides the boundary between Mukuru kwa Reuben which sits on the upper half of the image between River Ngong’ and the railway line while Mukuru kwa Njenga lies on the lower half of the image to the south of the railway line. Figure 14 shows a digitized image of each slum, Mukuru kwa Njenga and Mukuru kwa Reuben.

Table 10 Computed area under slum in hectares.

Slum	Spatial Area under slum (Hectares)		
	1978	1998	2008
Mukuru kwa Njenga	0	40.908	125.011
Mukuru kwa Reuben	0	20.996	77.103

Table 10 above shows the spatial area covered by each of the slums for each temporal period in hectares. As illustrated in figure 4, the slum did not exist prior to 1978 thus there is 0 hectares occupied by the slum. Figures 11 and 12 show the spatial area covered by the slum during the temporal period 1978 to 1998. The results are a spatial growth of approximately 40.9 hectares for Mukuru kwa Njenga and approximately 21 hectares for Mukuru kwa Reuben. Figures 13 and 14 show the area covered by the slum during the temporal period 1998 to year 2008. From the image, the spatial area covered by each of the slum as at 2008 stood at approximately 125 hectares for Mukuru kwa Njenga and approximately 77 hectares for Mukuru kwa Reuben.

Table 11 Table showing a comparison of the spatial growth per temporal period in hectares.

Slum	Period between 1978 and 1998	Period between 1998 and 2008
Mukuru kwa Njenga	41 hectares	84 hectares
Mukuru kwa Reuben	21 hectares	56 hectares
Total spatial growth per temporal period	62 hectares	140 hectares

Table 11 above shows a comparison of the spatial growth per temporal period per slum beginning with period between 1978 and 1998 that had a spatial growth of approximately 41

hectares for Mukuru kwa Njenga as compared to a spatial growth of 21 hectares for Mukuru kwa Reuben over the same temporal period. For the period between 1998 and 2008, Mukuru kwa Njenga slum had a spatial growth of approximately 84 hectares as compared to approximately 56 hectares for Mukuru kwa Reuben over the same temporal period.

4.2.2 Drivers of settlement growth

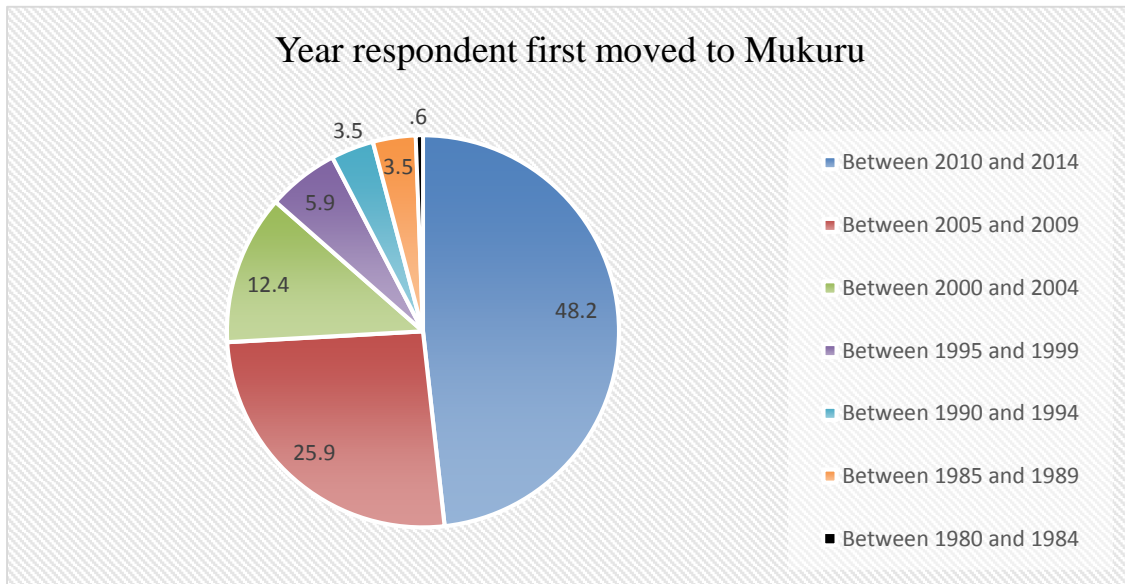


Figure 15 Chart showing the year respondent first moved to Mukuru area.

The spatial growth of a settlement is driven by the increase in population in a given area. This research study questioned the year the respondent first moved to the Mukuru area and the reasons for moving there.

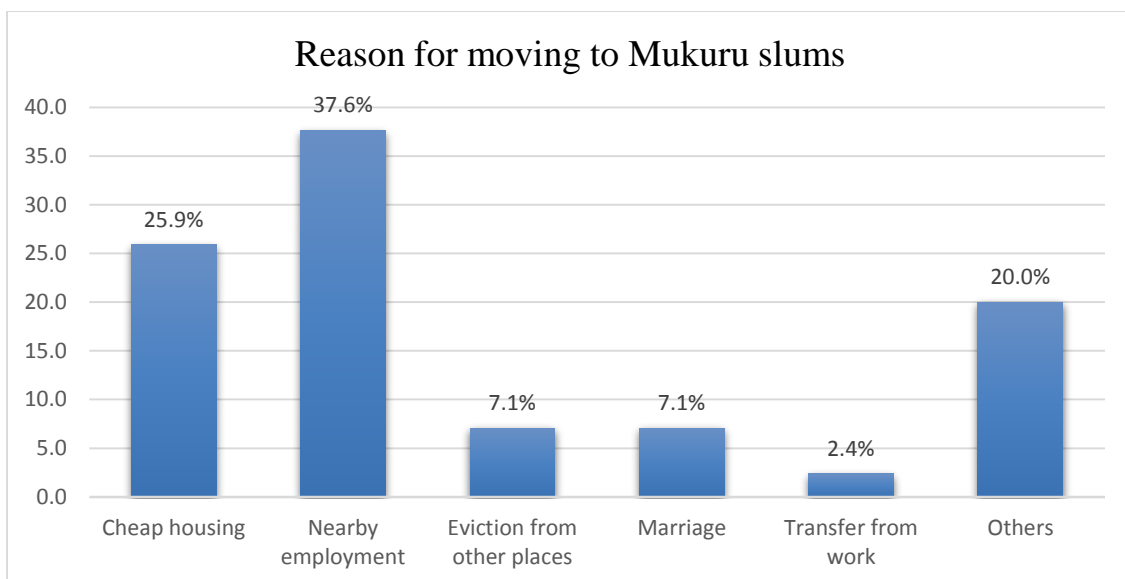


Figure 16 Graph showing results for reason for moving to Mukuru slum area.

Figure 15 shows the results after respondents were asked the year they first moved to Mukuru. The results indicate that a total of 86.5 % moved to Mukuru area between years 2000 and 2014. Only 13.5 % responded on having moved to Mukuru between years 1980 and 2000. None responded of moving to Mukuru area before 1980. The research also enquired the reasons for moving to the Mukuru area and not to other areas as indicated in figure 16. The results indicate that the main reason was due to access to nearby employment mainly Nairobi's industrial area standing at 37.6 % of the respondents while marriage and eviction from other places stood at 7.1 % each of the target population.

4.2.3 Discussion of findings on Settlement growth and transformation

The first objective of the study was to quantify the change over time in land use and identify the character change of the Mukuru slum at selected stages of development. Data analysis and interpretation of feedback from respondents and from aerial photographs and satellite imagery revealed the following major findings under this objective. It revealed that the Mukuru slums began developing after 1978. This is in agreement with the findings of Howden (2012) who indicates that the Mukuru slums began developing as a labour camp for the Reuben haulage empire owned by the British Army Veteran Jack Reuben in 1979. The spatial growth between 1979 and 1998 was approximately 41 hectares for Mukuru kwa Njenga slum and approximately 21 hectares for Mukuru kwa Reuben. On the other hand the spatial growth between 1999 and 2008 was approximately 84 hectares for Mukuru kwa Njenga and approximately 56 hectares for Mukuru kwa Reuben. This therefore indicates that the slum grew the most between 1999 and 2008 (over a 10 year period) as compared to the twenty year period from 1978 to 1998.

This is also supported by the findings displayed on figure 15 whereby 86.5 % of the respondents interviewed moved to the Mukuru slums area after the year 2000. Considering that most of this movement was driven by availability of nearby employment (in the nearby industrial area) and cheap housing then the most probable cause of this migration to the Mukuru slums area was due to search for better jobs mostly driven by rural to urban migration. This findings are in agreement with the views of Mitullah (2003) who also expresses the view that "The post-colonial period saw a relaxation of the colonial residential segregation policies, and major population shifts occurred, notably rural-to-urban migration, with little obstruction to the proliferation of urban shacks 'as long as they were not located near the central business district'. Slums sprang up all over the town in the proximity of employment.....The post-independence period also saw rapid urban population growth without corresponding housing provision....."

Table 12 Comparison of population in Nairobi province per Census year (KNBS, 2014)

Census Year	1969	1979	1989	1999	2009
Population of Nairobi	509,286	827,775	1,324,570	2,143,254	3,138,369
Population density	746	1,210	1,911	3,079	4,515

The table 10 shows a summary of population of Nairobi province and the population density per census year. The information presented illustrates the population growth experienced in the city of Nairobi since independence demonstrating an increase in population density from 746 in 1969 to 4,515 in 2009. With increasing population being unmatched by provision for decent housing and services, informal settlements continue to emerge and grow. Further, the Global Report on Human Settlements (2003) report notes the following “...Slums and urban poverty are not just a manifestation of a population explosion and demographic change, or even of the vast impersonal forces of globalization (rather) slums must be seen as the result of a failure of housing policies, laws and delivery systems, as well as of national and urban policies.” The same report goes ahead and notes that “... the urban poor are trapped in an informal and ‘illegal’ world- in slums that are not reflected on maps, where waste is not collected, where taxes are not paid and where public services are not provide.”

4.2.4 Change in character of the settlement

The character of a settlement can be described with regards to the size, shape, colour and orientation of structures within that settlement. Analysis on character of a settlement is mainly a visual analysis of two different settlements or sections of a settlement. In order to bring out the change in character of the study area during the selected temporal period, two different villages in the same settlement were selected in Mukuru kwa Reuben. Figure 11 shows a map of the Mukuru area from an aerial photograph taken in 1998. The photograph shows the area under which the informal settlement started growing i.e. pre-1998. In order to bring out the change in character, this area has been selected and compared to another area within the same settlement but in which the informal settlement developed in the period between 1998 and 2008.

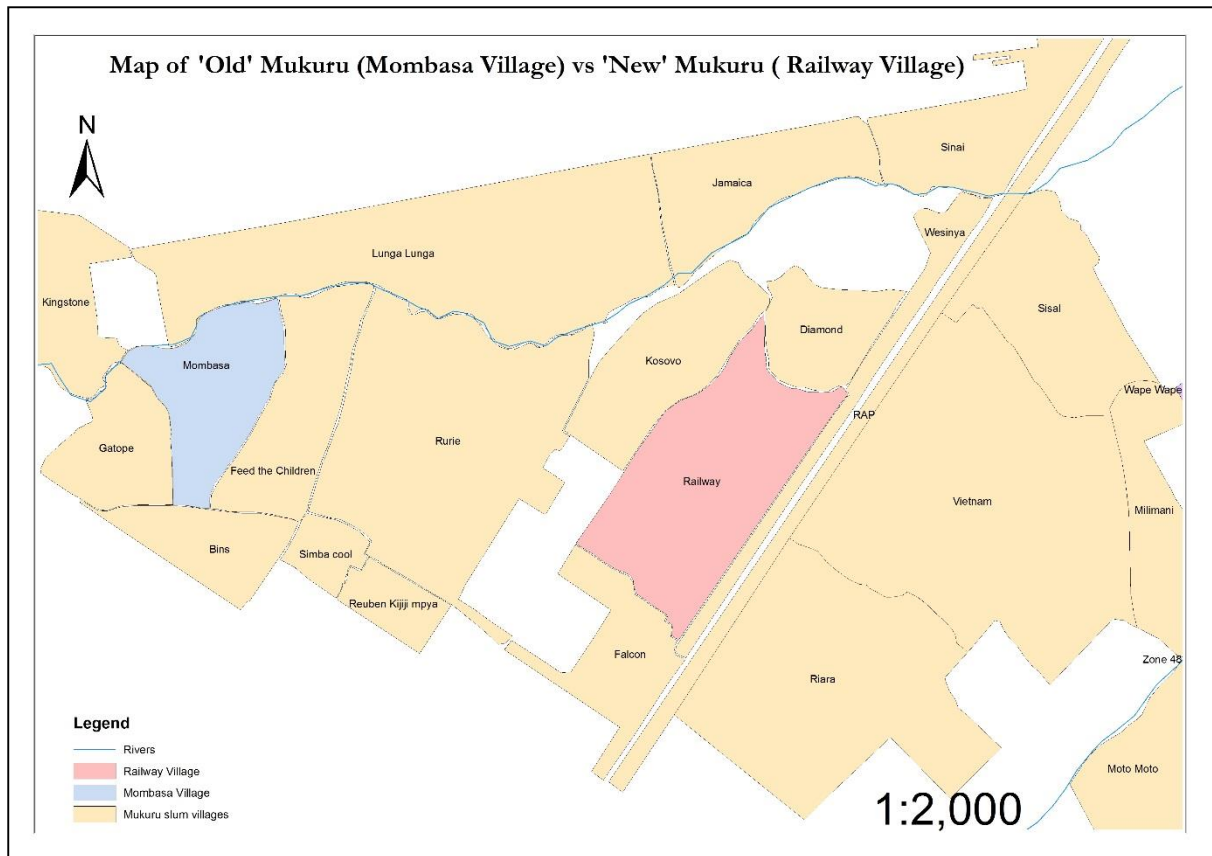


Figure 17 Map showing two different villages that developed during two different temporal periods. Pre-1998 for Mombasa village and Railway village for Post-1998.

The two different areas are illustrated in the figure 17.

Figure 18 shows a high resolution satellite image of the study area with the two areas Mombasa and Railway villages within Mukuru kwa Reuben being highlighted whereby area A represents Mombasa village which developed during the period 1978 to 1998 while area B represents Railway village which developed during the period 1998 to 2008 as illustrated by preceding aerial photographs.

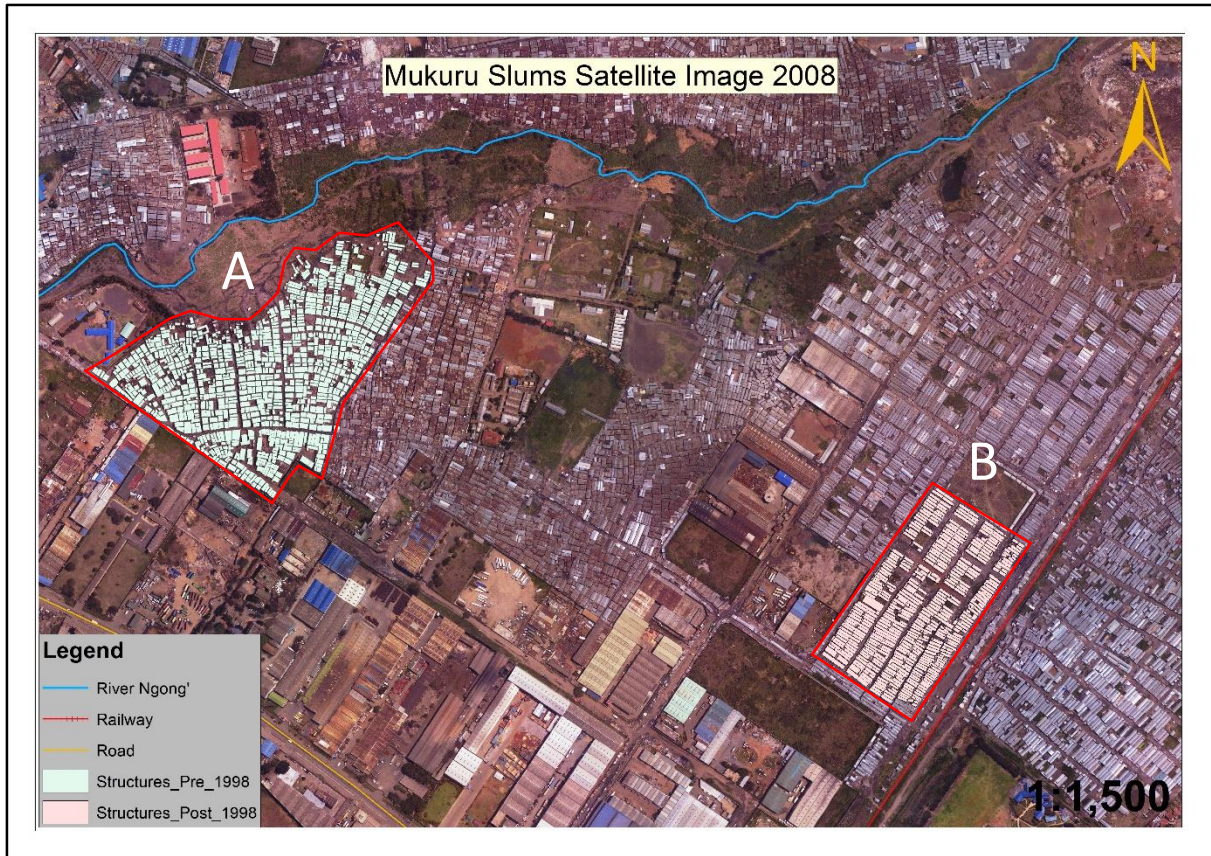


Figure 18 A character map of Mukuru slums showing two different sections of the slums (A and B) that developed in two different periods.

The same high resolution image showing the two settlements A and B is illustrated on figure 19 but at a lower scale.

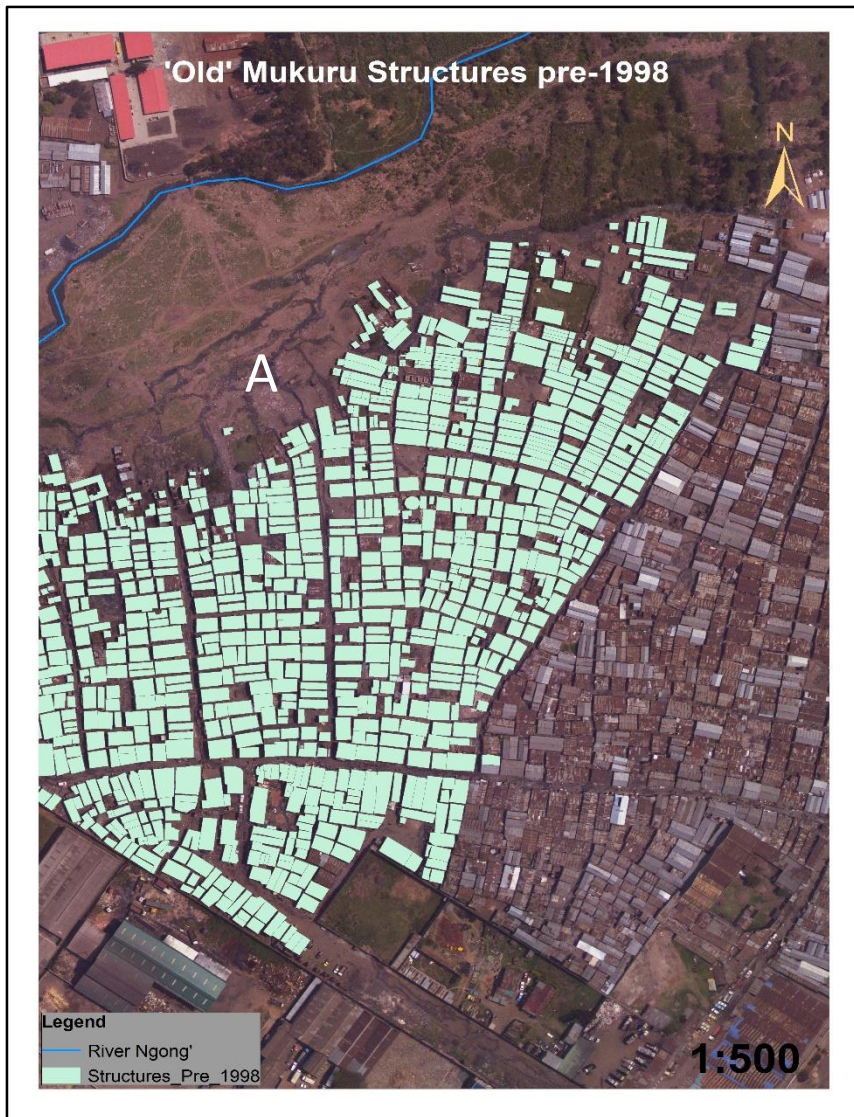


Figure 19 Character maps showing a comparison of structure alignment for Mukuru pre-1998 and post-1998.

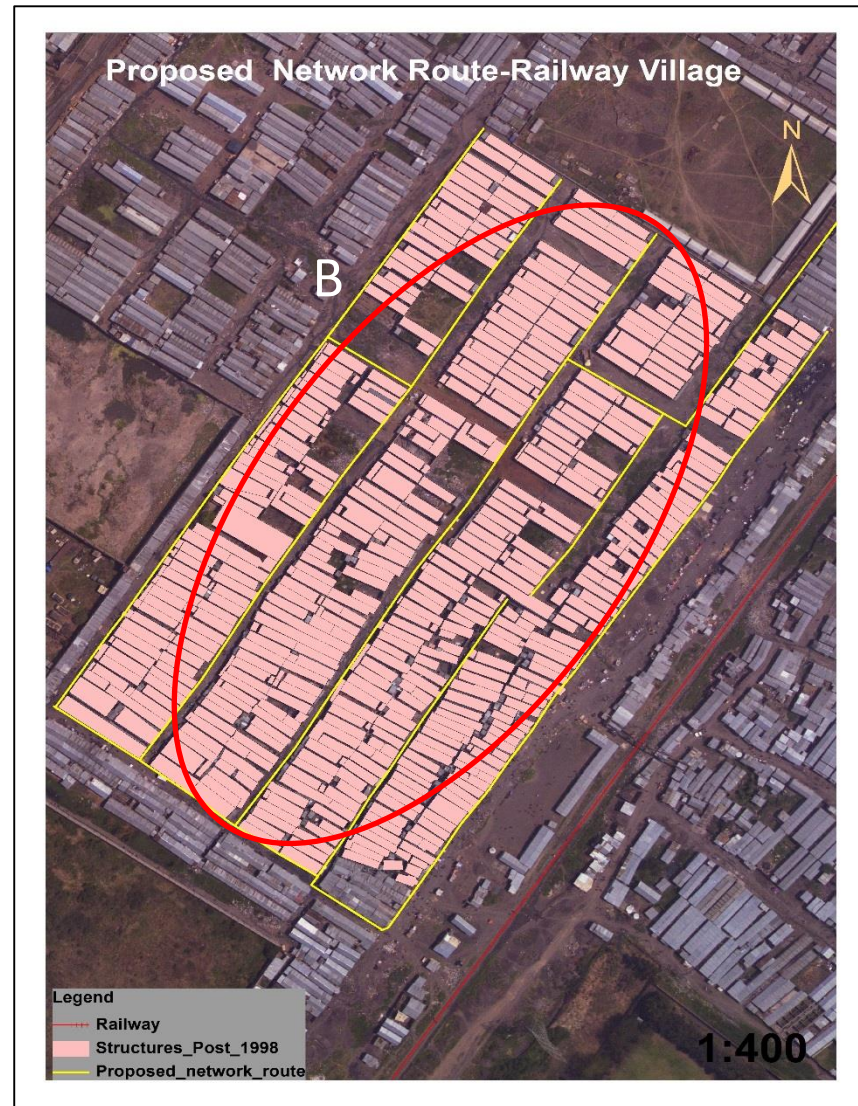


Figure 20 Character maps showing probable network routes pre and post 1998.

The change in size and shape of the structures has changed as much in both stages of analysis. The main change comes out with regards to orientation and alignment of the structures. It comes out clearly that the structures developed post 1998 (1999-2008) are well aligned and oriented similarly as opposed to those developed pre-1998 (1979-1998) and illustrated on figure 19. The character of any settlement has an implication on certain aspects of a society. The character of a settlement determines ease of movement within a settlement and the ease of service delivery within any settlement. From the analysis of the two settlements Mombasa and Railway villages, one can conclude that it may be easier to provide services and move around within Railway village which developed post-1998 as compared to doing the same within Mombasa village which developed pre-1998. This has been illustrated by the character map on figure 20 which shows existing possible network routes. The red eclipses indicate areas of focus whereby figure 20 (A) which illustrates Mombasa village that developed pre-1998, due to the haphazard constructions, the possible existing network routes do not reach all parts of the village. While figure 20 (B) illustrates Railway village that developed post-1998 whereby due to the proper uniform orientation of the existing structures, then the existing possible networks routes are uniformly aligned and oriented and reach almost all existing structures. It can be therefore be argued that the pre-1998 settlement developed spontaneously whereby there was completely no authority over the land hence the haphazard development. However, the development post-1998 is different in that it is much more organized hence it can be concluded that it is possible there was an authority that was guiding this development more so with regards to subdivision of the land.

A comparison on the impact of the change in character on service provision in the two different villages Mombasa and Railway was carried out and reported under the implication of the growth and transformation of Mukuru slums on service provision. (See section 4.3)

4.3 Implications of the growth and transformation of Mukuru slums on service provision

The second objective of this study was to determine the implications of the growth and transformation of Mukuru slums on service provision namely provision of clean and safe piped water, provision of electricity and provision of sewerage services. To achieve this

objective, the respondents during the household questionnaire were asked to respond to some questions relating to availability of key services. Some of these questions included; do you have access to clean piped water? , who (which institution) supplies your water? , is it satisfactorily clean and safe to use? , do you have access to electricity? , is it a legal connection by Kenya Power? , how much they pay for the electricity and water, level of satisfaction on the status of roads in the area was also asked. The findings on the implications of the growth and transformation of the slum on service provision were then compared with respect to the growth experienced pre-1998 and post-1998 in order to ascertain whether the change in character has had an effect on service provision.

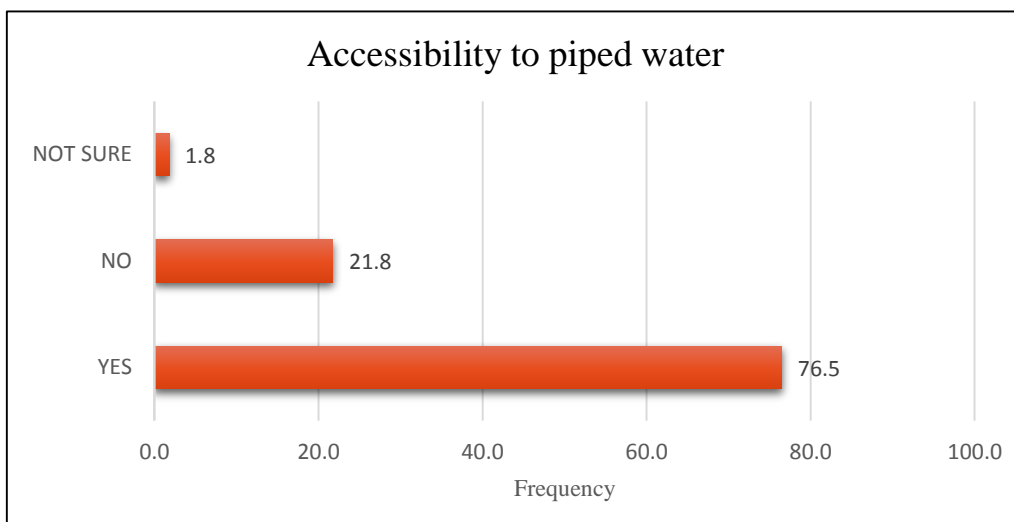


Figure 21 Graph on results of accessibility to piped water.

When the respondents were asked whether they have access to clean piped water, 76.5% of them replied that they do have access to piped water and only approximately 22% said that they do not have access to clean piped water. Approximately 2% of the respondents were not sure as displayed in figure 21.

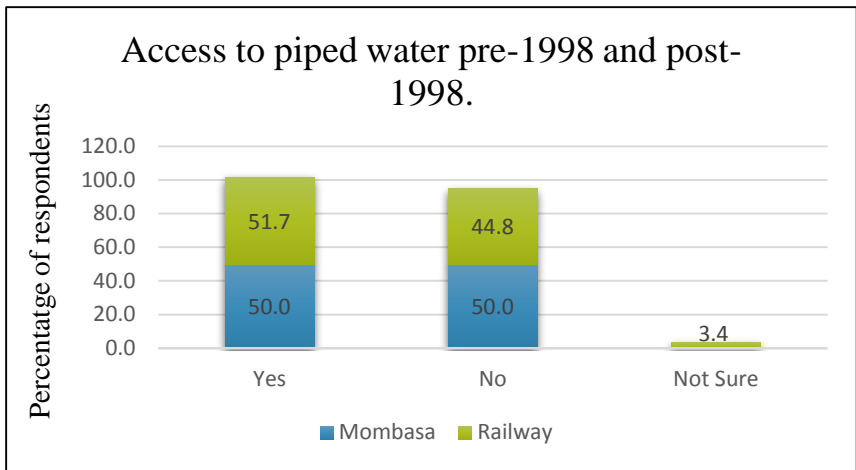


Figure 22 Comparison of accessibility to water pre-1998 and post-1998.

When an analysis was carried out comparing accessibility to water with respect to the slum villages that developed pre-1998 (Mombasa village) and those post-1998 (Railway village), 50% of the respondents in Mombasa village had access to water as compared to approximately 52% in Railway village.

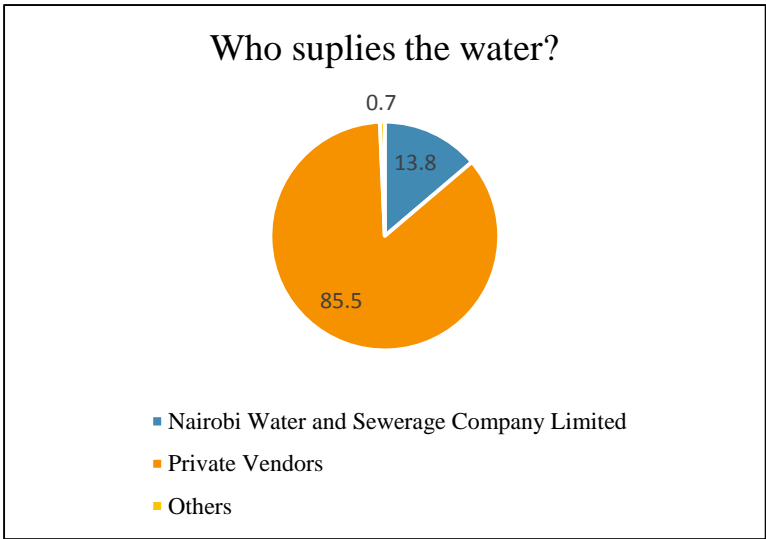


Figure 23 Chart of results on water suppliers.

When the respondents were asked who supplied their water for domestic purposes, 85.5% indicated private water vendors like the one shown in figure 24. Only 13.8% of the respondents got their water from the Nairobi Water and Sewerage Company limited. 0.7% indicated that they got their water from other sources for example rain water harvesting.



Figure 24 Plate of a private water vendor (Field study, 2014)

The study found out that some of the water vendors got their water from bore holes and from illegal connections to the main water pipes provided by the Nairobi water and sewerage company.

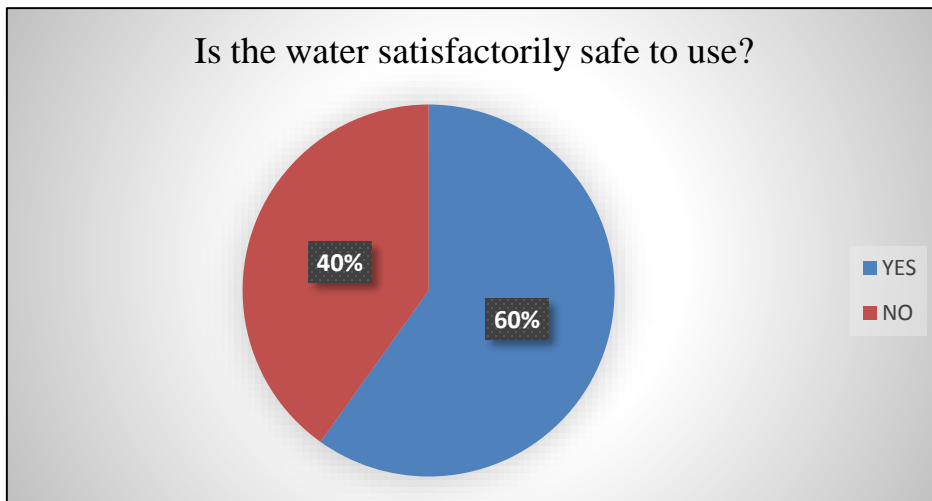


Figure 25 Chart showing results of satisfaction on safety of the available water.

The study also enquired from the respondents their opinion on the safety of the water they use whereby 60% of the respondents were satisfied with the quality of the water with the remaining 40 % not being satisfied with the quality of the water.



Figure 26 Plate showing a water vendor serving a customer from a pipe running under sewer water (Field study, 2014)

Figure 26 shows a water vendor selling water from a pipe running under dirty water as illustrated by the blackish water. This is obviously a health hazard that may result in water borne diseases.

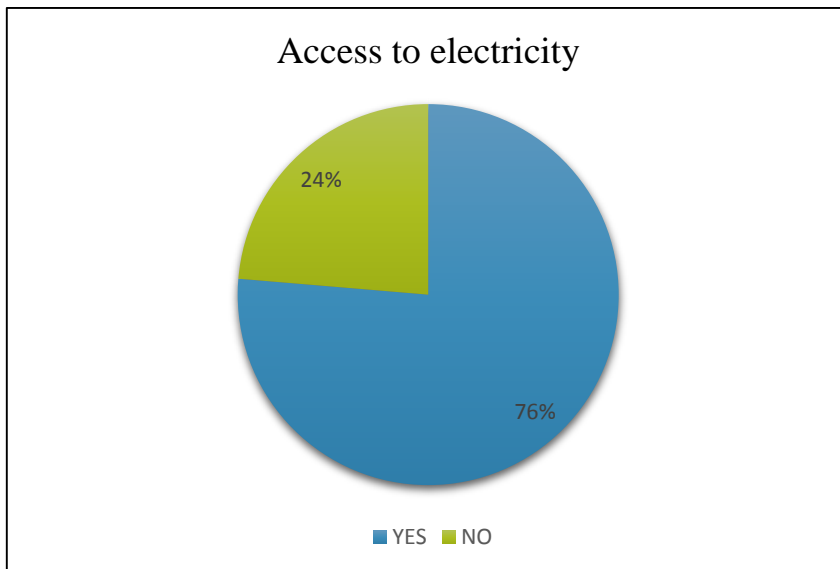


Figure 27 Chart displaying findings on access to electricity.

Figure 26 shows that access to electricity is high with only 24% of the respondents lacking access. When the respondents were asked whether their connection to power was a legal one, 66% responded that it was not a legal connection. Only 29% who had a legal connection with 5% not being sure. This results have been illustrated in figure 27.

The illegal power connections are made haphazardly and unprofessionally by private individuals who then charge per month for this illegal power supply. Residents of the slums have named the illegal power connections ‘*sambaza*’ meaning spread in Swahili and ‘*mrengo*’ meaning illegal in the local slang’ sheng’.

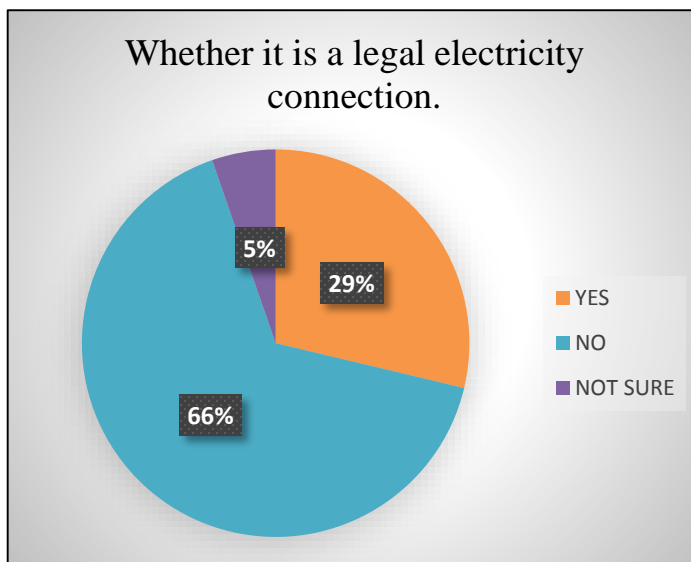


Figure 28 Chart showing results of legality of connectivity to power.

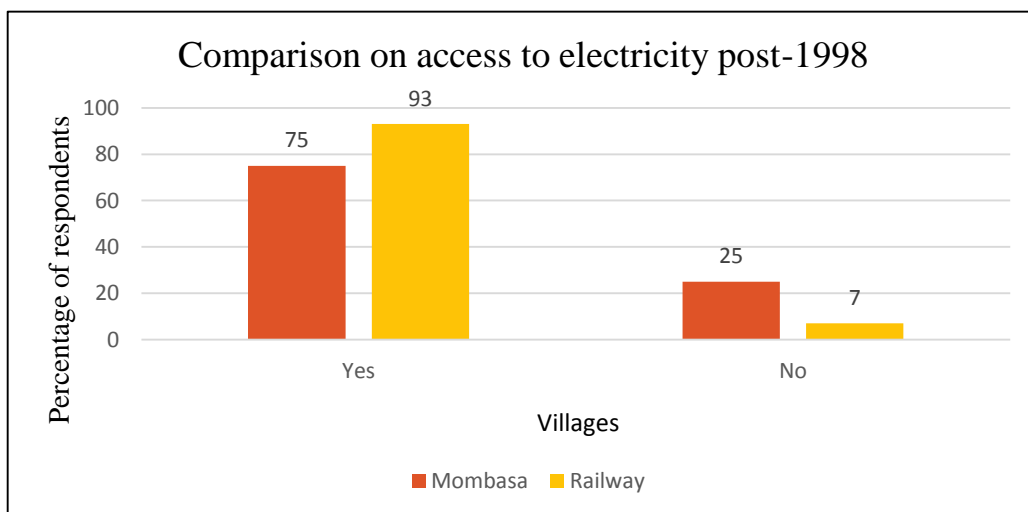


Figure 29 Graph showing comparison on access to electricity pre-1998 and post-1998.

When Mombasa village was compared to Railway village, the results indicate that 93% of the respondents in Railway village have access to electricity as compared to 75% in Mombasa village. This shows that a higher percentage of respondents by about 18% have access to electricity in Railway village as compared to Mombasa village.

Comparison on amount paid in each slum for electricity bill.

Table 13 Table showing comparison of the amounts paid in each slum for using electricity.

	Mukuru kwa Njenga	Mukuru kwa Reuben
Average bill (KES) per month	450	425
Mode (KES)	400	300
Min (KES)	300	300
Max (KES)	1700	1500

The table above shows the amounts paid per household per slum per month. Inhabitants of Mukuru kwa Njenga pay slightly higher by KES 25 to use power per month. They also pay the highest at KES 1700 per month as compared to KES 1500 per month for Mukuru kwa Reuben. This is a difference of KES 200 per month. Most of the respondents in Mukuru kwa Njenga pay slightly higher by KES 100 to use power as compared to those in Mukuru kwa Reuben.

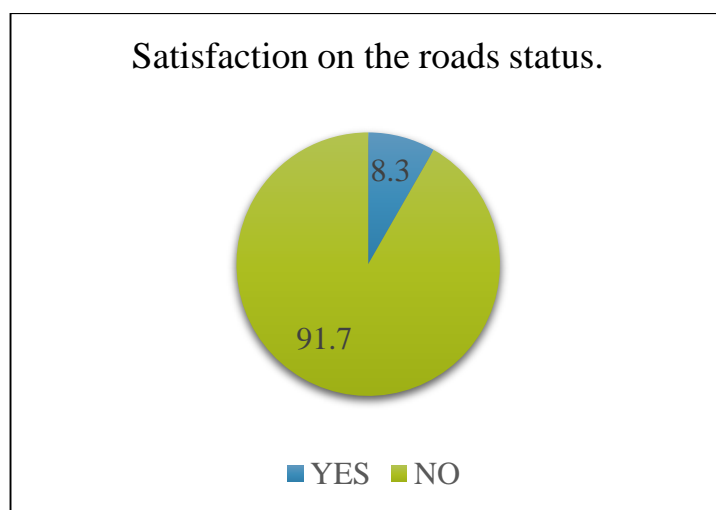


Figure 30 Chart showing findings on satisfaction on existing roads.

The research study also enquired on whether the residents were satisfied with the status of the roads in the area with only 8.3% of those interviewed responding positively as illustrated on figure 30, 91.7% responded that they were not satisfied with the status of roads in the area.

4.3.1 Discussion on findings on implications of slum growth and transformation to service provision.

The second objective of the study was to identify the planning implications resulting from the growth and transformation of the slum to service provision. From the findings of the study, slum growth has made it difficult to provide services namely safe drinking water, electricity, roads, sewer systems and solid waste disposal effectively. This has been demonstrated by the fact that even though most of the inhabitants of the slums have access to services like piped water, electricity and toilets, it is clear that the quality cannot be guaranteed. The water is mainly supplied by private vendors from whose source and safety cannot be verified. Some of the water pipes run under sewer water thus making it unhygienic. It is also clear that majority of those having access to electricity do not have a legal connection. It is this illegal connections that result in fires and deaths through electrocution since they are done unprofessionally thus posing a danger to the very users. The findings of the study agree with those of a (UN-Habitat, 2010) report stating that ‘...between 40 to 60 per cent of people in unplanned settlements in Eastern Africa lack adequate water and sanitation. Their access to water is only through street vendors.’

Service provision has however improved with the transformation of the settlement as illustrated by the comparison made on figures 22 and 29 comparing villages that developed pre-1998 (Mombasa village) and post-1998 (Railway village). With regards to access to piped water, the village that developed post-1998 reported a higher percentage of respondents with 51.7% reporting access to water as compared to 50% for the village that developed pre-1998. With regards to access to electricity, Railway village that developed post-1998 reported 93% of respondents having access to electricity as compared to 75% for Mombasa village that developed pre-1998. This therefore illustrates that the transformation or change in character of the settlement has contributed to ease of provision of services like piped water and electricity. The probable cause for this is that with the change in character

ensuring regular orientation and linearity of the structures has helped ease laying of service infrastructure for example pipes.

Considering that it is a right of every citizen more so one who pays taxes to access proper services, it is therefore the role of the concerned parties namely the County Government of Nairobi, the Kenya Power and the Nairobi City Water and Sewerage Company limited to ensure that the inhabitants of the slum areas also access services. Obudho (1997) notes the following “Access to infrastructure (in Nairobi) has been dependent on income levels rather than population density, with higher standards of provision in high-income areas than in high density low-income areas.” All illegal connections should be disconnected and proper connections facilitated. Ferguson (1996) discussing the impact lack of proper planning has on a settlement notes the following “The lack of a road network plays a fundamental role in increasing the public costs of squatting. A lack of road access makes the provision of urban services vital to health and safety difficult and costly. Installing water and sewer lines, which typically run beneath or along roads, often becomes prohibitively expensive. Police and garbage vehicles face great difficulty entering many areas. As a result, communities tend to have poor or no garbage collection and risk becoming criminal enclaves.” In the conclusion to their book, Rakodi (1997) notes “The failure of land sub division and servicing programmes to keep pace with urban growth, which has led to widespread illegal and informal development, and not only of low-income areas, has hindered the extension not only of water, electricity, and solid waste collection services but also of adequate sanitation arrangements and road networks to large areas of African cities.” This statement therefore indicates that it is not only a Kenyan problem, even not only African, the challenge remains matching urban growth (both spatially and with respect to population) with provision of services.

4.4 Implications of the growth and transformation of the Mukuru slums on the environment

The third objective of the study was to determine the implications of the growth and transformation of Mukuru slums on the environment. To achieve this objective, inhabitants of the Mukuru slums were asked to respond to several questions relating to the environment including whether they have access to a toilet, type of toilet, with how many other families

the toilet was shared, if they do not have access to a toilet how they got to dispose off waste and on issues relating to garbage disposal and collection. 94.6% of the respondents had access to a toilet as shown on figure 31 .

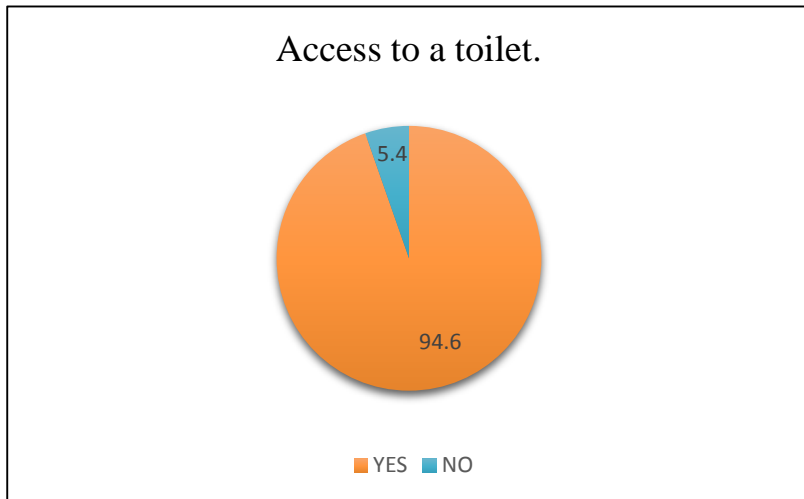


Figure 31 Chart showing proportion of respondents with access to a toilet.

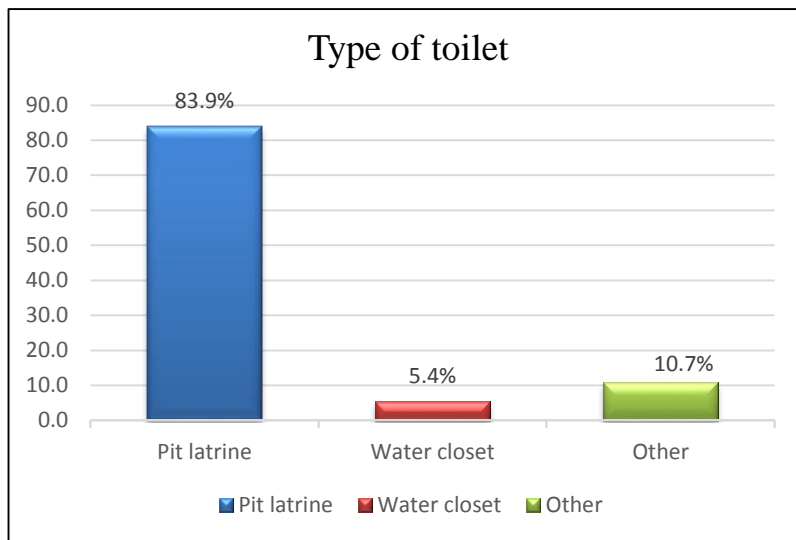


Figure 32 Graph showing proportion on types of toilets available.

Asked what type of toilet they had access to, 84% reported that they had access to a pit latrine toilet. Only 5% of the respondents had access to a water closet with 11% percent having access to other types of toilets namely Freshlife toilets which are charged KES 5 per use and are emptied on a daily service. There were also sawdust latrines and bio toilets.

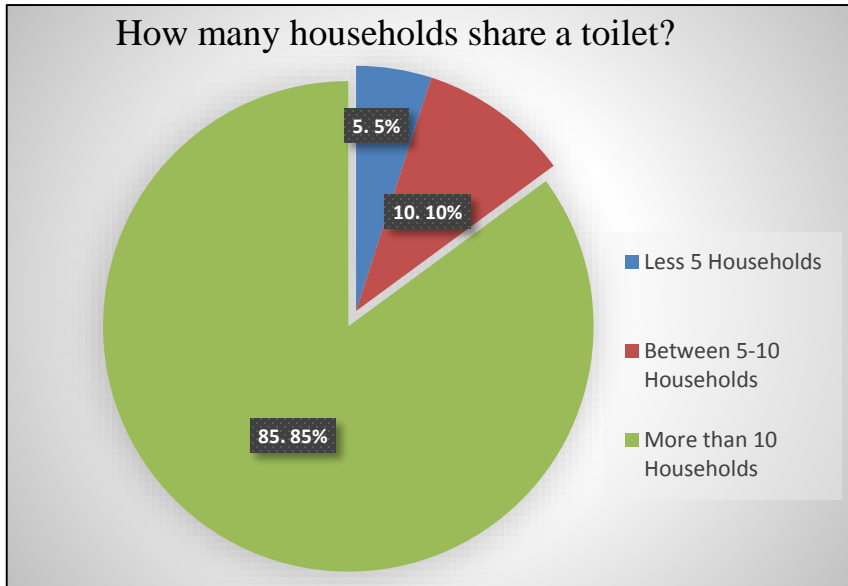


Figure 33 Chart showing no of households sharing a toilet.

Figure 33 charts the number of households sharing a toilet whereby approximately 86% of the households share a toilet with more than 10 other households while only approximately 6% of the respondents shared a toilet with less than 5 other households.

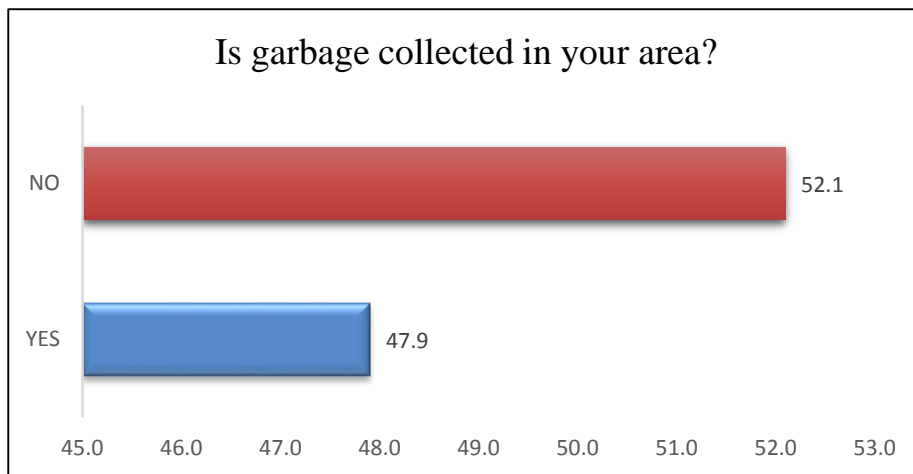


Figure 34 Chart showing results on whether garbage was collected in the area.

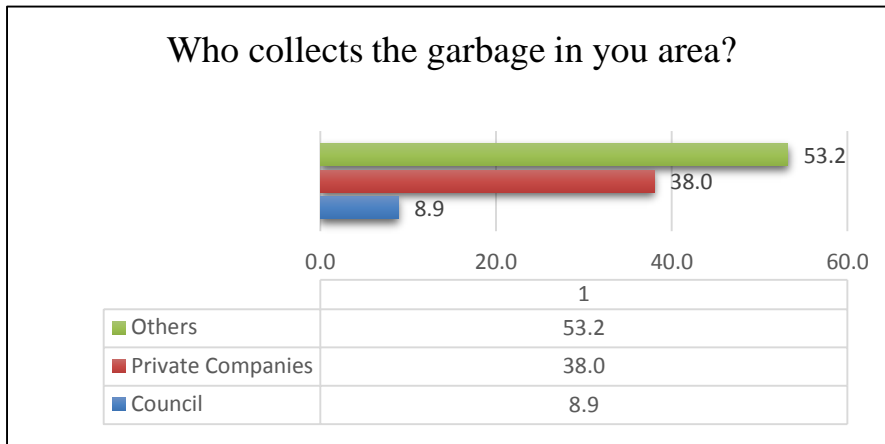


Figure 35 Chart showing who collects the garbage.

When the respondents were asked whether garbage is collected in their areas, approximately 52.1% responded that it was not collected as illustrated on figure 34.



Figure 36 Plate showing garbage dumped along a road in MCC area of Mukuru kwa Njenga (Field Study, 2014)

When asked who collects the garbage in the area, the respondents indicated that only 8.9 % of the garbage is collected by the County Government of Nairobi. 38% is collected by private companies that are made up of youth groups who join up and collect garbage at a fee. The rest 53.2% dispose their waste along the railway line, near the bridge (railway bridge crossing River Ngong’) and in other open places. These percentages of the results are indicated by the chart on figure 35. The plate on figure 36 illustrates the issue of garbage dumping in M.C.C village.

4.4.1 Discussion of findings on implications of slum growth and transformation to the environment.

The third objective of the study was to identify the planning implications on the environment in this slum areas. As indicated in the findings, over three quarters of respondents do have access to a toilet more so a pit latrine toilet. Out of these, approximately 96% of them share a toilet with more than 5 households. The Sphere Project Handbook (2014) indicates that a toilet should be shared by a maximum of 20 people. The average household size in the Mukuru slums as per computations from the total population divided by number of households indicated on table 2 and 3 in this report stands at 2.6 persons per household. 86% of the respondents share a toilet with more than 10 households loosely translating to over 20 people per toilet.

This is too high a ratio therefore making it very difficult to maintain clean conditions. 84% percent of the respondents use pit latrines which therefore implies that at least every 20 households have their own pit latrine. This implies that the number of pit latrines concentrated within the Mukuru area is very high. This brings up the issue of how clean and safe the water from boreholes used in this locality is, considering that there are fluids from the latrines that will seep into the ground and into the bore holes.



Figure 37 Plate of a pit latrine with garbage and dirty water. (Field Study, 2014)

The plate on figure 37 shows a pit latrine in one of the ‘plots’ or residential areas with dirty murky water ponding near the gate and garbage strewn behind it. These are the conditions the people of Mukuru are exposed to. An issue that arises is the disposal of the liquid waste once the pit latrines are full. The waste is collected by young men in drums and carted away either to an open sewer or to the nearby River Ngong’. The Global report on Human settlements (2003) notes the following “Human waste is the most toxic substance which most people come into contact; so there is a great need for its disposal to be safe and efficient.” However, this is not the case thus endangering the lives of the inhabitants of these informal settlements. The findings of this research concur with those of Karisa (2002) who concluded that riparian and utility reserves bore the blunt of most of the impacts with the most environmental effect being felt by Ngong’ River that cuts across the slum and the railway reserve that serves as the dumpsite to quite a large number of inhabitants.

With regards to garbage, less than half of the respondents indicated that garbage is collected in their area mainly by private individuals and groups. When asked who these groups are, the respondents indicated that mostly youth groups do collect the garbage at a fee but the question of how the garbage is then disposed arises since it came out clearly that after collection, the garbage is dumped along the railway line and on the riparian reserve of River Ngong’.



Figure 38 Plate showing garbage dumped in an open area with a child playing on it. (Field Study, 2014)

The plate on figure 38 is an example of how garbage is dumped on any available open area. The research study found out that only approximately 9% of the garbage is collected and properly dumped by the County government. Due to the very high population in the area, it may be difficult for the county government to provide garbage collection services in the slum area, however, this is not reason enough to expose the people and the environment. The findings of the research study agree with (Mutisya and Yarime, 2011) who in their works state “These unprecedented rates of urbanization can be linked to massive migratory movements as well as to natural growth, challenging urban planning and thereby causing environmental problems with far reaching effects.”

The solution to such a problem would be by empowering youths groups to be able to collect the garbage from each household as often as possible more so at least once a week and have this garbage placed on a central location from where the County government can then facilitate its collection and proper disposal. This will not only ensure a clean living environment for the people of Mukuru but will also provide employment opportunities for the young men and women. On the issue of pit latrines and disposal of liquid waste, the solution lies in proper planning of the area since it is very difficult to be able to deliver a service such as sewer system in an unplanned locality. However, the fresh life toilet initiative whereby residents pay per use and are emptied on a daily basis should be explored further and more toilets constructed since they are less harmful to the environment, are clean and safe to use and ultimately they provide employment to the locals.

5.0 Key Findings, Conclusions and Recommendations

From the statistics compiled during this study, a summary of the key findings, the conclusions that were drawn from them, and lessons that could be learnt were documented. Recommendations that are in line with the guidelines of international standards were also drawn.

5.1 Key Findings

This section was meant to give a summary of a number of the most important facts drawn from the study. The findings were deduced from the data collected during the research process and are based on an analysis of the project's objectives and its existing limitations. Key factors such as rapid population and spatial growth of informal settlements, the impacts of growth of informal settlements on service provision and on the environment were discussed.

5.1.1 Key Finding 1

The first key finding was that the Mukuru slums began developing after 1978. This concurs with the findings of Howden (2012) who indicates that the Mukuru slums began developing as a labour camp for the Reuben haulage empire owned by a British Army Veteran Jack Reuben in 1979. Another element of the first key finding was that most of the growth was driven by availability of cheap housing and nearby employment in the industrial area of the City. The same concurs with findings of Mitullah (2003) who argues that with the relaxation of the post-colonial rules that advocated for segregation, and with the rural-urban migration and with the "little obstruction to the proliferation of urban shacks 'as long as they were not located near the central business district'" Slums sprang up all over the town in the proximity of employment.

It is also evident that the spatial growth of the settlement was highest in the 10 years from 1998 to 2008 with a total spatial growth of 140 hectares as compared a total of 62 hectares for the period 1978 to 1998. This raises the issue on why such a high increase in growth over such a short period. Finally it is evident that the structures that developed post 1998 (1999-2008) are very well aligned and oriented similarly as opposed to those that developed pre-1998 (1979-1998).

5.1.2 Key Finding 2

It is evident that access to services is not a problem considering that approximately 76% of the respondents have access to both water and electricity. The emerging issue regards the quality of these services considering that 86% of the water is supplied by water vendors whose source of water cannot be verified and 66% of those having access to electricity admitting to having it illegally.

Another major finding is that the transformation of the settlement has had a positive impact on access to services as illustrated by the comparison on access to services between the village that developed pre-1998 and the one that developed post-1998.

5.1.3 Key finding 3

The third key finding is related to the impact that the existence of the slum has had on the environment whereby more than three quarters of the inhabitants of these settlements had access to a toilet had. However, more that 86% of these shared a toilet with more than 10 households hence sharing a toilet with at over 20 people which is against the required number as stipulated in the Sphere handbook (2014). Moreover, once the pit latrines were full, they were emptied manually and disposed off in the nearby Ngong' river.

Another emerging issue relates to disposal of garbage whereby you find that only less than 9% of the inhabitants whose garbage is collected by the relevant authorities. The rest is collected by private companies comprising of youth and women groups and also dumping on the railway reserve and riparian reserve. More so even the garbage collected by these youth and women groups, it still dumped along the railway and riparian reserve so it is not really a solution.

This findings concur with those of Karisa (2002) who concluded that riparian and utility reserves bore the blunt of most of the impacts with the most environmental effect being felt by Ngong' River that cuts across the (Mukuru) slum and the railway reserve that serves as the dumpsite to quite a large number of inhabitants.

5.2 Conclusions

This research study investigated the planning implications on service delivery and on the environment resulting from slum growth and transformation, a case study of Mukuru kwa Njenga and Mukuru kwa Reuben slums in Nairobi, Kenya. It intended to model the growth of the Mukuru slums and investigate the implications of this growth and transformation on service delivery and the environment. The study specifically sought to quantify the change over time and identify the change in character over selected stages of development, identify the implications of this growth and transformation on service provision and on the environment and ultimately suggest probable solutions to the problems identified.

5.2.1 Conclusion 1

The study established that the Mukuru kwa Njenga and Mukuru kwa Reuben slums had grown spatially from zero hectares in 1978 to approximately 125 hectares and approximately 77 hectares by year 2008 respectively.

The study also established that there had been a change in character of the structures and settlements developed in the initial stages of development of the slums as compared to those developed in the latter stages of development of the slum mainly pre-1998 and post-1998.

5.2.2 Conclusion 2

The change in character of the settlement had positively impacted service provision in that in the settlements that developed post-1998, access to services for example water and electricity is higher as compared to settlements that developed pre-1998. It can also be concluded that access to services in the slums is not a problem, the emerging issue is the quality and sustainability of these services.

5.2.3 Conclusion 3

The study concluded that poor waste disposal was a serious challenge in the Mukuru slums. Liquid waste was being disposed into surface run off channels and ultimately draining into the river when it rained. Solid waste was also being dumped in a very unhygienic manner thus exposing the residents to diseases.

Ultimately, the study concluded that the Mukuru slums developed from about 1978 with most growth seen between years 1998 to 2008 and this growth had serious implications on delivery of basic services and on the environment. It can therefore be concluded that slum growth and transformation does not lead to improved access to basic services.

5.2 Recommendations

These are the proposed solutions to the problems identified.

5.2.1 Recommendation 1: Implementation and Enforcement

The study showed that currently, services like water and power were present in the slum area. The only issue is the quality and sustainability of these services. The water was mainly unhygienic to use and the power was mainly illegal. The solution to the issue of delivering quality services to the inhabitants of slums is simply having properly planned localities as evidenced by the impact the change in character has had on the settlement. The concerned actors for example the Kenya Power and the Nairobi Water and Sewerage Company Limited should ensure delivery of legal and quality services. The relevant policies governing settlement growth for example Physical Planning Act (1996) need to be developed, implemented and enforced by the relevant bodies for example the County Government of Nairobi in order to guide the growth and development of this informal settlements which includes areas like Mukuru slums.

5.2.2 Recommendation 2: Awareness and Behavioural change

It was evident in the research that the inhabitants themselves were key to hygiene and sustainability of their living environment. Community based organizations and non-government organizations should be facilitated to create awareness and educate the populace on the benefits of a clean living environment. The inhabitants should be discouraged on the poor dumping of garbage.

With regards to provision of services for example garbage collection, the youths can be empowered by forming groups that can then be facilitated with safety clothing and tools to be able to collect garbage from individual households at a fee then bring this garbage to a central point from where it can then be transported and disposed as required. This will not

only ensure a clean living environment but also provide employment to the locals. The researcher also recommends enforcement of the laws governing occupancy of riparian reserves and the dumping of garbage and raw sewer into rivers for example River Ngong’.

5.3 Further Research

The research findings demonstrate that the slum grew spatially the most in the 10 year period from 1998 to 2008 by 140 hectares as opposed to 62 hectares in the 20 year period from 1978 to 1998. The researcher therefore encourages further research as to what could have driven such major growth in the Mukuru informal settlements.

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Appendix I: Sample Questionnaire

HOUSEHOLD QUESTIONNAIRE

Slum Growth and Space Transformation: The Implication on Service Delivery and Environment

February 2014

Questionnaire No: _____	Name of Slum:
Name of Interviewer: _____ _____	1. Mukuru kwa Njenga 2. Mukuru kwa Reuben
Date: _____	Name of Village: _____
Time Started: _____	Gender of Interviewee: 1. Male 2. Female
Time Ended: _____	Relationship of respondent with Household: 1. Father 2. Mother
	House hold Size: 1. 1 person 2. 2 people 3. Between 2 and 4 people 4. More than 4

1. Which year did you **first** move here?
 1. Between 2010 and 2014
 2. Between 2005 and 2009
 3. Between 2000 and 2004
 4. Between 1995 and 1999
 5. Between 1990 and 1994
 6. Between 1985 and 1989
 7. Between 1980 and 1984
 8. Before 1980

2. Why did you move here and not to another area?
 1. Cheap housing
 2. Nearby employment
 3. Eviction from other places
 4. Marriage
 5. Transfer from work
 6. Others

Specify _____

3. Access to water.

- a) Do you have access to clean piped water?
 1. YES
 2. NO
- b) If you have access to clean piped water, who supplies it?
 1. Nairobi Water and Sewerage Company Limited.
 2. Private vendors.
 3. Others.

Specify _____
- c) What quantity do you use **per day** in 20 liter jerry cans?
 1. 1-3
 2. 4-6
 3. 7-9
 4. Over 10
- d) What quantity do you use **per month** in 20 liter jerry cans?
 1. 1-10
 2. 11-20
 3. 21-30
 4. Over 31
- e) If you don't have access to piped water, from where do you get your water?
 1. Buy water from private vendors
 2. River
 3. Rain water harvesting
 4. Others

Specify _____
- f) Is it satisfactorily clean and safe to use?
 1. YES
 2. NO
- g) How much do you pay for the water
 1. Per day _____
 2. Per month _____
- h) How do you think the issue of lack of clean water in *Mukuru* can be solved?

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4. Access to electricity.

- a) Do you have access to electricity? 1. YES 2. NO
- b) If YES, is it a **legal connection** by Kenya Power?
- c) If NOT, who supplies the electricity?

Specify.....

.....
- d) How much do you pay to use the electricity **per month**?

5. Access to roads.

- a) Are you satisfied with the current status of roads in the area? 1. YES 2. NO
- b) In your own opinion, what should be done to solve the problem of accessibility in Mukuru?

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6. Solid Waste Management.

- a) Is garbage collected in the area? 1. YES 2. NO
- b) How often is the garbage collected in the area?
 1. Daily
 2. Weekly
 4. Monthly
 5. Never

- 3. Twice a month
- c) If YES, who does it?
 - 1. Council
 - 2. Private companies
 - 3. Others

Specify _____

- d) If NOT, how do you dispose it?
 - 1. Burning
 - 2. Burying
 - 3. Dumping in compost pit
 - 4. Others

Specify _____

- e) How do you think the issue of Solid waste can be solved in Mukuru?

7. Liquid waste management.

- a) Do you have access to a toilet? 1. YES 2. NO
- b) If yes, what type of toilet is it?
 - (i) Pit Latrine
 - (ii) Water Closet
 - (iii) other.

Please name _____

- c) Is the toilet shared? 1. YES 2. NO
- d) If Yes, with how many other households?
 - 1. Less 5 Households
 - 2. Between 5-10 Households
 - 3. More than 10 Households
- e) If you do not have access to a toilet, how do you dispose off your **toilet** waste?

8. Environmental Aspects.

- a) How far is you house from the Ngong' river?
 - 1. Less than 30m
 - 2. 30-60m
 - 3. 60-100m
 - 4. Over 100m
- b) What problems do you experience due to their living close to River Ngong'?

- c) How can these problems be solved?
 - 1. Flooding
 - 2. Mosquitoes causing Malaria
 - 3. Others

Specify _____

Notes: