A Study on Informal Settlements Upgrading Approach with Viewpoint of Sustainable Community in Developing Country

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Abstract

Informal settlements, hereinafter referred to IS, have become integral in the forms of urbanization across the global south. Types and extents of urban informality vary according to contextual socio-economic scenarios. In Rwanda, IS emerged in and around the capital City of Kigali since its creation early 20th century, due to natural growth and the flux of rural-urban migration. Apart from the capital city, other Rwandan cities, towns and centers grew randomly without short and/or long-term physical plans. Informal dwellings differ greatly in sizes, age and character and do not conform to zoning and service regulations. Notwithstanding their variations, however, these dwellings share similar morphological as well socio-economic problems.

By the year 2007, the Rwanda government officially launched a so-called "Kigali City Master Plan". Concerning the IS chapter, it suggests two approaches, namely: the on-site upgrading and total relocation. The Government of Rwanda, through its Ministry of Infrastructure and the Rwanda Housing Authority and in collaboration with private investors, adopted different countermeasures aiming at alleviating further proliferation of IS by onsite upgrading on one hand, and by total relocation and resettlement on the other hand.

Upgrading informal settlements is now widely accepted by governments and international agencies as the most effective way to improve conditions for their inhabitants. Such upgrading is endorsed by the Sustainable Development Goals along with a commitment to ensure access to adequate, safe and affordable housing as well as basic services by 2030 for all. To achieve the goals, a number of initiatives are into process including, but not limited to, the following: (1) Elaboration and implementation of urban planning and development tools such as: conceptual and detailed physical master plans, local urban development plans, sector specific plans and layout plans. (2) Informal settlement upgrading strategies. (3) Development of secondary cities.

In order to alleviate the pressure on the capital city, thereby achieving a sustainable urbanization growth rate, the Government collaborated with the World Bank and selected six cities, throughout the country, to become the poles of economic growth and development by equipping them with pulling infrastructures and services that attract people to the capital city.

This research focuses on the on-site upgrading of informal settlements as a sustainable solution that leaves intact the residents' socio-economic long-lasting networks. Previous researches on this topic do exist, but there are still gaps in clear guidelines of best upgrading practices. We highlight the socio-economic clustering formations by assessing the interrelationships among dwellings typologies with available public infrastructures, utilities and services. The unique approach of this research bases on the examination and analysis of methodically collected data that enables the

formulation of scientific-based evidences of the existing conditions, their inter-dependency relationships as well their hierarchies towards a sustainable response.

To carry out this research, we collected metric data on predefined socio-economic and demographic indicators from two different informal settlements sites. By combining the on-site surveys, self-observations and interviews, we assembled required data to fulfill our research focus on IS communities levels.

Furthermore, for a better understanding on Kigali city's and Rwanda position among other cities and countries with comparable conditions, we relied on the open-source data from the World Bank's annual compilation and ranking of world's countries on socio-economic and demographic indicators.

In order to alleviate the gaps in information for onsite informal settlement upgrading, we designed this study to address answers to main questions about hierarchical clustering among households, their cause and their relationships with existing public infrastructure, services and utilities. We also crosschecked the concerned IS communities standards of living with the minima recommended by the United Nations organizations like the World Health Organization, UN-habitat and the United Nation Development Program.

Our simplistic exploratory data exercise has shown that cities with slums cluster among themselves, most of times with respect to the countries income levels. Concerning the study precincts, hierarchies do exist among the households, whereby they sort into clusters groups with respect to their socio-economic standpoints, expressed by the differences in levels of housing quality as well as the accessibility to public infrastructures, utilities and services. According to UN-Habitat's indicators and thresholds for defining slums and informal settlements, our findings from data analysis showed that, for each study precinct, slums hold about one third of total households. The slums share in the study precincts is almost half the rate of the overall Kigali city's slums; this makes a strength for the precinct's on-site upgradability, as fewer dwellings will have to be replaced. Referring to the World Health Organization recommended standards for minimum levels of health and hygiene, more than half of both precincts dwellers fall under the bottom line of recommended minima for basic sanitation services.

The findings from this research will enlighten the implementers of the on-site upgrading projects to prepare adequate physical plans responding to the needs of informal dwellers on one hand, and their integration to the overall city fabric. Furthermore, the findings will redound to developing world cities' informal settlements and slums upgrading efforts; considering that it will contribute to a better understanding of their inner challenges.

Key words: informal settlements, on-site upgrading, relocation, building typologies, hierarchical clustering, essential functions, Sustainable Development Goals.

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Acronyms

CBD: Central Business District

CoK: City of Kigali

GDP: Gross Domestic Product

GoR: Government of Rwanda

HFCs: Hydrofluorocarbons

ICT: Information Communication Technology

IS: Informal Settlements

JICA: Japan International Cooperation Agency

KCMP: Kigali City Master Plan

LEED ND: Leadership in Energy and Environmental Design, Neighborhood Development

MDGs: Millenium Development Goals

MININFRA: Ministry of Infrastructure

MSA: Measure of Sampling Adequacy

MSL: Mean Sea Level

N/A: Not Applicable

NISR: National Institute of Statistic of Rwanda

PCA: Principal Components Analysis

PPP: Public Private Partnership

REG: Rwanda Energy Group

RHA: Rwanda Housing Authority

RTDA: Rwanda Transportation Development Agency

RURA: Rwanda Utilities Regulation Agency

SDGs: Sustainable Development Goals

SWOT: Strength – Weaknesses – Opportunities – Threats

UHI: Urban Heat Island

UNDP: United Nations Development Programs

UNICEF: United Nations International Children's Emergency Fund

USD: United States of America Dollar

WASAC: Water and Sanitation Corporation

WHO: World Health Organization

Preface

This research studies the feasibility of on-site informal settlement upgrading. The main consideration is the interdependency relationship among public infrastructures, utilities and services. The text deals with building materials and typologies, sanitation conditions, public infrastructure and utilities status as well as the accessibility scenarios. This research thesis targets both decision makers and implementers who are in charge informal settlement upgrading. The principal knowledge of informal settlements status quo towards a responsive and sustainable informal settlements upgrading are clarified by the contents of this research thesis. It has a unique approach of relying on scientific data analysis to highlight the morphological as well as the socio-economic standpoints of an informal settlement, towards an evidence – based onsite upgrading solution.

Important aim of this text is to give the leader a full package of understanding informal settlement situation for Kigali city in particular, and global context in general. The document assumes a minimum prior knowledge of architecture and civil engineering, as well as basic statistics background involved in some sections of this text.

Where definitions and units of measurement are involved, they are expressed in appropriate and understandable manner, or referenced to relevant technical literature. If a numerical approach is necessary, it is worked systematically to ease its understanding.

Writing style is kept simple throughout the document but it contains a technical content and level of accuracy appropriate to this level of study.

The text body is complemented by labelled drawings and figures to help explain and highlight the true meaning of the texts that they are referred to.

Many thanks to individual people and organizations who contributed, in one way or another, to the production of this research thesis. Big thanks to Professor Asano Junichiro for his continuous guidance and wise editing of the contents. Thanks also to laboratory colleagues for their kind logistics and technical supports.

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The list is long but the space is limited. To everyone who contributed in any way to this work, allow me to say"ARIGATO GOZAIMASHITA"

Special thanks to my wife Angélique Mudahogora, my sons and daughters, for being my inspiration and moral support throughout.

While credit to this work is attributed to your contribution, any omissions and/ or commissions in judgement and choice are solely my responsibility.

Chapter 1 General introduction

1.1. Background of the study

Informal settlements in developing countries are the by-products of the rapid urbanization driven by the economic and political changes associated with industrialization and globalization. Informal settlements are generally the result of internal and external migratory trends, rapid increases of population within urban centers, and the financial and administrative inability to provide adequate land, infrastructure, services, and housing to the poorest segments of the population (David Gouverneur, 2015).

Formal urbanites often perceive informal settlements as a threat and manifest their desire to eradicate them. Informal neighborhoods are most often wrongly perceived as place of poverty, violence, drugs and unhealthy living conditions. However, this perception of informal settlements and their inhabitants is often distorted, as both groups socialize on daily routine formal turf as fellow citizens. Formal residents rarely access the informal areas; consequently, the lack of full information helps to stigmatize these settlements. This lack of contact is associated to some clear reasons, such as the concern for safety, insufficient or absence of roads and transportation system, as well as scarce amenities and public spaces.

Although the colonialism was an undeniable part of the historical process and formation of some societies, its legacy led to social stratification and extreme social inequality (Valentin, Raduan, 2009). Informality attitude varies from country to country but tends to travel a similar path. Kigali, as capital city of Rwanda, was officially founded in 1907 in the nation's geographic center by the Germans who had been granted the colonial concession of Tanzania, Rwanda and Burundi at the Berlin Conference of 1885. It is after the independence from 1 July 1962 that Kigali became the capital city of the new Republic of Rwanda, with an area of about 2.5 km^2 and a population of 6,000 people (G. Nduwayezu et al., 2016). Being located at the country's center, Kigali city became a central node of transport links, trade and industry; hence continuously growing up. In 1990, the city expanded to 112 km^2.

After the war and genocide against Tutsis in 1994, a defining period in the city's history, Kigali has known a continuous growth mostly due to the massive repatriation of refugees whose majority targeted the capital city.

"Migration is the demographic process that links rural to urban areas, generating or spurring the growth of cities" (Salim Neema, 2015). In the same context, the pressure of internal rural to urban

migration and a high annual population growth of 2.6% (World Bank, 2019) resulted into administrative reforms leading to an unprecedented expansion of Kigali city, jumping from 314 km^2 in 2000 to 730 km^2 in 2005 (Kigali city archives, 2019). The city's urbanization followed a concentric urban land use model, expending from the CBD, to low and medium-class residential areas and to modern high-class housing in the suburbs (University of Rwanda, 2018).

A High deficiency between the housing demand and offer resulted to the proliferation of informal settlements in all corners of the city. According to Planet Consortium (2012), "Total housing requirements in Kigali city by 2022 are projected to be 458,265 dwelling units. These requirements could be met by maintaining part of the existing housing stock that is in good condition or upgradeable (114,197 DU) plus building of new dwellings (344,068 DU)".

Rwanda Housing Authority carried out a housing stock survey in 2012. It revealed that among the 223,000 dwelling units existing at that time, 19.15% were in good conditions, 32.06% recommended for upgrading and 48.79% to be replaced (Aimé T. and Roger M., 2018).

This situation is not unique for Kigali city; Nazire Haroon (2016) conducted a study in Kabul city–Afghanistan and found that 63.2% houses in the studied areas were in poor physical conditions condition, 25% are in moderate conditions, while only 14.7% were in good conditions. Napier (2002) found that there are countries having equal rates of informal settlements, despite the fact that they have varying levels of urbanization, namely: Burkina Faso with 12.4%, Congo with 11.8%, and South Africa with 11.6%. Generally, in developing regions, "the need for decent affordable housing is particularly acute" (UN-Habitat, 2012).

At a global level, UN-Habitat (2018) described a slum as "the physical and spatial manifestation of urban poverty and intra-city inequality".

On one hand, UN-Habitat defines a slum household as anyone deprived of one or more of the following conditions: (i) access to improved water; (ii) access to improved sanitation facilities; (iii) sufficient living area–not overcrowded; (iv) structural quality/durability of dwellings; and (v) security of tenure. This perception resembles to the Haroon Sajjad's (2014) slums household's condition indicators, namely: construction materials, access to drinking water, sanitation facilities, wastes disposal, family size, and access to healthcare.

On the other hand, UN-Habitat (2018) describes informal settlements as residential areas whereby: (i) inhabitants have no security of tenure vis-à-vis the land or dwellings they inhabit. (ii) The neighborhoods usually lack, or cut off from basic services and formal city infrastructure. (iii) Housing may not comply with current planning and building regulations; it is often situated in geographically and environmentally hazardous areas, and may lack a municipal permit.

UN-Habitat argues that informal settlements can result from real estate speculation practices that do not necessarily adhere to urban codes, making them poorly planned and unauthorized.
The same organization concludes that “slums are the poorest and most dilapidated form of informal settlements”.

According to UN-Habitat (2017), “generating evidence-based knowledge on informal settlements and slums enhances the capacity of stakeholders to develop inclusive citywide plans”. In this regards, this research targeted the upgradable part of housing stock, with a main objective to describe in detail informal settlements’ infrastructures and services status quo by evidence-based scientific data to contribute strengthening the socio-economic development of a household, as argued by Beat W. and John M. (2017). Different activities in urban areas crystallize professional and occupational roles, which in turn are attached to positions that help provide access to the daily needs and wishes in life, such as shelter, health care, education, to mention but a few. UN-Habitat (2003) argued that “in varying degrees, these positions form hierarchical structures in which some people have more wealth and power than others”.

In order to alleviate the worsening living conditions of informal settlements’ poor dwellers without disrupting their community networks and livelihood opportunities, the best approach is the on-site upgrading. Mercy, Elena and Gubevu (2017) stated that “physical improvements and a full package of basic services are absolutely crucial to improve the living conditions, reduce vulnerabilities and improve the safety of informal settlement dwellers”. Banashree Banerjee et al. (2012) mentioned the streets as the “starting point for a physical integration of informal settlements into the formal and official systems of city planning”. Furthermore, Daniel Ehebrecht (2017) stated that “technical upgrading of informal settlements can have immense positive effects on the respective beneficiary community’s well-being: through installation of rainwater drainages, sanitation facilities, sewages and the provision of potable water, health conditions can improve greatly”. Providing basic infrastructures and services revealed to be the key focus for sustainable physical informal settlements upgrading. Koen Olthuis, et al. (2015) carried out a study on 88 informal settlements areas and found that “investment into physical slum upgrading is predominantly focused on the provision of basic needs for health and safety”. According to the Kigali City Master Plan (OZ Architecture et al., 2013), the study area is a precinct within upgradable informal settlements. Therefore, findings from this study will guide for a sustainable on-site upgrading approach, hence improve the quality of life of the urban poor.

While a recent study on the precinct suggested the on-site upgrading approach (Institute for Energy and Environmental Research, Kigali city and UN-Habitat, 2015); there are no prompt details on key

parameters for housing status, accessibility networks and sanitation situation. These three parameters are the most common challenges for the urban poor as highlighted by Joshi Deepa (2020) in a comparative study among informal settlements in Bangladesh, Kenya and India.

1.2. Research problem

From the above, it is evident that, majority of residents in Kigali city are informally housed in an unregulated environment. Different authors consider that unplanned housing in urban areas are due to inadequate planning and lack of proper housing policies in place (Drunkerley, 1983; Schilderman and Lowe, 2002; Marie Huchzermeyer, 2011; Jason Corburn and Alice Sverdlik, 2017; Fatma Roble Maalim Gai, 2018). However, concerning Kigali city, its master plan (KCMP) of 2007 and revised in 2019, suggested clear guidelines to formalize the informal in two ways: (1) onsite upgrading, consisting of providing facilities and improving elements of physical infrastructure, such as paving the streets and footpaths, improving drains and sanitation as well as supplying electricity and water. (2) Redevelopment, consisting of relocating residents of an informal area to newly planned residential sites; followed by a total demolition and redevelopment. The revised KCMP provides clear mapping and classifies each informal area in either scenario.

In order to alleviate the gaps in information for onsite informal settlement upgrading and in line with the Sustainable Development Goals implications, we designed this study to address answers to following main question: "What is the key infrastructure defining the current socio-economic standpoint of the study precincts"?

Following sub questions will help to answer the main question:

(i) Are there any interrelationships among different indicators in informal settlements?

(ii) Are there any forms of hierarchical clusters among the households?

(iii) According to indicators and thresholds for defining informal settlements and slums, how do the study precincts qualify?

(iv) How is the housing status in terms of durability and overcrowding, as pre-defined by the United Nations Human Settlement Program?

(v) How about the space and density requirements as recommended by the World Health Organization for healthy housing?

(vi) Does the current sanitation situation comply with the minimum standards as recommended by the World Health Organization?

This study's findings will not only enlighten the ongoing efforts of human settlements formalization in Rwanda, but will also redound to other countries' informal settlements and slums

upgrading efforts. Based on scientifically analyzed data that can be collected from any informally settled area, this research will pave a way to a better understanding of any concerned area's inner challenges. Administrators and implementers of cities' plans will focus on what is essential while considering the onsite upgrading option.

1.3. Research objective

Focused on realistic scientific data analysis, this research addresses one main objective of assessing and analyzing the main reason(s) behind the existing conditions of housing, public infrastructure, facilities and services within the selected onsite upgradable informal settlement areas. Towards achieving this objective, we carried out a systematic data collection aiming at finding interdependency relationships among pre-defined socio-economic as well as socio-demographic indicators.

1.4. Delimitation of the research scope

The overall purpose of this research is to highlight the status-quo of the operating mechanisms of the essential functions inside informal settlements of Kigali city in terms of mobility, cleanliness, and service networks. Thereby showing the interdependency relationships tying them with the housing typologies as well as the socio-economic standpoints of concerned communities.

This study will seek to find out the common denominator(s) governing the social and physical functionalities in informal settlements precincts.

1.5. Significance of the Study

While a recent study on the research areas suggested the on-site upgrading approach (Institute for Energy and Environmental Research, Kigali city and UN-Habitat, 2015), there are no prompt details on key parameters for housing status, accessibility networks and sanitation situation. However, those three parameters are the most common challenges for the urban poor as highlighted by Joshi Deepa (2020) in a comparative study among informal settlements in Bangladesh, Kenya and India.

On one hand, UN-Habitat (2018) defines a slum household as anyone deprived of one or more of the following conditions:

(i) Access to improved water;
(ii) Access to improved sanitation facilities;
(iii) Sufficient living area–not overcrowded;
(iv) Structural quality/durability of dwellings; and

(v) Security of tenure.

The above perception don't differ much to the Haroon Sajjad's (2014) slums household's condition indicators, namely: construction materials, access to drinking water, sanitation facilities, wastes disposal, family size, and access to healthcare.

On the other hand, UN-Habitat (2018) describes informal settlements as residential areas whereby:

(i) Inhabitants have no security of tenure vis-à-vis the land or dwellings they inhabit.

(ii) The neighborhoods usually lack, or cut off from basic services and formal city infrastructure.

(iii) Housing may not comply with current planning and building regulations; it is often situated in geographically and environmentally hazardous areas, and may lack a municipal permit.

Furthermore, UN-Habitat argues that informal settlements can result from real estate speculation practices that do not necessarily adhere to urban codes, making them poorly planned and unauthorized. The same organization concludes, "Slums are the poorest and most dilapidated form of informal settlements".

UN-Habitat (2017), further argued, "Generating evidence-based knowledge on informal settlements and slums enhances the capacity of stakeholders to develop inclusive citywide plans". To this regards, this research targeted the upgradable part of housing stock, with a main objective to describe in detail informal settlements' infrastructures and services status-quo by evidence-based scientific data to contribute strengthening the socio-economic development of a household. As also stated by Beat W. and John M. (2017).

Different activities in urban areas crystallize professional and occupational roles, which in turn are attached to positions that help provide access to the daily needs and wishes in life, such as shelter, health care, education, to mention but a few. UN-Habitat (2003) argued, "In varying degrees, these positions form hierarchical structures in which some people have more wealth and power than others".

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community's well-being: through installation of rainwater drainages, sanitation facilities, sewages and the provision of potable water, health conditions can improve greatly".

Providing basic infrastructures and services revealed to be the key focus for sustainable physical informal settlements upgrading. Koen Olthuis, et al. (2015) carried out a study on 88 informal settlements areas and found that "investment into physical slum upgrading is predominantly focused on the provision of basic needs for health and safety".

According to the Kigali City Master Plan (OZ Architecture et al., 2013), the study areas are precincts within upgradable informal settlements. This study spotted the above-mentioned gaps then suggested an evidence-based scientific analysis of existing conditions as prerequisite for efficient onsite upgrading scenario that improves the quality of life of the urban poor.

1.6. Previous studies

There are several previous researches about upgrading informal settlements in Kigali city. For instance, Emily Elizabeth Benken (2017) conducted a research about informal settlement eradication in Kigali city: comparison of informal settlements in Rwanda with respects to those of other East African countries, dwelling density, criminality, land security and physical conditions. This study proposes the following approaches:

(1) Green field: an undeveloped area is provided with basic plots and housing where informal settlement residents are relocated to;
(2) Rollover approach: current housing in an area is demolished; new housing and infrastructure is developed in its place;
(3) Infill development: Redeveloping an "underutilized" space to create new housing;
(4) Public social housing: government-funded housing is provided;
(5) In situ upgrading: upgrading infrastructure and service availabilities, rather than housing, with the least amount of expropriation possible;
(6) Core housing: provision of the minimum structure of a house that still needs some construction by residents in a new location;
(7) Site and services: residents are given a plot and basic infrastructure in a new location;
(8) Incremental housing: incremental loans are distributed to residents for the gradual construction of a house in a new location.

Alice Nikuze and Richard Sliuzas (2019) did a research on Livelihood impacts of displacement and resettlement on informal households - A case study from Kigali: this research emphasizes on the impacts of relocation and resettlement. It argues that relocation of the population is a complex process

that induces various negative socio-economic impacts on the livelihoods of affected households, leading to significant impoverishment risks. In this study, it was also found that informal households affected by resettlement processes in the name of city modernization experience the negative livelihood of impacts not only after physical relocation, but also before their physical relocation to a new living environment. In addition to the psychological impacts, such as stress and fear in the pre-displacement phase, informal settlement dwellers waiting to be relocated in Kigali experienced several adverse socio-economic impacts, including insecurity of tenure, financial instability, social divisions, and food insecurity. Compared to other landowners, the owners of houses for rent (property owners) are more vulnerable to impoverishment risk in the pre-relocation stage due to a loss of rental income, upon which they heavily depend. This research provides evidence that the lack of timely and accurate information about the resettlement process and the resulting uncertainties are the most significant causes of pre-relocation impoverishment risks among the households to undergo displacement. This study also showed that, with respect to post-relocation stage, relocated informal households experienced significant adverse effects on their housing assets that deserve much attention. These negative resettlement outcomes include the lack of privacy, overcrowding, and poor sanitation. In addition, our research shows that resettled informal settlement dwellers experienced several other serious post-relocation impoverishment risks, including social disarticulation, loss of income, loss of access to fair markets, food insecurity, loss of access to transportation services, and other basic amenities, of which the intensity vary depending on the resettlement site. Most of these post-relocation impoverishment risks are more severe in the case of off-site relocation than for on-site resettlement. This study recommends that households to be resettled should be key actors in resettlement planning and decision-making on crucial issues, such as housing design, resettlement site selection, and livelihood security.

The Ministry of Infrastructure of Rwanda (2015) carried out a study on National Informal Settlement Upgrading Strategy. This study lists general characteristics of informal settlement in Kigali city:

- Structural instability of the contained buildings;
- Badly passable access within neighborhoods,
- Limitation or lack of direct access roads to the neighborhood;
- Lack of public or semi-public open space within the neighborhood;
- Lack of sewers and/or sewage treatment;
- Flooding, sliding land and land erosion due to steep slopes and insufficient storm water management and erosion control including the lack of canals and culverts;

- Degradation of wetlands and natural water courses resulting from unplanned settlement and commercial activities;
- unprotected rivers and ravines posing danger particularly during rainy season;
- Insufficient waste management.

Inline to informal settlement upgrading, the study suggest following principles to be respected:

- The demolition of existing built structures and relocation of residents shall be kept to a minimum;
- Existing built structures and uses shall be formalized if their assessment has confirmed compliance with the planning objectives for the area;
- The mix of land uses shall be promoted to provide variable socio-economic options in the area;
- Upgrading may include, but not limited to, the following: Re-plotting or plot readjustment to combine small land tracts to a larger plot; on-site improvements such as public infrastructure, facilities and services; contribution of land to public infrastructure, facilities and services provision, improvement to building structures.

Bashir Ahmad Amiri and Nsenda Lukumwena (2018) did an Overview of Informal Settlement Upgrading Strategies in Kabul City and the Need for an Integrated Multi-Sector Upgrading Model. Concerning the in-situ redevelopment, this study says that this upgrading approach replaces the existing physical fabric of the settlement through the on-site construction of the public housing as an alternative to the demolished houses of the residents. The main objective of this intervention is the upgrading of the inner-city informal settlements in response to the current urbanization and population growth, through vertical redevelopment. To do so, the Ministry of Urban Development and Housing started to build the public housing project mainly under two-phases, where, in the first phase of the project the available undeveloped land in the area is developing to house the residents of the area in order to acquire their plot for the second phase of the project. The mechanism is very simple, where each family is provided an apartment of $85m^2$ as an exchange to $200m^2$ of their land/house, in order to consider their legal right and livelihood on staying to the same location. The problem associated with this type of upgrading is that it is considered as a slum clearance approach and people do not trust the government or the private sector in providing alternative housing. Another concern with this method is that they convert all the vacant and agricultural plots into residential apartments, thus changing completely the physical and spatial configuration of the area by demolishing all the buildings, without consideration of the newly built structures, which could have been preserved.

Mercy Brown-Luthango, Elena Reyes and Mntungwa Gubevu (2016), carried out a study on Informal settlement upgrading and safety: experiences from Cape Town, South Africa. The main

concern of this paper was to consider whether and how the process of upgrading impact the quality of life of residents of informal settlements after the upgrading project, with a particular focus on the nature and extent of violence and insecurity. This was done by analyzing three upgrading projects, located in different neighborhoods in the city of Cape Town. This paper argues that physical improvements and a full package of basic services are crucial to improve the living conditions, reduce vulnerabilities and improve the safety of informal settlement dwellers, but these need to be supported by social and economic programs in order to bring about the settlement transformation. Findings across the three sites suggests that, in a context of high unemployment, poor education and limited opportunities to break the cycle of poverty, the impact and sustainability of upgrading interventions alone are limited without targeted longer-term state-driven programs to address the underlying root causes of violence and crime.

Ola Ahmed Saad, Mohamed Anwar Fikry and Asmaa El-Sayed Hasan (2019), carried out a study on Sustainable upgrading for informal areas in Egypt. This researh discusses the sustainability as means of achieving quality, efficiency and improvements in informal areas using the three pillars of sustainability: social, economic and environmental. It also aims at carrying out a comparative analysis of case studies for sustainable upgrading of informal areas in Brazil and India to observe the impact on their dwellers' life after upgrading. The comparison and evaluation of results ends with suggestions applicable on Egyptian informal areas in order to achieve more efficient and sustainable upgraded areas. This study argues that, despite the methods and attempts exerted to overcome the emergence of informal areas, it is still appearing inexorably. Because the methods used are directed to improve the physical environment only, the situation is getting worse and deteriorating over time and non-maintenance. For those reasons, this study examines the phenomenon of informal areas and the causes of their aggravation and solutions that must be followed to find a sustainable way until this epidemic turns into a positive, sustainable, productive, socially, economically and environmentally enhanced area. This research discusses studies of two examples of informal areas, their analysis, methods used to solve the problems and the extent of sustainability. After prompt analyzing and comparison of the two projects, this study suggests the steps by which a sustainable design can be applied in Egypt. The participation of the community is considered to be one of the most important steps to ensure satisfaction with the results and meet the needs of the inhabitants. In order to achieve sustainability in upgrading informal areas, attention should be paid to economic and social development.

UN-Habitat (2015) published a research on Urban Transformation in Slums. UN-Habitat upholds that street-led citywide slum upgrading is a simple and straightforward approach that

rationalizes the layout of settlements and generates spatial urban patterns that essentially transform slums into neighborhoods and connected economies, through a process of physical integration with the larger urban area. Where streets, and public space act as the primary conduits for social and economic transformation that benefit the city as a whole. Streets are proposed as the starting point of settlement upgrading and the link for integration with the city and its development plan. The approach promotes better planning and urban restructuring of slums and informal settlements in order to improve mobility, accessibility and provision of basic services. The existing settlement morphology, particularly the street pattern and availability of open spaces determine the extent to which improvements are possible. The approach does not advocate ad-hoc infrastructure improvements that take the existing spatial and urban layout configuration of settlements for granted and leaves them intact.

Mike Majale (2002) did a study on Regulatory Guidelines for Urban Upgrading towards Effecting pro-poor Change. In this study, the author argues that urban upgrading, at its most basic level, involves improving the physical environment of informal settlements. According to the World Bank, this concerns about improving and/or installing basic urban infrastructure such as water, sanitation, waste collection, storm drainage, access roads and footpaths, and street lighting. However, upgrading also involves regularizing security of land tenure and housing improvements, as well as improving access to municipal services and amenities and social support programs (e.g. health, education). The emphasis in upgrading initiatives has generally been on infrastructural and physical improvements, and to a lesser extent economic development. Considerably less attention has been paid to community development and social upgrading, even though these are equally important in the logic that informal settlements are composed of people, not just housing. Hence, physical upgrading of the environment, without enhancing the self-respect of the inhabitants and helping them achieve sustainable livelihoods will not produce lasting improvements.

Hendler, Y. & Fieuw, W. (2018) published a research report on Cape Town – South Africa, entitled “exploring partnerships with local government: a people’s led approach to informal settlement upgrading”. In this study report, the authors argue that, as stated by David Sattertwaite, upgrading informal settlements is now widely accepted by governments and international agencies as the most effective way to improve conditions for their inhabitants. Such upgrading is endorsed by the Sustainable Development Goals along with a commitment to ensure access to adequate, safe and affordable housing as well as basic services by 2030 for all. The study report concludes that, as an approach, in-situ upgrading recognizes existing power relations between actors, social networks and livelihoods in a settlement. It is critical to engage with these actors, existing patterns and logics to

facilitate a meaningful, community-centered interaction. Successful informal settlement upgrading should therefore be marked by the central endorsement and participation of residents. This is critical as upgrading projects often involve the internal relocation of some residents to open space for infrastructure development such as roads, water and sanitation reticulation and service points, parks and facilities.

1.7. Study limitation

The empirical results reported herein should be considered in the light of some limitations.

The first was the allocated budget that constrained us to select the minimum acceptable sample size for multivariate statistical data analysis; the results could have been better with larger sample.

The second limitation was the heterogeneity in religions, whereby we omitted some social related questions that appeared to be taboos or not in line of beliefs of some religious groups. Without this constraint, we could have achieved a better understanding of socio-economic standpoint.

The third limitation was the lack of demographic records within the study precincts that could have revealed the pressure exerted on available public infrastructure and services.

Further research should consider larger sample size and design the questionnaire keeping in mind of different religious affiliations to meet their respective beliefs.

1.8. Outline of the thesis

❖ **Chapter 1 General introduction:**

Settle in with a summary grounding in the history and relevance of this type of research to prepare the journey of the leader. After considering the historical formation of informal settlements and their current conditions, this chapter introduces the research problem and objectives in a limited scope, thereafter go through the previous related studies.

❖ **Chapter 2 Conceptual and theoretical framework:**

This chapter introduces the challenges and significance of informal settlements in Rwanda and their current ongoing upgrading initiatives. It highlights the spatial structure and historical evolution of Kigali city and its current master plan as an umbrella of its ongoing transformation despite some challenges for overall resilience strategies.

❖ **Chapter 3 From history to recent transformations and future trends of Kigali city:**

This section summarizes the historical background of Kigali as a main city of the colonial regime, as well as a capital city of the Republic of Rwanda after the independence from western powers. The chapter further flyover the morphological formation formations of the city and its ongoing transformations after its first master plan until recently.

❖ **Chapter 4 Research Design and Methodology for the Empirical Study:**

From research design and strategy to reliability and internal validity, this chapter treats case by case the following viewpoints:

The criteria for selection of the study areas, the historical context, physical features and topography, existing socio-economic public facilities and amenities, study areas within the master plan contexts, methodological approaches, data sources and collection techniques and finally the methods of data analysis.

❖ **Chapter 5 Findings from Case Study Areas:**

After detailed information on each case study area, this section analyses the obtained results case by case.

❖ **Chapter 6 Comparison of Findings by cross cases analysis:**

This section will cross analyze the similarities and dissimilarities of involved cases results, thereby to deduce their common denominator.

❖ **Chapter 7 Simulation analysis of onsite upgrading towards a sustainable community**

The simulation consists at suggesting the creation of service streets throughout the selected area, based on the existing mobility rhythm and order of the neighboring community, by modeling of two scenarios to assess the on-site resettlement capacity and its implementation feasibility under the Public Private Partnership.

❖ **Chapter 8 General Conclusions**

Chapter 2 Conceptual and theoretical framework

2.1. Contextualization of informality for Rwanda and Kigali city

This section will consider the level of informality for Rwanda as a country and for Kigali as its capital and biggest city. Referring to the open source data from the World Bank, and considering only countries with slums having only one city with a population of more than one million, we will check the position of Rwanda and its capital city on a global context.

Selection criteria: countries falling in the same context as Rwanda (having slums and only one city with a population of more than one million) whose data is available from the year 2000 to 2017.

Table 2-1: Alphabetical list of selected countries and their respective cities

SN	Country		City	
	Name	**Code**	**Name**	**Code**
1	Afghanistan	AFG	Kabul	KAB
2	Algeria	DZA	Alger	ALG
3	Angola	AGO	Luanda	LAD
4	Armenia	ARM	Yerevan	EVN
5	Benin	BEN	Cotonou	COO
6	Burkina Faso	BFA	Ouagadougou	OUA
7	Burundi	BDI	Bujumbura	BJM
8	Cambodia	KHM	Phnom Penh	PNH
9	Central African Rep.	CAF	Bangui	BGF
10	Chad	TCD	N'Djamena	NDJ
11	Congo	COG	Brazzaville	BVZ
12	Cote d'Ivoire	CIV	Yamoussoukro	YAM
13	Djibouti	DJI	Djibouti	JIB
14	Ethiopia	ETH	Addis Ababa	ADD
15	Gabon	GAB	Libreville	LBV
16	Gambia	GMB	Banjul	BJL
17	Guatemala	GTM	Nueva	NUE
18	Guinea	GIN	Conakry	CKY
19	Haiti	HTI	Port-au-Prince	PAP

20	Honduras	HND	Tegucigalpa	TGU
21	Jordan	JOR	Amman	AMM
22	Kenya	KEN	Nairobi	NBO
23	Laos	LAO	Vientiane	VTE
24	Liberia	LBR	Monrovia	ROB
25	Madagascar	MDG	Antananarivo	TNR
26	Malawi	MWI	Lilongwe	LLW
27	Mali	MLI	Bamako	BKO
28	Mauritania	MRT	Nouakchott	NKO
29	Mongolia	MNG	Ulaanbaatar	ULN
30	Mozambique	MOZ	Maputo	MPM
31	Myanmar	MMR	Nay Pyi Taw	NPT
32	Nepal	NPL	Kathmandu	KTM
33	Nicaragua	NIC	Managua	MGA
34	Niger	NER	Niamey	NIM
35	Panama	PAN	Panama City	PTY
36	Paraguay	PRY	Asunción	ASU
37	Peru	PER	Lima	LIM
38	Rwanda	RWA	Kigali	KGL
39	Senegal	SEN	Dakar	DKR
40	Sierra Leone	SLE	Freetown	FRE
41	Somalia	SOM	Mogadishu	MGQ
42	Sudan	SDN	Khartoum	KRT
43	Tanzania	TZA	Dar es Salaam	DSM
44	Thailand	THA	Bangkok	BKK
45	Togo	TGO	Lomé	LOM
46	Tunisia	TUN	Tūnis	TUN
47	Uganda	UGA	Kampala	KAM
48	Yemen	YEM	Sana'a	SAH
49	Zambia	ZMB	Lusaka	LUN
50	Zimbabwe	ZWE	Harare	HRE

2.2. Addressing informality challenges by SDGs domestication

Despite the universality the universality of the Sustainable Development Goals, there is a need to individualize them through their domestication in order to understand what the goals and their respective targets mean for each country's national development. As argued by Alfred R. (2016), "SDGs are not one –size- fits –all". Therefore, the Rwanda government opted for an intelligent choice among the 2030s targeted SDGs items that fits well in solving major poverty challenges faced by the population.

(Figure sketching, illustration and comments: author; SDGs logos: from UNDP website)

Figure 2-1: Rwanda SDGs domestication initiatives

Informal settlements and slums areas are the main hosts of most of the negative side of SDGs menu related to poverty, inequality and injustice, peace, stability as well as environmental degradation. In this regards, the Government of Rwanda set up measures and strategies prohibiting further informal settlements proliferation. In addition, existing informally settled areas will either undergo onsite upgrading to meet at least the minimum living standards, or be totally relocated for decent resettlements.

Rwanda is among few countries worldwide that have adopted and tried the domestication of SDGs. In collaboration with both international and local partners, mandated government agencies started the feasibility assessment of switching the so-generalized SDGs into specific national goals, addressing the country's specific needs. In this regards, following strategies and plans have been initiated at national and local government scales:

(1) The Economic Poverty Reduction Strategy (EDPRS);

(2) The Sector Strategic Plans (SSPs);

(3) The District Development Plans (DDPs) at the local government level.

Referring to the enormous progress made to the Millennium Development Goals (MDGs), whereby for instance the extreme poverty reduced from 60.4% by 2000 to 39.1% by 2015 (NISR, 2017); there is a white hope that through the domestication of SDGs the side effects challenges of informal settlements and slums will be progressively and surely addressed.

2.3. Positioning Rwanda among countries with comparable SDGs indicators

In order to position the standpoint of Rwanda among other countries, we will consider a variation of indicators (demographic, sociological, economical, ICT and gender) from the World Bank's open data source of two different periods[1], namely 2000 and 2017.

Following are indicators that we selected for analysis:

(1) Population density (people/sq. km of land area)

(2) Birth rate, crude (per 1,000 people)

(3) Population living in slums (percentage urban pop)

(4) People using at least basic sanitation services (percentage population)

(5) Nurses and midwives (per 1,000 people)

[1] The two reference years were chosen according to the availability of data on selected indicators and for all countries in the package.

(6) Hospital beds (per 1,000 people)

(7) Electric power consumption (kWh per capita)

(8) GDP per capita (USD)

(9) Unemployment rate (percentage of total labor force)

(10) Age dependency ratio (percentage of working-age pop)

(11) Children out of school (percentage of primary school age)

(12) Lower secondary completion rate (percentage of relevant age group)

(13) Primary completion rate (percentage relevant age group)

(14) Pupil-teacher ratio, primary 2017

(15) Proportion of women seats in national parliaments (percentage)

(16) Female labor force participation rate, female (Percentage of female ages 15+)

(17) Mobile cellular subscriptions (per 100 people)

(18) Individuals using the Internet (percentage of population)

All above-mentioned indicators have metric data for the two reference years.

In order to highlight possible relationships among different countries, we relied on Principal Components Analysis (PCA) to reduce the data dimension to small set that still contains the information in the large set.

We carried out advanced statistical tests to assume that enough structure does exist for our data to be factor analyzed.

In this regards, we checked the Measure of Sampling Adequacy (MSA) to quantify the degree of inter-correlations among the variables and the appropriateness of factor analysis.

We found a MSA of 0.8, qualified as meritorious[2] to carry out our data analysis by PCA.

Thereafter, we instructed the data processing tool to extract seven factors based on eigenvalues greater or equal to one.

- **Outcomes of data analysis:**

[2] MSA classification: 0.80 or above is meritorious; 0.70 or above is middling; 0.60 or above is mediocre; 0.50 or above is miserable; and below 0.50 is unacceptable.

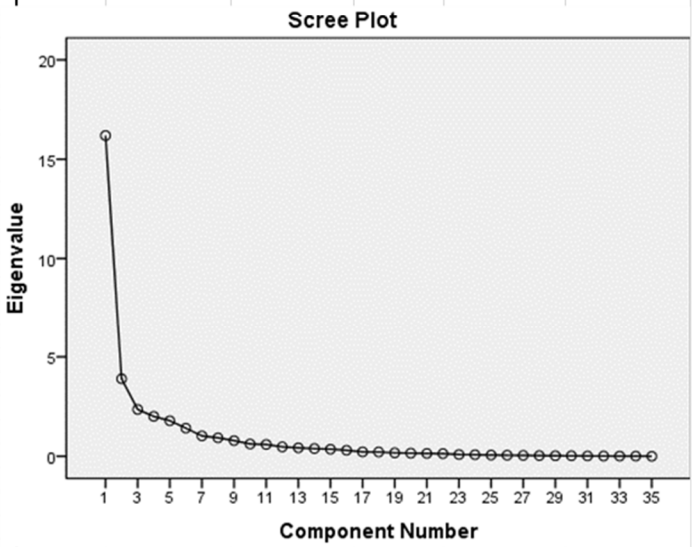
Table 2-2: correlation among indicators matrix

Indicators	Population density (people/sq. km of land area) 2017	Population density (people/sq. km of land area) 2000	Birth rate, crude (per 1,000 people) 2017	Birth rate, crude (per 1,000 people) 2000	Population living in slums (% urban pop) 2017	People using at least basic sanitation services (%	People using at least basic sanitation services (%	Nurses and midwives (per 1,000 people) 2017	Nurses and midwives (per 1,000 people) 2000	Hospital beds (per 1,000 people) 2017	Hospital beds (per 1,000 people) 2000	Electric power consumption (kWh per capita) 2017	Electric power consumption (kWh per capita) 2000	GDP per capita (USD) 2017	GDP per capita (USD) 2000	Unemployment rate (% of tota labor force) 2017	Unemployment rate (% of tota labor force) 2000	Age dependency ratio (% of working-age pop) 2017	Age dependency ratio (% of working-age pop) 2000	Children out of school (% primary school age) 2017	Children out of school (% primary school age) 2000	Lower secondary completion rate(% of relevant age group)	Lower secondary completion rate(% of relevant age group)	Primary completion rate (% relevant age group) 2017	Primary completion rate (% relevant age group) 2000	Pupil-teacher ratio, primary 2017	Pupil-teacher ratio, primary 2000	Proportion of women seats in national parliaments (%) 2017	Proportion of women seats in national parliaments (%) 2000	Female labor force participation rate, female (%	Female labor force participation rate, female (%	Mobile cellular subscriptions (per 100 people)	Mobile cellular subscriptions (per 100 people)	Individuals using the Internet (% of population) 2017	Individuals using the Internet (% of population) 2000
Population density (people/sq. km of land area) 2017	1.00																																		
Population density (people/sq. km of land area) 2000	**0.98**	1.00																																	
Birth rate, crude (per 1,000 people) 2017	-0.03	-0.15	1.00																																
Birth rate, crude (per 1,000 people) 2000	0.03	-0.09	**0.92**	1.00																															
Population living in slums (% urban pop) 2017	0.00	-0.04	**0.62**	**0.71**	1.00																														
People using at least basic sanit services (% pop) 2017	0.03	0.11	**-0.80**	**-0.80**	**-0.76**	1.00																													
People using at least basic sanit services (% pop) 2000	0.08	0.12	**-0.71**	**-0.75**	**-0.79**	**0.88**	1.00																												
Nurses and midwives (per 1,000 people) 2017	0.00	0.08	**-0.60**	**-0.73**	**-0.65**	**0.60**	**0.63**	1.00																											
Nurses and midwives (per 1,000 people) 2000	0.08	0.20	**-0.56**	**-0.62**	-0.44	0.46	0.49	**0.50**	1.00																										
Hospital beds (per 1,000 people) 2017	-0.12	-0.08	-0.41	**-0.57**	-0.37	0.38	0.42	**0.63**	0.22	1.00																									
Hospital beds (per 1,000 people) 2000	-0.07	-0.01	-0.48	**-0.64**	-0.49	0.44	**0.50**	**0.74**	0.40	**0.87**	1.00																								
Electric power consumption (kWh per capita) 2017	-0.19	-0.13	**-0.69**	-0.79	-0.72	**0.75**	**0.77**	**0.78**	0.44	**0.59**	**0.67**	1.00																							
Electric power consumption (kWh per capita) 2000	-0.18	-0.12	**-0.65**	**-0.76**	**-0.74**	**0.71**	**0.76**	**0.81**	0.43	**0.56**	**0.65**	**0.97**	1.00																					
GDP per capita (USD) 2017	-0.20	-0.16	**-0.55**	**-0.59**	**-0.57**	**0.60**	**0.56**	**0.53**	0.38	0.30	0.35	**0.78**	**0.75**	1.00																					
GDP per capita (USD) 2000	-0.15	-0.12	-0.48	**-0.54**	**-0.56**	**0.54**	**0.54**	0.46	0.32	0.18	0.17	**0.69**	**0.69**	**0.89**	1.00																				
Unemployment rate (% of total labor force) 2017	-0.17	-0.14	-0.10	-0.20	-0.18	0.25	0.27	0.35	0.33	0.22	0.26	0.27	0.33	0.15	0.33	1.00																			
Unemployment rate (% total labor force) 2000	-0.27	-0.26	-0.14	-0.27	-0.28	0.27	0.32	0.26	0.25	0.22	0.21	0.30	0.31	0.18	0.37	**0.78**	1.00																		
Age dependency ratio (% working-age pop) 2017	-0.03	-0.14	**0.97**	**0.94**	**0.59**	**-0.78**	**-0.70**	**-0.60**	**-0.55**	-0.46	**-0.51**	**-0.69**	**-0.64**	**-0.55**	**-0.52**	-0.16	-0.21	1.00																	
Age dependency ratio (% working-age pop) 2000	0.12	-0.01	**0.70**	**0.72**	**0.55**	**-0.58**	**-0.52**	**-0.52**	**-0.59**	-0.17	-0.29	**-0.62**	**-0.59**	**-0.55**	**-0.54**	-0.15	-0.20	**0.67**	1.00																
Children out of school (% primary school age) 2017	-0.17	-0.17	0.38	0.43	0.45	-0.24	-0.28	-0.37	-0.15	-0.30	-0.26	-0.32	-0.30	-0.22	-0.21	0.29	0.12	0.40	0.23	1.00															
Children out of school (% primary school age) 2000	-0.04	-0.09	**0.69**	**0.74**	**0.71**	**-0.63**	**-0.63**	**-0.56**	-0.34	-0.46	-0.46	**-0.66**	**-0.65**	**-0.52**	**-0.50**	0.04	-0.08	**0.68**	**0.46**	**0.67**	1.00														
Lower secondary completion (% relevant age group) 2017	-0.06	0.03	**-0.75**	**-0.78**	**-0.61**	**0.62**	**0.59**	**0.67**	0.41	**0.55**	**0.61**	**0.64**	**0.61**	0.46	0.33	0.13	0.24	**-0.75**	**-0.54**	-0.32	**-0.55**	1.00													
Lower secondary completion (% relevant age group) 2000	-0.16	-0.11	**-0.62**	**-0.65**	**-0.61**	**0.59**	**0.66**	**0.65**	0.45	**0.53**	**0.58**	**0.63**	**0.64**	0.41	0.35	0.36	0.37	**-0.60**	-0.45	-0.21	**-0.58**	**0.78**	1.00												
Primary completion rate (% relevant age group) 2017	0.03	0.10	**-0.70**	**-0.69**	**-0.67**	**0.57**	**0.51**	**0.53**	0.32	0.38	0.42	0.49	0.48	0.37	0.30	-0.06	0.13	**-0.67**	**-0.48**	**-0.57**	**-0.71**	**0.79**	**0.58**	1.00											
Primary completion rate (% relevant age group) 2000	-0.11	-0.05	**-0.67**	**-0.70**	**-0.71**	**0.59**	**0.67**	**0.67**	0.42	0.49	**0.53**	**0.69**	**0.73**	**0.53**	**0.49**	0.23	0.25	**-0.65**	**-0.50**	-0.34	**-0.73**	**0.76**	**0.85**	**0.68**	1.00									
Pupil-teacher ratio, primary 2017	0.15	0.07	**0.67**	**0.65**	**0.65**	**-0.65**	**-0.62**	**-0.53**	-0.44	-0.25	-0.32	**-0.59**	**-0.58**	**-0.50**	**-0.51**	-0.29	-0.27	**0.67**	**0.60**	0.17	0.45	**-0.71**	**-0.66**	**-0.56**	**-0.72**	1.00								
Pupil-teacher ratio, primary 2000	0.05	-0.02	**0.63**	**0.61**	**0.59**	**-0.65**	**-0.63**	-0.48	-0.46	-0.31	-0.41	**-0.56**	**-0.55**	-0.44	-0.36	-0.31	-0.25	**0.62**	0.44	0.10	0.39	**-0.73**	**-0.67**	**-0.59**	**-0.71**	**0.84**	1.00							
Proportion of women seats in national parliaments (%) 2017	0.24	0.20	0.07	0.04	-0.06	0.09	-0.01	0.04	-0.20	-0.03	0.01	-0.10	-0.10	-0.10	-0.11	-0.15	-0.07	0.09	0.20	-0.14	-0.08	0.00	-0.11	0.10	-0.12	0.17	0.12	1.00						
Proportion of women seats in national parliaments (%) 2000	0.14	0.09	0.22	0.24	0.08	-0.08	-0.23	-0.16	-0.24	-0.08	-0.09	-0.15	-0.19	-0.10	-0.13	-0.17	-0.18	0.27	0.26	-0.10	0.09	-0.20	-0.34	-0.07	-0.30	0.32	0.27	**0.62**	1.00					
Female labor force participation rate (% female ages 15+) 2017	0.27	0.26	0.19	0.22	0.21	-0.42	-0.46	-0.16	-0.23	-0.14	-0.08	-0.29	-0.28	-0.19	-0.32	**-0.64**	**-0.62**	0.24	0.13	-0.31	0.00	-0.19	-0.34	-0.01	-0.25	0.41	0.45	0.20	0.28	1.00				
Female labor force participation rate (% female ages 15+) 2000	0.27	0.26	0.24	0.27	0.27	-0.45	-0.49	-0.21	-0.23	-0.15	-0.11	-0.33	-0.33	-0.27	-0.41	**-0.65**	**-0.66**	0.29	0.17	-0.31	0.05	-0.27	-0.42	-0.05	-0.31	0.44	0.46	0.13	0.27	**0.97**	1.00			
Mobile cellular subscriptions (per 100 people)	-0.04	0.03	**-0.54**	**-0.63**	**-0.65**	**0.56**	**0.55**	**0.56**	0.32	0.29	0.34	**0.61**	**0.60**	**0.52**	**0.55**	0.12	0.17	**-0.58**	**-0.61**	-0.37	**-0.58**	**0.65**	0.45	**0.59**	**0.57**	**-0.57**	-0.46	-0.09	-0.17	-0.22	-0.28	1.00		
Mobile cellular subscriptions (per 100 people)	-0.15	-0.13	-0.40	-0.42	**-0.50**	0.47	0.47	0.34	0.17	0.23	0.26	**0.67**	**0.66**	**0.80**	**0.76**	0.09	0.12	-0.42	-0.34	-0.16	**-0.51**	0.36	0.39	0.26	0.49	-0.40	-0.32	-0.14	-0.14	-0.18	-0.25	0.48	1.00	
Individuals using the Internet (% of pop) 2017	-0.09	-0.03	**-0.66**	**-0.69**	**-0.72**	**0.74**	**0.71**	**0.56**	0.42	0.19	0.36	**0.72**	**0.72**	**0.68**	**0.71**	0.28	0.26	**-0.67**	**-0.59**	-0.29	**-0.59**	0.45	0.46	0.44	**0.52**	**-0.60**	-0.49	0.01	-0.18	-0.34	-0.41	**0.62**	**0.62**	1.00	
Individuals using the Internet (% of pop) 2000	-0.06	-0.02	**-0.57**	**-0.59**	**-0.54**	**0.58**	**0.60**	**0.57**	0.35	0.32	0.35	**0.78**	**0.76**	**0.87**	**0.78**	0.09	0.07	**-0.54**	**-0.56**	-0.21	**-0.54**	0.47	0.45	0.36	**0.58**	-0.48	-0.47	-0.07	-0.11	-0.20	-0.27	**0.55**	**0.64**	**0.59**	1.00

Table 2-3: Eigenvalues

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	16.192	46.264	46.264	16.192	46.264	46.264	8.57	24.484	24.484
2	3.896	11.132	57.396	3.896	11.132	57.396	6.509	18.597	43.081
3	2.354	6.725	64.121	2.354	6.725	64.121	3.892	11.119	54.2
4	2.006	5.732	69.853	2.006	5.732	69.853	3.548	10.137	64.337
5	1.786	5.102	74.955	1.786	5.102	74.955	2.148	6.137	70.475
6	1.412	4.034	78.99	1.412	4.034	78.99	2.073	5.922	76.397
7	1.026	2.931	81.92	1.026	2.931	81.92	1.933	5.523	81.92
8	0.926	2.646	84.566						
9	0.788	2.25	86.816						
10	0.617	1.762	88.578						
11	0.593	1.693	90.271						
12	0.471	1.346	91.617						
13	0.423	1.209	92.826						
14	0.385	1.1	93.926						
15	0.355	1.015	94.941						
16	0.301	0.86	95.801						
17	0.219	0.625	96.426						
18	0.215	0.615	97.04						
19	0.173	0.493	97.533						
20	0.154	0.44	97.972						
21	0.138	0.394	98.366						
22	0.13	0.373	98.739						
23	0.086	0.246	98.985						
24	0.078	0.222	99.207						
25	0.061	0.174	99.381						
26	0.049	0.14	99.521						
27	0.043	0.122	99.643						
28	0.031	0.09	99.733						
29	0.027	0.077	99.81						
30	0.022	0.064	99.874						
31	0.014	0.041	99.915						
32	0.012	0.033	99.948						
33	0.01	0.027	99.975						
34	0.007	0.02	99.996						
35	0.002	0.004	100						

Extraction Method: Principal Component Analysis.



In an exercise to group countries with respect to the aforementioned demographic and socio-economic indicators, we submitted them to factor analysis carried out using indicators' values in both 2000 and 2017 years. Principal components analysis was used as the extraction method. Based on an examination of Eigen values and a scree plot, as shown on Table 2-3 above, we realized that seven factors, explaining a total variance of 81.92% should be extracted; thereafter submitted to a Varimax rotation. Table 2-4 below contains the rotated factor loadings matrix. Considering values from + or – 0.5 as high scores, factor 1 with its high negative scores to birth rate and its high positive or negative scores to basic education indicators, would be named *birth control and education*. Factor 2 would be named *industrialization and ICT* due to its high positive scores of electric power consumption, GDP and ICT related indicators. The high positive scores of unemployment indicator in combination with high negative scores on gender balance qualify the factor 3 as *gender inequality and joblessness*. Factor 4 scores high on medical logistics and personnel indicators, it is therefore named *medical*

services. Factor 5 represent *congested countries* due to its very high scores on population density. Factors 6 and 7 would be named *active population* and *gender equality* respectively.

Table 2-4: Rotated component matrix

SN	Variables	Components						
		1	2	3	4	5	6	7
1	Population density (people/sq. km of land area) 2017	0	-0.085	-0.172	-0.04	**0.951**	-0.002	0.131
2	Population density (people/sq. km of land area) 2000	0.068	-0.08	-0.172	-0.02	**0.955**	0.107	0.074
3	Birth rate, crude (per 1,000 people) 2017	**-0.724**	-0.335	-0.012	-0.18	-0.119	-0.396	0.088
4	Birth rate, crude (per 1,000 people) 2000	**-0.661**	-0.368	-0.07	-0.363	-0.056	-0.459	0.037
5	Population living in slums (% urban pop) 2017	**-0.641**	-0.472	-0.107	-0.209	-0.034	-0.179	-0.169
6	People using at least basic sanitation services (% population) 2017	**0.634**	0.473	0.288	0.139	0.165	0.211	0.14
7	People using at least basic sanitation services (% population) 2000	**0.592**	0.477	0.316	0.244	0.211	0.133	0.018
8	Nurses and midwives (per 1,000 people) 2017	0.415	0.365	0.114	**0.641**	0.088	0.261	0.02
9	Nurses and midwives (per 1,000 people) 2000	0.3	0.153	0.214	0.215	0.233	**0.617**	-0.244
10	Hospital beds (per 1,000 people) 2017	0.27	0.108	0.047	**0.874**	-0.08	-0.01	0.008
11	Hospital beds (per 1,000 people) 2000	0.305	0.146	0.054	**0.877**	0.008	0.113	-0.001
12	Electric power consumption (kWh per capita) 2017	0.414	**0.686**	0.134	0.472	-0.081	0.186	-0.031
13	Electric power consumption (kWh per capita) 2000	0.398	**0.68**	0.159	0.481	-0.07	0.159	-0.04
14	GDP per capita (USD) 2017	0.239	**0.883**	0.044	0.138	-0.101	0.125	-0.055
15	GDP per capita (USD) 2000	0.186	**0.865**	0.219	-0.008	-0.081	0.204	-0.004
16	Unemployment rate (% of total labor force) 2017	-0.046	0.066	**0.839**	0.262	-0.031	0.205	-0.061
17	Unemployment rate (% of total labor force) 2000	0.094	0.04	**0.768**	0.176	-0.227	0.25	0.075
18	Age dependency ratio (% of working-age pop) 2017	**-0.693**	-0.333	-0.066	-0.208	-0.108	-0.418	0.099
19	Age dependency ratio (% of working-age pop) 2000	-0.451	-0.396	-0.017	-0.014	0.055	**-0.629**	0.207
20	Children out of school (% primary school age) 2017	-0.409	-0.146	0.495	-0.196	0	-0.274	-0.293
21	Children out of school (% primary school age) 2000	**-0.614**	-0.438	0.207	-0.282	-0.008	-0.186	-0.154
22	Lower secondary completion rate(% of relevant age group) 2017	**0.817**	0.159	0.053	0.361	-0.025	0.073	-0.071
23	Lower secondary completion rate(% of relevant age group) 2000	**0.687**	0.186	0.256	0.433	-0.076	-0.026	-0.18
24	Primary completion rate (% relevant age group) 2017	**0.849**	0.106	-0.164	0.168	-0.041	0.166	0.148
25	Primary completion rate (% relevant age group) 2000	**0.737**	0.346	0.088	0.353	-0.049	-0.043	-0.16
26	Pupil-teacher ratio, primary 2017	**-0.761**	-0.301	-0.267	0	0.047	-0.08	0.218
27	Pupil-teacher ratio, primary 2000	**-0.768**	-0.196	-0.323	-0.112	-0.088	0.073	0.198
28	Proportion of women seats in national parliaments (%) 2017	0.056	-0.075	-0.039	0.003	0.16	-0.109	**0.862**
29	Proportion of women seats in national parliaments (%) 2000	-0.207	-0.024	-0.143	-0.025	0.031	-0.076	**0.809**
30	Female labor force participation rate, female (% female ages 15+) 2017	-0.211	-0.144	**-0.875**	0.057	0.097	0.075	0.128
31	Female labor force participation rate, female (% female ages 15+) 2000	-0.244	-0.213	**-0.878**	0.043	0.103	0.078	0.089
32	Mobile cellular subscriptions (per 100 people) 2017	**0.562**	0.458	0.025	0.072	-0.036	0.211	-0.015
33	Mobile cellular subscriptions (per 100 people) 2000	0.196	**0.853**	0.011	0.081	-0.083	-0.121	-0.092
34	Individuals using the Internet (% of population) 2017	0.438	**0.656**	0.223	0.016	0.008	0.314	0.076
35	Individuals using the Internet (% of population) 2000	0.287	**0.822**	0.013	0.18	0.051	0.047	-0.091
Extraction Method: Principal Component Analysis.		**Birth control and education**	**Industrialization and ICT**	**Gender inequality & joblessness**	**Medical services**	**High population density**	**Active population**	**Gender equality**
Rotation Method: Varimax with Kaiser Normalization.								
Rotation converged in 7 iterations.								

From the rotated matrix, we notice that every indicator has only one high loading[3] (negative or positive) to only one of the principal components.

[3] An Eigenvalue greater or equal to +(-) 5 is considered as a high factor loading in this research

From the Table 2-3 above, the first two principal components explain more than a half (43.1%) of the total variance explained (81.92%). Figure 2-1 below shows a two-dimensional positioning of all concerned countries with respect to the first two components.

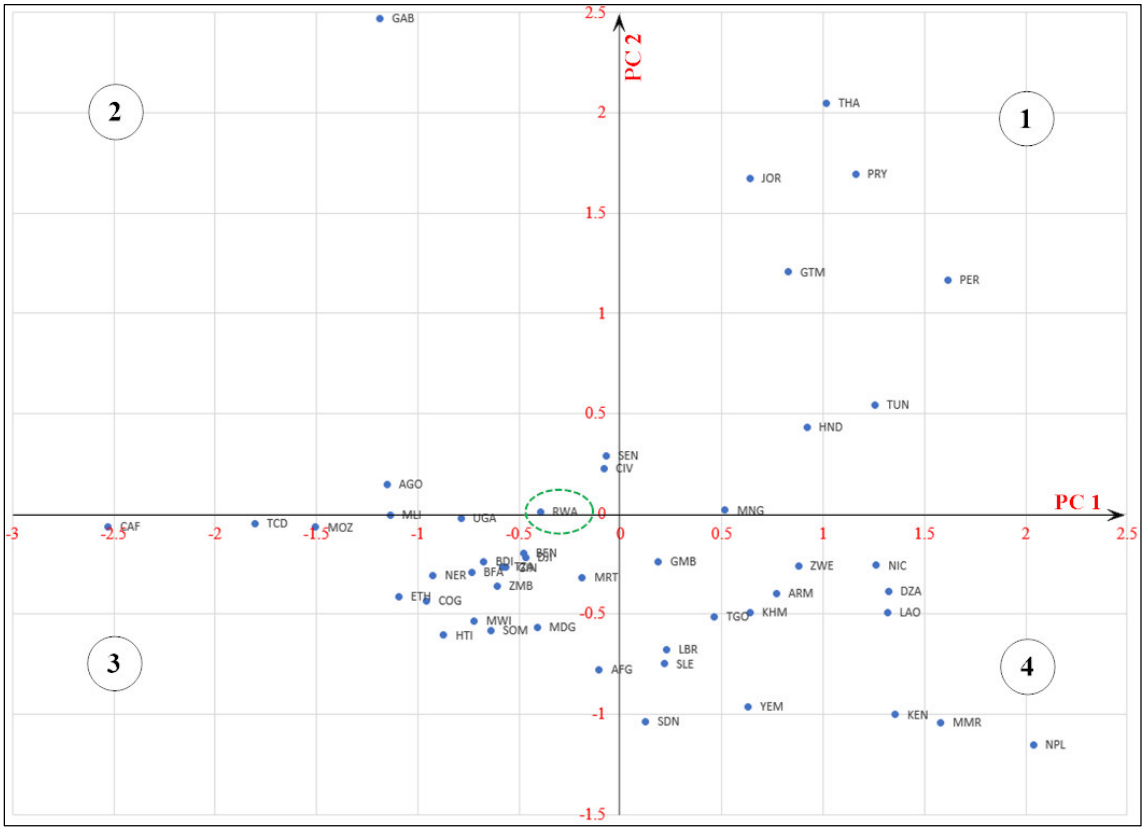


Figure 2-2: Rwanda position to the first two principal components

From the Figure 2-2, on one hand Rwanda (highlighted in a green ellipsoid) loads slightly negative to the birth control and basic education component, despite its policy to make compulsory the nine years basic education. Both its highest population density among all concerned countries (485.65 people/km^2 in 2017) and its high crude birth rate (32.02 / 1000 people in 2017) justify that position. On the other hand, due to its continued efforts to develop the ICT sector and easing the conditions for doing business whereby Rwanda ranks 2nd in Africa and 38th in the world (World Bank, 2019). Moving anti-clock from the first quadrant, we find six upper middle-income countries[4] (World Bank, 2017) and two lower-middle income countries.

[4] The World Bank classifies countries into four income categories: high income, upper-middle income, lower-middle income and low-income.

Rwanda, a low-income country, is located in the second quadrant together with three lower-middle income, one upper-middle income country and one high-income country (Panama) which an outlier on figure 1 scatter graph. The third quadrant contains one lower-middle income country and all remaining countries fall into low-income category. The fourth quadrant counts five low-income countries together with nine lower-middle income and one upper-middle income countries.

Figure 2-3 shows varying positions of Rwanda with respect to countries having factors loadings either positive or negative greater than one standard deviation. On the two first factors whereby economic implications are concerned, itis to notice that countries tend to separate into opposite poles of income levels.

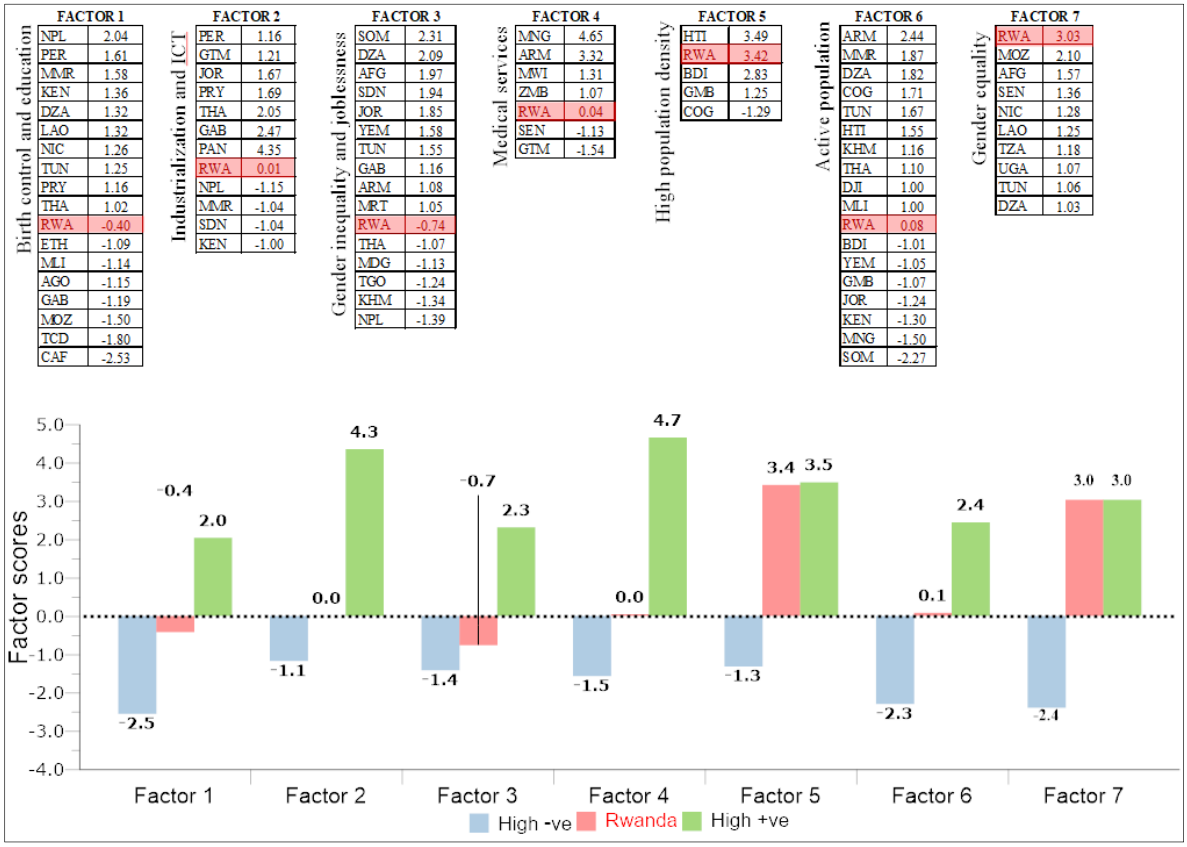


Figure 2-3: Rwanda position with respect to high factor scores

After the examination of factors, we experimented a clustering to explore how countries having slums with only one city of a population greater than one million people split out into demographic and socio-economic blocks. We used a K-means clustering procedure in order to obtain separate optimal groupings of concerned countries.

Table 2-5: Clusters memberships by K-means

8 clusters			9 clusters			10 clusters			11 clusters			12 clusters		
Country code	Cluster	Distance	Country code	Cluster	Distance	Country code	Cluster	Distance	Country code	Cluster	Distance	Country code	Cluster	Distance
BEN	1	381.51	CIV	1	372.56	PER	1	556.51	GAB	1	0.00	PRY	1	0.00
KEN	1	269.99	COG	1	406.39	PRY	1	556.51	AGO	2	607.52	AGO	2	0.00
KHM	1	253.04	DJI	1	546.96	AGO	2	607.52	DJI	2	607.52	ARM	3	208.64
MMR	1	332.19	HND	1	403.91	DJI	2	607.52	ARM	3	208.64	MNG	3	208.64
MRT	1	357.10	LAO	1	510.88	ARM	3	208.64	MNG	3	208.64	**AFG**	**4**	193.61
SDN	1	362.55	NIC	1	339.96	MNG	3	208.64	**AFG**	**4**	230.08	**BDI**	**4**	522.25
SEN	1	232.10	PER	2	696.37	**AFG**	**4**	230.08	**BDI**	**4**	573.95	**BFA**	**4**	131.79
ZMB	1	585.85	PRY	2	741.62	**BDI**	**4**	573.95	**BEN**	**4**	479.32	**CAF**	**4**	274.65
ZWE	1	766.61	THA	2	911.60	**BEN**	**4**	479.32	**BFA**	**4**	101.27	**ETH**	**4**	221.40
PAN	2	0.00	ARM	3	208.64	**BFA**	**4**	101.27	**CAF**	**4**	322.05	**GIN**	**4**	252.92
ARM	3	314.29	MNG	3	208.64	**CAF**	**4**	322.05	**ETH**	**4**	203.22	**GMB**	**4**	336.25
JOR	3	786.84	**AFG**	**4**	193.61	**ETH**	**4**	203.22	**GIN**	**4**	197.29	**HTI**	**4**	643.83
MNG	3	545.75	**BDI**	**4**	522.25	**GIN**	**4**	197.29	**GMB**	**4**	330.93	**LBR**	**4**	124.99
AFG	**4**	193.61	**BFA**	**4**	131.79	**GMB**	**4**	330.93	**HTI**	**4**	634.52	**MDG**	**4**	179.14
BDI	**4**	522.25	**CAF**	**4**	274.65	**HTI**	**4**	634.52	**LBR**	**4**	109.53	**MLI**	**4**	250.41
BFA	**4**	131.79	**ETH**	**4**	221.40	**LBR**	**4**	109.53	**MDG**	**4**	226.60	**MOZ**	**4**	445.37
CAF	**4**	274.65	**GIN**	**4**	252.92	**MDG**	**4**	226.60	**MLI**	**4**	203.74	**MWI**	**4**	336.62
ETH	**4**	221.40	**GMB**	**4**	336.25	**MLI**	**4**	203.74	**MMR**	**4**	613.35	**NER**	**4**	228.05
GIN	**4**	252.92	**HTI**	**4**	643.83	**MMR**	**4**	613.35	**MOZ**	**4**	466.66	**NPL**	**4**	320.36
GMB	**4**	336.25	**LBR**	**4**	124.99	**MOZ**	**4**	466.66	**MWI**	**4**	395.53	**RWA**	**4**	458.74
HTI	**4**	643.83	**MDG**	**4**	179.14	**MWI**	**4**	395.53	**NER**	**4**	269.69	**SLE**	**4**	234.92
LBR	**4**	124.99	**MLI**	**4**	250.41	**NER**	**4**	269.69	**NPL**	**4**	274.03	**SOM**	**4**	421.14
MDG	**4**	179.14	**MOZ**	**4**	445.37	**NPL**	**4**	274.03	**RWA**	**4**	455.06	**TCD**	**4**	225.26
MLI	**4**	250.41	**MWI**	**4**	336.62	**RWA**	**4**	455.06	**SDN**	**4**	437.97	**TGO**	**4**	95.82
MOZ	**4**	445.37	**NER**	**4**	228.05	**SDN**	**4**	437.97	**SLE**	**4**	283.03	**TZA**	**4**	387.87
MWI	**4**	336.62	**NPL**	**4**	320.36	**SLE**	**4**	283.03	**SOM**	**4**	474.00	**UGA**	**4**	143.25
NER	**4**	228.05	**RWA**	**4**	458.74	**SOM**	**4**	474.00	**TCD**	**4**	232.90	**YEM**	**4**	404.75
NPL	**4**	320.36	**SLE**	**4**	234.92	**TCD**	**4**	232.90	**TGO**	**4**	121.46	BEN	5	381.51
RWA	**4**	458.74	**SOM**	**4**	421.14	**TGO**	**4**	121.46	**TZA**	**4**	328.18	KEN	5	269.99
SLE	**4**	234.92	**TCD**	**4**	225.26	**TZA**	**4**	328.18	**UGA**	**4**	120.95	KHM	5	253.04
SOM	**4**	421.14	**TGO**	**4**	95.82	**UGA**	**4**	120.95	**YEM**	**4**	361.69	MMR	5	332.19
TCD	**4**	225.26	**TZA**	**4**	387.87	**YEM**	**4**	361.69	PAN	5	0.00	MRT	5	357.10
TGO	**4**	95.82	**UGA**	**4**	143.25	GTM	5	0.00	DZA	6	409.73	SDN	5	362.55
TZA	**4**	387.87	**YEM**	**4**	404.75	GAB	6	0.00	JOR	6	558.34	SEN	5	232.10
UGA	**4**	143.25	AGO	5	621.92	THA	7	0.00	TUN	6	545.23	ZMB	5	585.85
YEM	**4**	404.75	GTM	5	621.92	DZA	8	409.73	PRY	7	0.00	ZWE	5	766.61
GAB	5	0.00	DZA	6	409.73	JOR	8	558.34	CIV	8	320.53	GAB	6	0.00
AGO	6	1501.38	JOR	6	558.34	TUN	8	545.23	COG	8	617.01	DZA	7	409.73
CIV	6	557.94	TUN	6	545.23	CIV	9	320.53	HND	8	805.76	JOR	7	558.34
COG	6	548.89	PAN	7	0.00	COG	9	617.01	KEN	8	484.94	TUN	7	545.23
DJI	6	302.73	BEN	8	381.51	HND	9	805.76	KHM	8	649.43	CIV	8	372.56
HND	6	478.85	KEN	8	269.99	KEN	9	484.94	LAO	8	675.03	COG	8	406.39
LAO	6	523.20	KHM	8	253.04	KHM	9	649.43	MRT	8	378.93	DJI	8	546.96
NIC	6	557.91	MMR	8	332.19	LAO	9	675.03	NIC	8	517.24	HND	8	403.91
DZA	7	271.63	MRT	8	357.10	MRT	9	378.93	SEN	8	560.72	LAO	8	510.88
GTM	7	817.11	SDN	8	362.55	NIC	9	517.24	ZMB	8	614.26	NIC	8	339.96
TUN	7	754.54	SEN	8	232.10	SEN	9	560.72	ZWE	8	710.29	PAN	9	0.00
PER	8	696.37	ZMB	8	585.85	ZMB	9	614.26	GTM	9	0.00	THA	10	0.00
PRY	8	741.62	ZWE	8	766.61	ZWE	9	710.29	THA	10	0.00	PER	11	0.00
THA	8	911.60	GAB	9	0.00	PAN	10	0.00	PER	11	0.00	GTM	12	0.00

Table 2-5 above shows the eight, nine, ten, eleven and twelve clusters solutions. Note that Rwanda has kept its cluster number four throughput all clustering solutions. For eight-cluster solution, Rwanda groups with sub-Saharan African countries apart from Afghanistan, Haiti, Nepal and Yemen.

Within the nine-cluster solution the same group of countries in cluster four, remain unchanged. The ten-cluster solution enlarge the group of cluster four countries from twenty three to twenty six, with Benin, Myanmar and Sudan joining the group. The last situation remains unchanged in cluster eleven until the three countries leave the group in the twelve-cluster solution.

To conclude, apart from Myanmar, Nepal and Tanzania classified as lower-middle income, all other countries that joined Rwanda in cluster four fall within the low-income countries class. It is also to notice the change in number of outliers countries, the first two cluster solutions count two outliers Panama and Gabon. The middle clustering solution brings out four outliers with Guatemala and Thailand joining, whereas the last two clustering solutions add Angola, Peru and Paraguay to make seven outliers.

Table 2-6: Ten clusters solution by K-means clustering

Cluster membership			Final Cluster Centers											
Country	cluster	Distance		Cluster										Average
				1	2	3	4	5	6	7	8	9	10	
Peru	1	556.51	Population density (people/sq. km of land area) 2017	20.93	32.32	52.72	121.57	150.13	8.01	135.47	67.04	52.90	55.24	69.63
Paraguay	1	556.51	Population density (people/sq. km of land area) 2000	17.04	22.05	54.68	80.07	108.15	4.77	123.22	44.52	37.09	40.76	53.24
Angola	2	607.52	Birth rate, crude (per 1,000 people) 2017	19.46	31.61	19.57	34.84	24.91	32.16	10.51	21.83	29.65	19.26	24.38
Djibouti	2	607.52	Birth rate, crude (per 1,000 people) 2000	25.15	39.82	16.11	42.59	35.34	33.38	14.52	22.85	35.91	23.45	28.91
Armenia	3	208.64	Population living in slums (% urban pop) 2017	25.65	62.10	26.00	65.93	34.50	37.00	25.00	14.47	45.50	25.80	36.19
Mongolia	3	208.64	People using at least basic sanitation services (% population) 2017	82.06	56.74	76.06	30.99	65.06	47.41	98.75	91.95	48.48	83.32	68.08
Afghanistan	4	230.08	People using at least basic sanitation services (% population) 2000	67.27	37.40	67.43	20.33	63.30	34.46	92.02	86.42	31.97	61.07	56.17
Burundi	4	573.95	Nurses and midwives (per 1,000 people) 2017	1.48	0.57	4.97	0.69	0.07	2.95	2.96	2.70	1.06	3.09	2.05
Benin	4	479.32	Nurses and midwives (per 1,000 people) 2000	1.26	0.68	2.59	0.72	1.05	0.49	1.49	1.83	0.65	2.77	1.35
Burkina Faso	4	101.27	Hospital beds (per 1,000 people) 2017	1.21	1.10	6.10	0.77	0.44	1.30	2.10	1.85	1.33	2.25	1.84
Central Afr. Rep.	4	322.05	Hospital beds (per 1,000 people) 2000	1.41	1.28	6.97	0.54	0.70	0.40	2.20	1.84	1.08	2.21	1.86
Ethiopia	4	203.22	Electric power consumption (kWh per capita) 2017	1449.13	349.78	1984.00	110.78	601.19	1167.85	2538.80	1560.73	401.69	2064.18	1222.81
Guinea	4	197.29	Electric power consumption (kWh per capita) 2000	775.12	146.29	1175.60	55.45	332.19	880.04	1448.07	983.13	298.21	1266.53	736.06
Gambia	4	330.93	GDP per capita (USD) 2017	6195.54	3505.10	3791.96	709.39	4451.45	7230.40	6592.91	3896.11	1852.26	15150.35	5337.55
Haiti	4	634.52	GDP per capita (USD) 2000	1809.60	662.51	548.48	299.16	1664.30	4125.72	2007.74	1876.16	634.91	4060.32	1768.89
Liberia	4	109.53	Unemployment rate (% of total labor force) 2017	4.04	8.75	12.03	5.39	2.46	19.98	2.03	14.10	5.35	3.90	7.80
Madagascar	4	226.60	Unemployment rate (% of total labor force) 2000	7.52	7.28	8.60	4.88	2.77	17.37	2.39	19.47	6.89	3.73	8.09
Mali	4	203.74	Age dependency ratio (% of working-age pop) 2017	54.02	74.67	48.74	84.44	65.97	67.80	40.43	55.45	74.37	54.44	62.03
Myanmar	4	613.35	Age dependency ratio (% of working-age pop) 2000	64.84	88.79	73.77	89.79	81.26	75.97	43.91	64.81	85.75	60.01	72.89
Mozambique	4	466.66	Children out of school (% primary school age) 2017	7.06	29.22	4.14	19.46	11.69	9.09	1.73	7.15	13.40	13.22	11.62
Malawi	4	395.53	Children out of school (% primary school age) 2000	0.87	63.81	10.00	45.00	14.32	17.00	1.08	7.57	28.37	4.70	19.27
Niger	4	269.69	Lower secondary completion rate(% of relevant age group) 2017	83.40	36.06	97.11	41.50	56.94	37.00	78.59	70.71	55.72	76.80	63.38
Nepal	4	274.03	Lower secondary completion rate(% of relevant age group) 2000	72.76	15.92	74.59	20.26	29.60	21.60	27.15	68.82	32.39	45.47	40.86
Rwanda	4	455.06	Primary completion rate (% relevant age group) 2017	93.13	58.49	91.75	66.11	79.94	71.90	93.45	90.68	81.74	89.80	81.70
Sudan	4	437.97	Primary completion rate (% relevant age group) 2000	93.93	27.95	90.42	44.22	55.51	68.94	84.89	87.09	58.21	92.05	70.32
Sierra Leone	4	283.03	Pupil-teacher ratio, primary 2017	21.05	40.23	22.90	42.49	20.18	24.53	16.89	20.61	35.11	21.96	26.59
Somalia	4	474.00	Pupil-teacher ratio, primary 2000	27.85	40.65	24.33	47.68	32.56	51.94	20.79	25.10	42.97	24.74	33.86
Chad	4	232.90	Proportion of women seats in national parliaments (%) 2017	20.72	20.61	17.60	20.85	12.66	17.09	4.80	24.16	25.07	18.31	18.19
Togo	4	121.46	Proportion of women seats in national parliaments (%) 2000	6.67	7.73	6.79	9.87	8.85	9.17	4.81	4.99	9.69	9.86	7.84
Tanzania	4	328.18	Female labor force participation rate, female (% female ages 15+) 2017	63.01	63.33	50.25	60.93	39.70	42.97	59.21	17.74	59.12	50.97	50.72
Uganda	4	120.95	Female labor force participation rate, female (% female ages 15+) 2000	53.73	61.12	50.01	62.80	41.24	36.51	65.62	15.93	57.39	44.86	48.92
Yemen	4	361.69	Mobile cellular subscriptions (per 100 people)	116.26	42.10	121.63	68.89	118.16	128.98	175.60	111.76	97.73	128.57	110.97
Guatemala	5	0.00	Mobile cellular subscriptions (per 100 people)	10.12	0.09	3.51	0.32	7.35	9.77	4.85	3.03	1.57	13.54	5.42
Gabon	6	0.00	Individuals using the Internet (% of population) 2017	54.90	35.01	44.23	16.18	65.00	62.00	52.89	59.56	28.32	57.87	47.60
Thailand	7	0.00	Individuals using the Internet (% of population) 2000	1.91	0.15	1.28	0.16	0.71	1.22	3.69	1.96	0.37	6.55	1.80
Algeria	8	409.73												
Jordan	8	558.34												
Tunisia	8	545.23	**Proposed clusters names from examination of clusters centers to different indicators:**											
Cote d'Ivoire	9	320.53	**Cluster 1:** Birth controlled upper middle-income countries with good basic education system											
Congo	9	617.01	**Cluster 2:** Female dominated manpower Lower middle-income countries with poor education system											
Honduras	9	805.76	**Cluster 3:** Knowledge and ICT based indutrializing countries											
Kenya	9	484.94	**Cluster 4:** High slums rate populous low-income countries with poor infrastructure and basic eduction											
Cambodia	9	649.43	**Cluster 8:** Low slums rate countries with good basic infrastructure and education											
Laos	9	675.03	**Cluster 9:** Lower middle-income countries with average socio-economic progress											
Mauritania	9	378.93												
Nicaragua	9	517.24	**Outliers:**											
Senegal	9	560.72	**Guatemala** (5): Very high population density and very low rate of medical personnel											
Zambia	9	614.26	**Gabon** (6): Very low population density											
Zimbabwe	9	710.29	**Thailand** (7): Very low children out of school											
Panama	10	0.00	**Panama** (10): Very high GDP per capita											

For a deep understanding of the clusters memberships, we examined the final cluster centers to different indicators of the middle (ten-cluster solution), as shown in Table 2-5 above, which offers unique character in grouping countries.

Figure 2-3 below shows the geographical distribution of different countries clusters. We notice that apart from the clusters 1 and 3, which only occur on Asia and South America respectively, all other clusters are present on the three continents in unequal proportions.

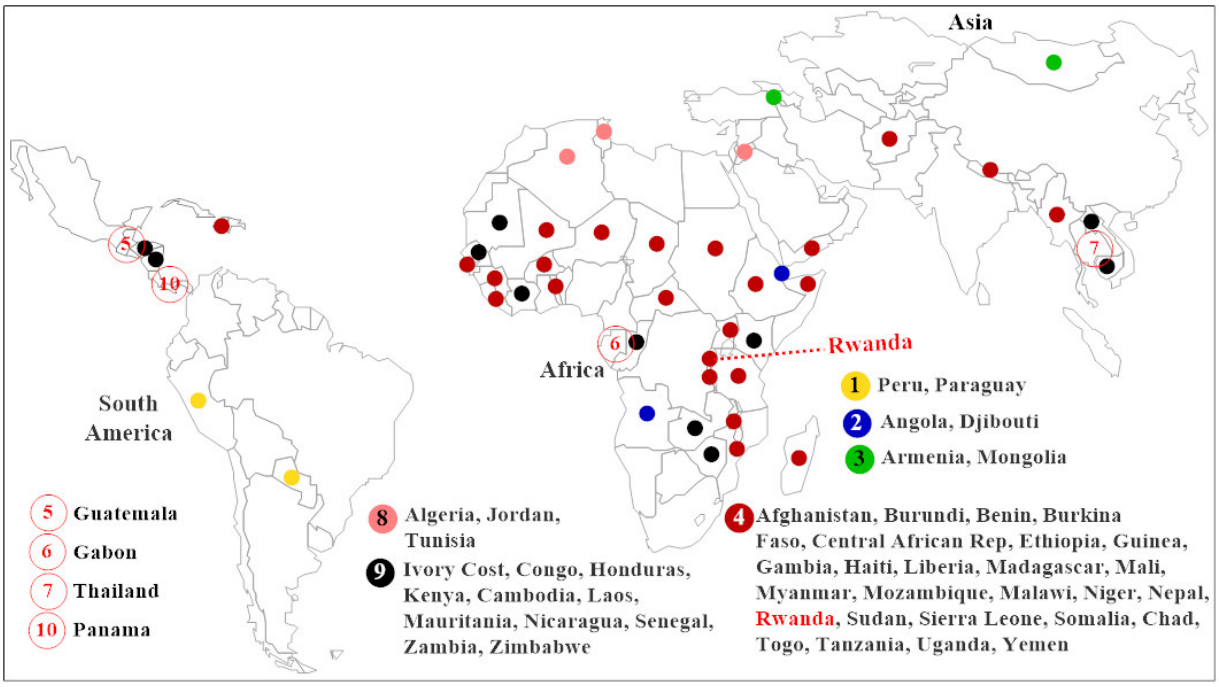


Figure 2-4: Rwanda clustering among countries with slums

2.4. Positioning Kigali city among other cities with comparable SDGs indicators

After examination of the position of Rwanda among other countries with slums and having only one city with a population of more than one million, we narrowed down to cities level and analyzed the position of Kigali city with respect to other cities. To carry out this analysis, we relied on two principal indicators, namely: the percentage of urban population living in slums and the percentage of urban population having access to basic sanitation services[5]. We selected the two indicators as a basis of analysis because the incidence of slums has generally a direct impact on people's overall sanitation status. Table 2-6 below summarizes the results of analysis. It shows the statistics for the

[5] This World Banks's indicator summarizes all together the public services involved in basic sanitation, namely: solid and liquid wastes disposal systems, quality and quantity water, public and private latrines, to mention but a few.

two base years of 2000 and 2017, thereafter the encountered change for every city in terms of the increase or the decrease, for the seventeen years period, in population leaving in slums as well as in urban people having access to basic sanitation services.

Table 2-7: Population living in slums versus people having access to basic sanitation services

Country	City	X	Y	X	Y	City code	Population in slums	Access to basic sanit
		2017		2000			Increase or Decrease (%)	
Afghanistan	Kabul	70.7	62.3	62.7	29.6	KAB	8.0	32.7
Algeria	Alger	11.8	89.7	10.0	91.4	ALG	1.8	-1.7
Angola	Luanda	48.6	64.3	65.8	47.5	LAD	-17.2	16.8
Armenia	Yerevan	9.3	99.7	14.4	92.3	EVN	-5.1	7.4
Benin	Cotonou	58.8	26.5	74.3	19.0	COO	-15.5	7.5
Burkina Faso	Ouagadougou	57.1	39.4	65.9	50.3	OUA	-8.8	-10.9
Burundi	Bujumbura	47.7	41.7	64.3	40.6	BJM	-16.6	1.1
Cambodia	Phnom Penh	45.1	95.8	78.9	46.4	PNH	-33.8	49.4
Central African Rep.	Bangui	95.4	49.1	91.9	26.1	BGF	3.5	23
Chad	N'Djamena	86.9	30.1	93.9	25.5	NDJ	-7.0	4.6
Congo	Brazzaville	47.8	27.2	53.4	16.3	BVZ	-5.6	10.9
Cote d'Ivoire	Yamoussoukro	60.1	46.1	55.3	39.0	YAM	4.8	7.1
Djibouti	Djibouti	64.5	76.3	65.6	58.1	JIB	-1.1	18.2
Ethiopia	Addis Ababa	64.3	19.6	88.6	16.0	ADD	-24.3	3.6
Gabon	Libreville	36.6	48.7	38.7	35.5	LBV	-2.1	13.2
Gambia	Banjul	27.1	45.5	45.4	50.5	BJL	-18.3	-5
Guatemala	Nueva	31.0	79.2	48.1	81.5	NUE	-17.1	-2.3
Guinea	Conakry	50.1	33.8	57.3	23.6	CKY	-7.2	10.2
Haiti	Port-au-Prince	65.9	43.8	93.4	27.8	PAP	-27.5	16
Honduras	Tegucigalpa	38.6	85.3	34.9	75.8	TGU	3.7	9.5
Jordan	Amman	23.4	97.4	15.8	98.6	AMM	7.6	-1.2
Kenya	Nairobi	46.5	34.7	54.8	35.7	NBO	-8.3	-1
Laos	Vientiane	21.1	95.4	31.4	67.1	VTE	-10.3	28.3
Liberia	Monrovia	70.3	27.7	68.3	25.3	ROB	2.0	2.4
Madagascar	Antananarivo	61.2	17.8	84.1	9.4	TNR	-22.9	8.4
Malawi	Lilongwe	65.1	34.1	66.4	32.0	LLW	-1.3	2.1
Mali	Bamako	47.2	53.3	75.4	33.9	BKO	-28.2	19.4
Mauritania	Nouakchott	73.2	74.8	79.9	34.5	NKO	-6.7	40.3
Mongolia	Ulaanbaatar	38.3	66.3	64.9	64.2	ULN	-26.6	2.1
Mozambique	Maputo	77.2	52.3	78.2	31.7	MPM	-1.0	20.6
Myanmar	Nay Pyi Taw	56.1	76.0	45.6	82.5	NPT	10.5	-6.5
Nepal	Kathmandu	49.3	67.3	64.0	32.6	KTM	-14.7	34.7
Nicaragua	Managua	42.2	83.7	60.0	70.5	MGA	-17.8	13.2
Niger	Niamey	58.8	43.8	82.6	25.2	NIM	-23.8	18.6
Panama	Panama City	22.1	92.3	23.0	71.5	PTY	-0.9	20.8
Paraguay	Asunción	17.1	94.2	17.6	85.1	ASU	-0.5	9.1
Peru	Lima	33.1	79.6	46.2	77.2	LIM	-13.1	2.4
Rwanda	Kigali	42.1	51.9	79.7	63.3	KGL	-37.6	-11.4
Senegal	Dakar	29.5	65.0	48.9	63.1	DKR	-19.4	1.9
Sierra Leone	Freetown	59.7	25.7	97.0	20.4	FRE	-37.3	5.3
Somalia	Mogadishu	72.1	61.1	73.5	44.7	MGQ	-1.4	16.4
Sudan	Khartoum	88.4	60.1	91.6	40.5	KRT	-3.2	19.6
Tanzania	Dar es Salaam	40.1	42.6	70.1	10.6	DSM	-30.0	32
Thailand	Bangkok	23.7	99.2	26.0	89.2	BKK	-2.3	10
Togo	Lomé	54.3	28.6	62.1	24.4	LOM	-7.8	4.2
Tunisia	Tunis	8.1	95.3	8.0	93.6	TUN	0.1	1.7
Uganda	Kampala	48.3	26.1	75.0	30.6	KAM	-26.7	-4.5
Yemen	Sana'a	66.2	87.9	67.2	85.8	SAH	-1.0	2.1
Zambia	Lusaka	54.6	36.2	57.2	45.9	LUN	-2.6	-9.7
Zimbabwe	Harare	33.5	46.2	3.3	65.0	HRE	30.2	-18.8
X: population living in slums (% of urban population)						**(+): increase**		
Y: people with access to basic sanitation services (% of urban population)						**(-): decrease**		
							: highest increase/decrease	

In order to understand further the behavioral displacements for each of the fifty cities, we distributed them in a two-dimensional plan with the coordinates from the Table 2-7 above.

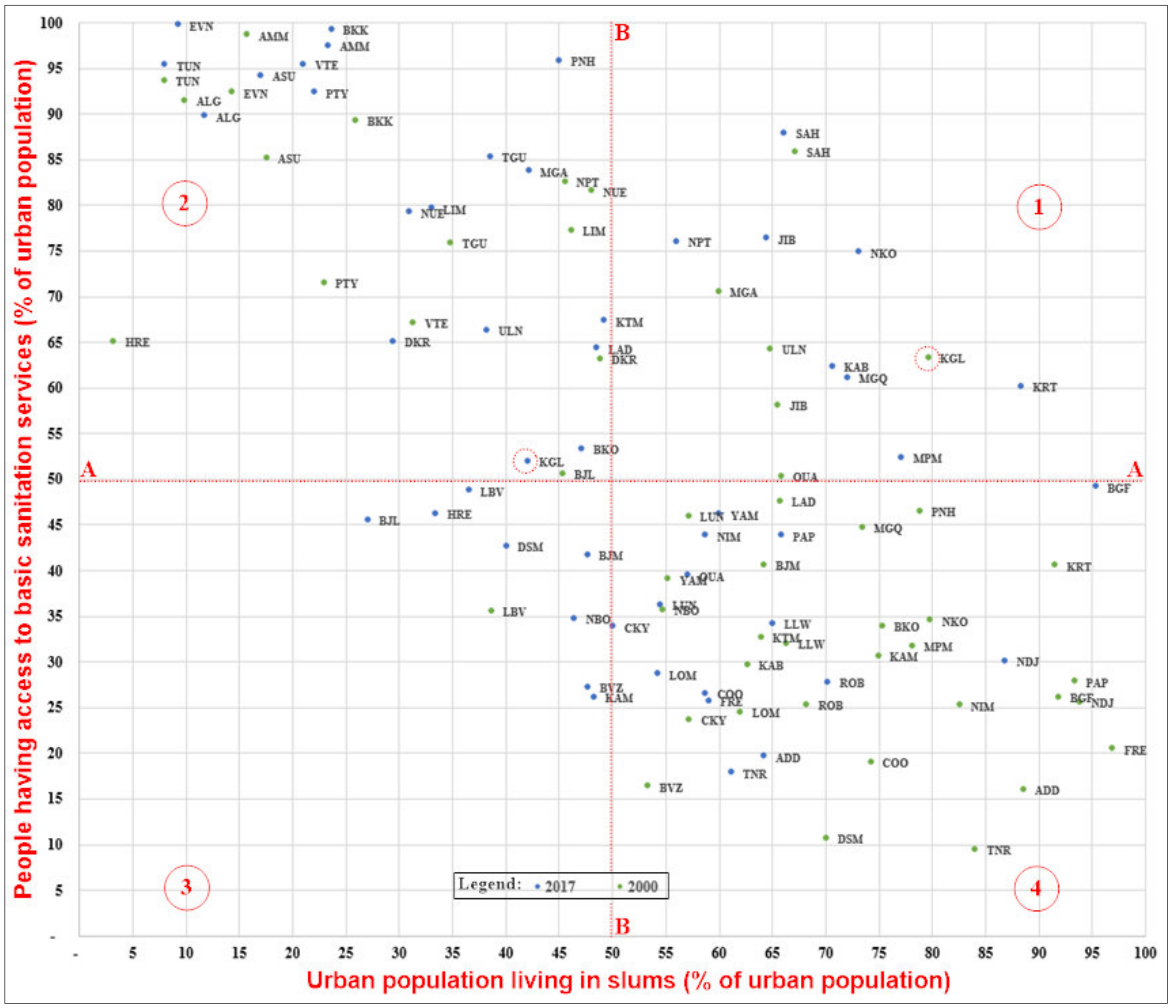


Figure 2-5: Position of Kigali city with respect to population in slums and basic sanitation services

For a better understanding of different cities positions and the impact on their displacements, we divided the distribution plan on Figure 2-5 above into four symmetrically equal quadrants with help of the two medians AA and BB, both passing by the 50% point of the two indicators in horizontal and vertical directions respectively. Thereafter, we made an inventory of cities belonging to every quadrant in the two reference years in order to derive the respective displacements of cities throughout different quadrants, described as follow:

- First quadrant: high slums rate with good basic sanitation services;
- Second quadrant: low slum rate with good basic sanitation services (best conditions);
- Third quadrant: low slum rate with poor basic sanitation services;

- Fourth quadrant: high slums rate with poor basic sanitation services (worst conditions).

Table 2-7 below shows the cities memberships to quadrants, whereas Table 2-8 sorts cities in sets of same displacements from one quadrant to another one.

Table 2-8: Cities memberships to quadrants

Quadrant 1		Quadrant 2		Quadrant 3		Quadrant 4	
2000	2017	2000	2017	2000	2017	2000	2017
Djibouti	Djibouti	Alger	Alger	Libreville	Libreville	Addis Ababa	Addis Ababa
Sana'a	Sana'a	Amman	Amman		Brazzaville	Antananarivo	Antananarivo
Kigali	Kabul	Asunción	Asunción		Bujumbura	Bangui	Bangui
Managua	Khartoum	Bangkok	Bangkok		Dar es Salaam	Conakry	Conakry
Ouagadougou	Maputo	Dakar	Dakar		Harare	Cotonou	Cotonou
Ulaanbaatar	Mogadishu	Lima	Lima		Kampala	Freetown	Freetown
	Naypytaw	Nueva	Nueva		Banjul	Lilongwe	Lilongwe
	Nouakchott	Panama city	Panama city		Nairobi	Lomé	Lomé
		Tegucigalpa	Tegucigalpa			Lusaka	Lusaka
		Tunis	Tunis			Monrovia	Monrovia
		Vientiane	Vientiane			N'Djamena	N'Djamena
		Yerevan	Yerevan			Niamey	Niamey
		Banjul	Bamako			Port-au-Prince	Port-au-Prince
		Harare	Kathmandu			Yamoussoukro	Yamoussoukro
		Naypytaw	Kigali			Bamako	Ouagadougou
			Luanda			Brazzaville	
			Managua			Bujumbura	
			Phnom Penh			Dar es Salaam	
			Ulaanbaatar			Kabul	
						Kampala	
						Kathmandu	
						Khartoum	
						Luanda	
						Maputo	
						Mogadishu	
						Nairobi	
						Nouakchott	
						Phnom Penh	

Observations from Table 2-7 above:

- First quadrant: two cities have kept their membership; four cities (including Kigali) have left whereas six new cities joined the quadrant. By 2000 this quadrant hosted cities from sub-Saharan Africa, Asia and south-America, while by 2017 it was dominated by sub-Saharan African cities (four out of six)
- Second quadrant: twelve cities have remained members; three cities have left while seven cities (including Kigali) joined. This quadrant highlights a stable character, mostly dominated by south-American cities.
- Third quadrant: the only one member city in 2000 have remained and it was joined by seven additional cities. In both reference years, this quadrant is occupied only by sub-Saharan Africa cities.
- Fourth quadrant: fourteen cities have kept their membership; fourteen have left whereas only one city joined. This quadrant is a host of most sub-Saharan Africa cities.

In the year 2000 only three cities out of 28 were not sub-Saharan, whereas that proportion narrowed down to only one city out of fifteen.

Table 2-9: Cities displacements throughout quadrants

From 1 to 1	From 1 to 2	From 1 to 3	From 1 to 4	From 2 to 2	From 2 to 1	From 2 to 3	From 2 to 4	From 3 to 3	From 3 to 1	From 3 to 2	From 3 to 4	From 4 to 4	From 4 to 1	From 4 to 2	From 4 to 3
Djibouti	Kigali	N/A	Ouagadougou	Alger	Naypytaw	Banjul	N/A	Libreville	N/A	N/A	N/A	Addis Ababa	Kabul	Bamako	Brazzaville
Sana'a	Managua			Amman		Harare						Antananarivo	Khartoum	Kathmandu	Bujumbura
	Ulaanbaatar			Asunción								Bangui	Maputo	Luanda	Dar es Salaam
				Bangkok								Conakry	Mogadishu	Phnom Penh	Kampala
				Dakar								Cotonou	Nouakchott		Nairobi
				Lima								Freetown			
				Nueva								Lilongwe			
				Panama city								Lomé			
				Tegucigalpa								Lusaka			
				Tunis								Monrovia			
				Vientiane								N'Djamena			
				Yerevan								Niamey			
												Port-au-Prince			
												Yamoussoukro			

From Table 2-8, we notice that the city of Kigali made a considerable step in slums reduction by shifting from high slums rate quadrant to the low rate one. However, that rapid shift exerted a high pressure to pre-existing basic sanitation services, as it will be later discussed herewith.

The quasi-stability of the second quadrant is to be highlighted. Mostly composed by higher middle-income countries, there have been no displacements of member countries from the year 2000. However, the city of Harare (capital city of Zimbabwe) recorded a high increase in slums (30.2%), together with a fall (18.8%) in people accessibility to basic sanitation services. The case of Harare links to a political instability that characterized the country throughout the selected reference period.

Libreville (the capital city of Gabon), the only city occupying the third quadrant by the year 2000, stayed in the same quadrant with a slight decrease in slums rate (2.1%) and an increase of 13.25 in people accessing the basic sanitation services. By the year 2017, five more sub-Saharan African cities joined the city of Libreville to make six cities from the same region.

Dominantly occupied by low-income's sub-Saharan African countries cities, the fourth quadrant as the worst case with respect to the two indicators of comparison, is characterized by an instability in both internal and external movements. It is to notice that, apart the city of Ouagadougou (Burkina Faso) that joined by 2017, this quadrant is a supplier to the other quadrants with better conditions. By the year 2000, more than a half of all concerned cities (28 over 50). However, this number reduced by only 14 cities remaining within this quadrant but with noticeable improvements in slums reduction and amelioration of basic sanitation conditions.

Overall, the dynamism of cities within the fourth quadrant highlights continuous efforts of low-income countries' cities to migrate from worse to improved living conditions.

For further analysis of Kigali city position among other cities, we deduced from the Figure 2-5 only the cities with decrease records in slums rate, as Kigali city.

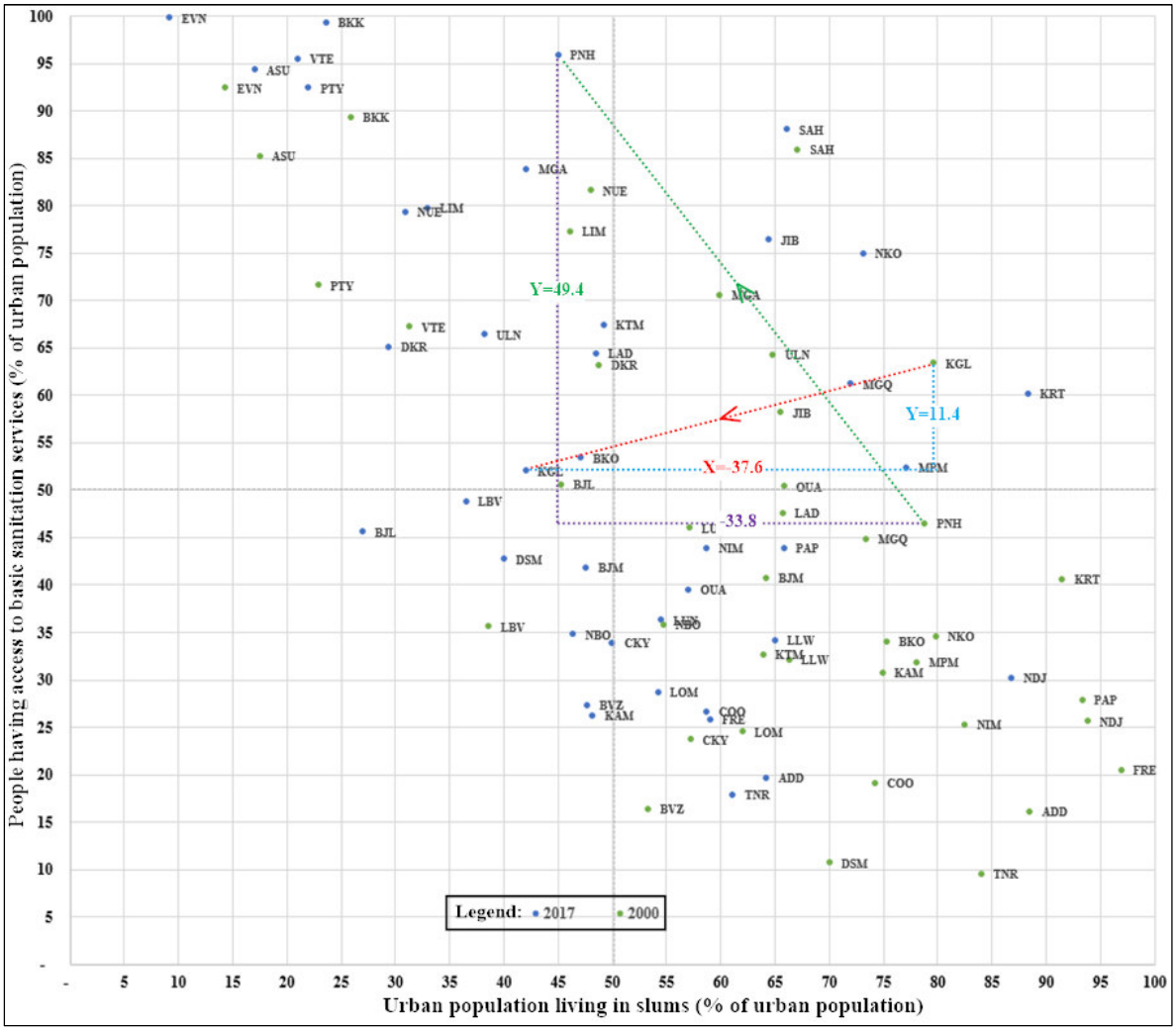


Figure 2-6: Cities with decrease in slums rate

From Figure 2-6, Kigali city recorded the highest decrease in slums of 37.6% from the year 2000 to 2017. This was the direct result of the government's strong policy prohibiting further proliferations of new slums and the total relocation of critical slums areas to planned settlements sites. However, this strong response exerted a high demand exceeding the supply in basic public services, hence a diminution of 11.4% in people having access to basic sanitation services.

On the other hand, the city of Phnom Penh (Cambodia) have not only recorded a considerable decrease in slums (33.8%), but have also scored the highest increase in people accessing the basic sanitation services.

According to UN-Habitat (2010) “After the retreat of the Khmer Rouge in 1979, the Cambodia's capital city Phnom Penh began to receive an influx of migrants from rural areas who settled in the city's mushrooming informal settlements. To help address this situation and the increasing urban poverty, a number of initiatives were launched. As a follow-up to an earlier successful squatter support project phase, the Phnom Penh Urban Poverty Reduction Project started in November 2000. In May 2003, there was a breakthrough in government policy by committing to upgrade 100 slum settlements per year over the next 5 years. This has brought all the stakeholders to work together towards in-situ upgrading.”

Chapter 3 From history to recent transformations and future trends of Kigali city

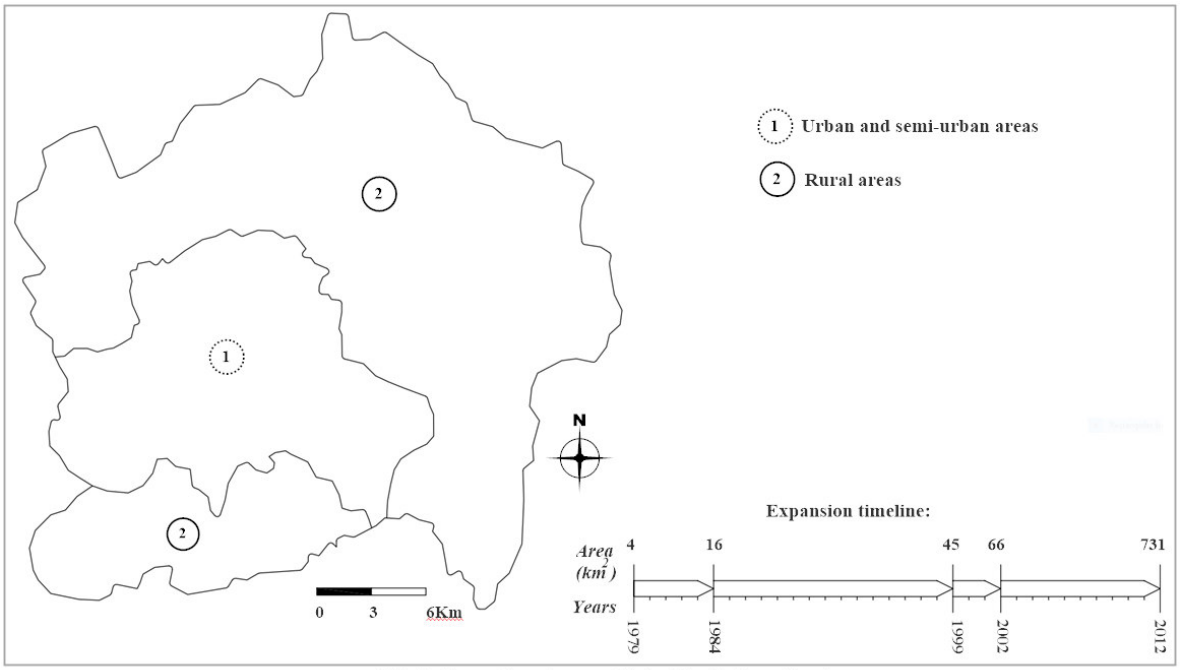
3.1. Background

3.1.1. Brief history of Kigali city

In the year 1907, the colonial administration of Rwanda was declared independent, hence separated from a formerly so-called Rwanda-Urundi. One year after, Kigali became the administrative district of the new Rwanda colonial concession (Jean, 2014).

Kigali has been the economic, cultural, and transport hub of Rwanda. The city became Rwanda's capital in 1962 when independence was gained from western powers (Helen, 2016). The city is located in the nation's geographical center.

The settlement began as a small colonial outpost and functioned as a trade center during the German colonial administration (after 1895). It was chartered as a city in 1907, becoming a regional center during the Belgian colonial period of 1919–1962.

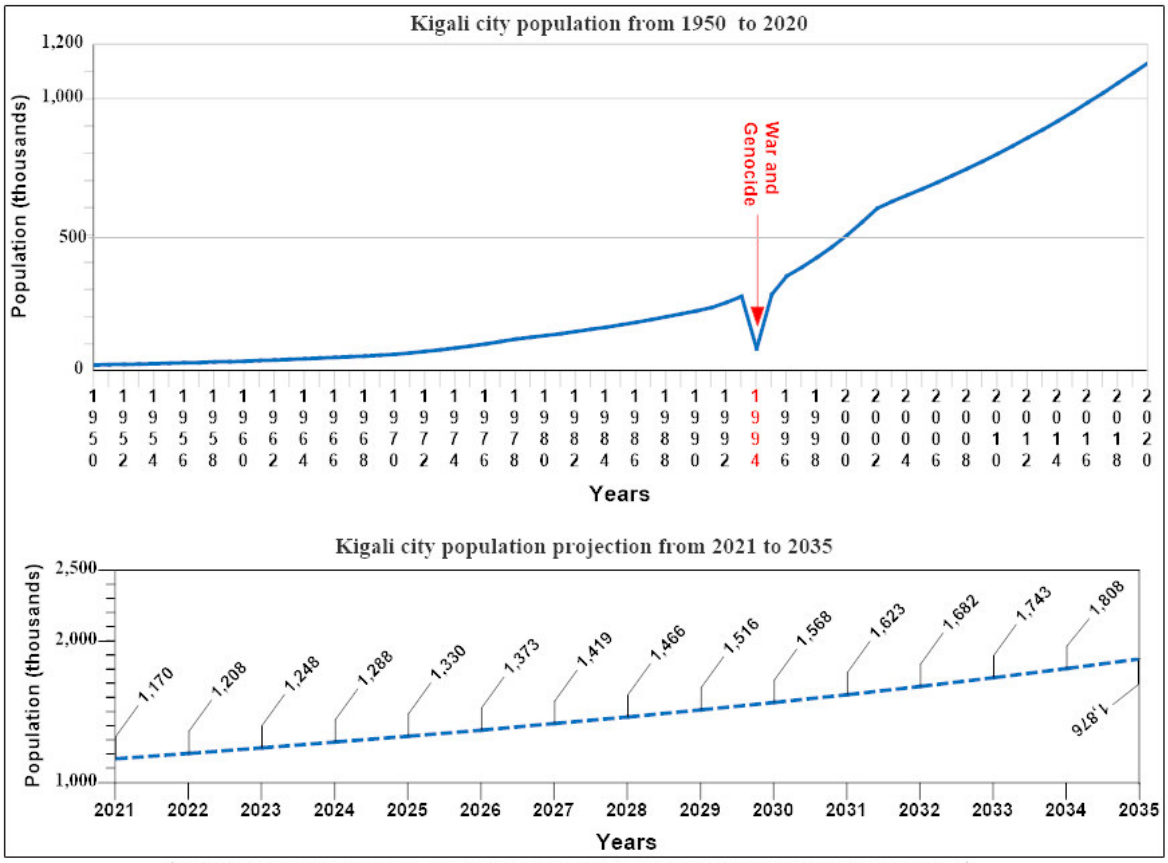


(Illustration:author, Source of data: Kigali city archives)

Figure 3-1: Kigali urban expansion throughout history

By the year 1909, there were few tens of commercial shops mostly owned by Indian traders. The colonial regime had built some residential houses for administrators, a military camp and a prison. By that time, Kigali as a capital city occupied about 200 hectares with a population of around 6,000 people. Since then, Kigali city has known a tremendous expansion both in area and population sizes. As shown on the Figure 3-1, the city covered 731Km^2 by 2012 of which 12.7% urban and 87.3% rural (Division of Urban Planning, 2018).

Kigali was one location of the 1994 genocide and of fierce fighting between the national army and the Rwanda Patriotic Front. After the war and genocide, the new government made efforts to bring the people together. At present, Kigali is safer, cleaner, and more competitive; a modern city with expanding opportunity.



(Graph illustration: author, source of data: National Institute of Statistics of Rwanda)

Figure 3-2: History of Kigali city population and its projection

The city's annual population growth rate is 4.2%. As argued by the World Bank (2017), this high growth rate is mostly due to higher urban fertility rates, lower infant mortality rates, and a high level

of rural-urban migration. Figure 3-2 highlights an epic increase in urban population since 1950's until recently, and its projection until 2035.

From the year 2007, the city launched its first Master Plan for governance in line with the *Vision 2020 of Rwanda*, based upon research and analysis of a wide range of background conditions and technical aspects. Environmental conditions, land use, and infrastructural, cultural, and socioeconomic factors, along with economic and demographic projections, were analyzed as economics and urban development plans were enacted.

3.1.2. Brief geographic conditions

Kigali city takes its name from the Mount Kigali. The city spreads on a hilly relief, sprawling across about four ridges and the valleys in between. The hill crests have an average elevation of 1,600 meters, while the valleys are around 1,300 meters. The city is almost enclosed by high hills, the highest of which is Mount Kigali, with an elevation of 1,853 meters above sea level.

Due to the high altitude, Kigali has a pleasant tropical highland climate. The variation in temperatures ranges from 20°C to 21.6°C throughout the year. There are four seasons: Long rains from mid-March to mid-May, short rains from mid-October to mid-December; a long dry period from mid-May to mid-October; and a short dry season from mid-December to mid-March. Average annual precipitation is 900mm. However, the seasonal allocations have been recently fluctuating due to the global climate change. The city center is located on one of the city's four ridges, while the main administrative area is located on another ridge. Residential houses as well as office buildings tend to hierarchize from the tops of the ridges, downgrading from the hills sides towards the valleys.

3.1.3. Brief governance structure

According to the Constitution of Rwanda, the country is a presidential republic in which the chief of state is the president, elected by popular vote for a seven-year term, and is eligible for a second term. The head of government is the prime minister. The bicameral parliament consists of a senate of 26 members, both elected and appointed to serve eight-year terms, and a chamber of deputies of 80 seats to serve five-year terms.

According to the ministry of local governance's territorial subdivisions, Kigali is a province-level city governed by a city council that appoints an executive committee to run the day-to-day operations of the city. The council of the city of Kigali governs the city, whereas the everyday management of the city is overseen by an executive committee, which is headed by a mayor deputized by two vice-

mayors; one in charge of urbanization and infrastructure and another in charge of socio-economic affairs (Kigali city website, 2021). The city is split into three administrative districts, namely:

(i) Nyarugenge: is the central district and progress towards the southwest and southeast of the city. Hosting about 25 percent of the total city's population (NISR, 2012). The average elevation of Nyarugenge District is 1,000 m above the sea level and hosts the Mount Kigali with an elevation of 1,853m. Due to such hilly topography coupled with large-scale deforestation, soil erosion and landslides in the district are key recurrent problems faced by the City (Nyarugenge district website, 2021).

(ii) Kicukiro: situated in the southeast of Kigali, hosts about 28 percent of the total population of the city ((NISR, 2012). The district has a hilly structure with elevations above mean sea level ranging from 1336 to 1833 meters. The hydrographs of the District are largely constituted by streams and rivers. The average temperature is 22°C and an annual rainfall varying between 900 and 1150 mm. (Kicukiro district website, 2021).

(iii) Gasabo: located in the northeast of Kigali City, it is the largest district of the city covering more than half of the total city's area (492 km^2 out of 731 km^2) from which only 16 percent is urban, while 84 percent is rural. The district hosts 47 percent of Kigali city's population ((NISR, 2012). Gasabo district is characterized by a mixture of high mountains with average altitude of 1,800m mainly located in the rural zone, sloping basins and valleys. The district has over 30 wetlands and small rivers traversing through the valleys. These marshlands or wetlands provide potentialities to the district of enhancing agriculture productivity, tourism and improve environmental ecological system as well. (Gasabo district website, 2021).

3.2. Informal settlement upgrading approaches

In order to alleviate further proliferation of informal settlements due to housing demand, which has been always far away from the available housing stock, the Government of Rwanda initiated different alternatives of affordable housing that suit for different income levels. Affordable housing is defined here as 'relationship between housing and people'. For some people, all housing is affordable, no matter how expensive it is; for others, no housing is affordable unless it is free (Abed A., 2012). In Kigali city, affordability in housing markets is a challenge to low income families, as construction costs continuously increase. Housing affordability is most often referred to the relation between the housing cost and the household income. The common way to clarify this relation is to categorize households with respect to their income levels.

In addition to the ongoing onsite informal settlements upgrading projects throughout the city's areas that qualify for upgradability; the Rwanda government enacted a law establishing guidelines for contracts between the public and private investors in order to implement the approach of total relocation of high risks informal areas. This initiative is called "Public Private Partnership" (Office of the Prime Minister of Rwanda, 2018).

3.2.1. Onsite upgrading

Figures 3-3 and 3-4 below show examples of current onsite upgrading initiatives. The example shown on Figure 3-3 is one among many others onsite upgrading projects underway. This project was contracted between the city of Kigali and a private consulting company to conduct a feasibility study on upgrading an informal settlement area of 137.8 hectares.

Figure 3-3: On-site informal housing upgrading by land readjustment

From its inception report, the consulting company revealed that "68.2 percent of houses are constructed in non-durable and non-sustainable construction materials; 3.4 percent of structures have a flush toilet; 44.1 percent have a private pit latrine, whereas 48.6 percent have a shared pit latrine" (third National Urban Forum, 2019). Narrow and eroded footpaths characterize the accessibility conditions to the most of dwellings. Under this initiative, informal settlement will be onsite upgraded through land readjustment, whereby dwellers will contribute there portions of lands in exchange of new apartments units.

3.2.2. Total relocation and resettlement Government's project

Shown on the Figure 3-4 below is one of many ongoing total relocation and resettlement initiatives under a so-called "Integrated Landscape Restoration of Degraded Areas Project". This Project aims at resettling the inhabitants living in high risks zones of mountains surrounding the Kigali city, thereafter establish a green cover recovery on degraded land of steep mountains surrounding Kigali city, hence provide a protection against soil erosion, landslide and siltation of rivers. The initial project report revealed that 13,670 households required an emergency relocation from their current occupied lands (Household Assessment and Housing Settlement Proposal, 2018). As the relocation and resettlement of all concerned households requires short to long-term budget implications, the Government took emergency measures to relocate temporally all concerned households exposed to imminent danger of landslides and/or flooding in low-lying wetlands zones.

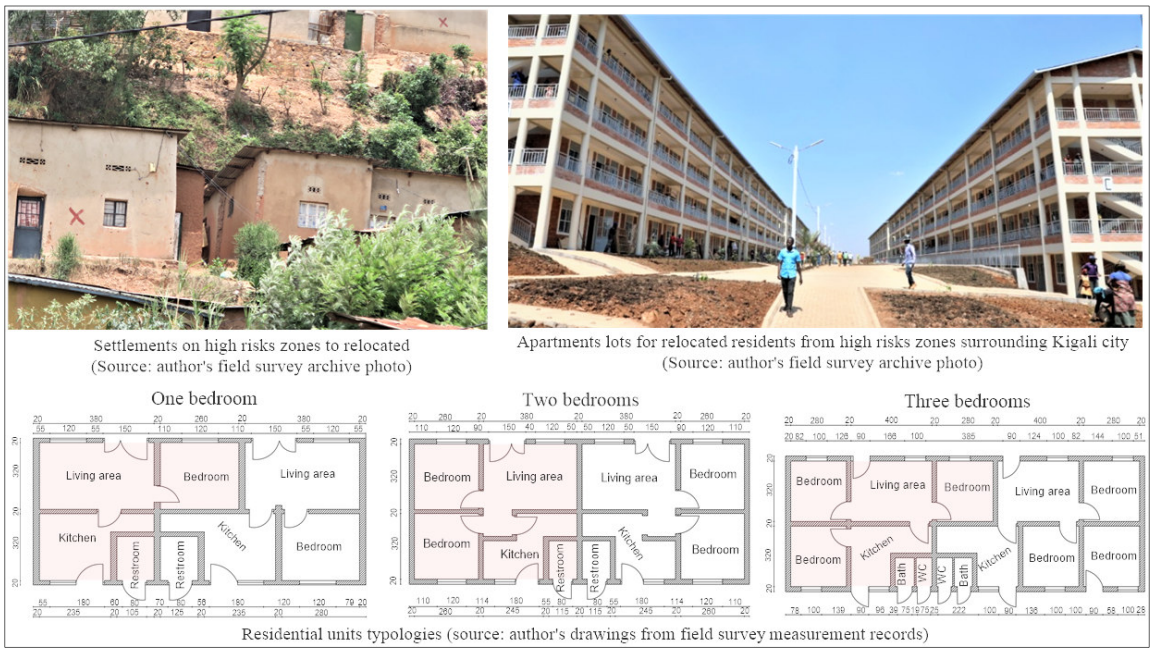


Figure 3-4: Total relocation and resettlement Government's project

3.3. Revised Kigali city master plan 2020 – 2050 in line with SDGs

In September 2020, the city of Kigali launched a new and accommodative master plan 2020 -2050 that brings flexibility in building and enhances social inclusion, among others.

It indicates key integral areas of land use, shown on Figure 3-11 below, which will define the city throughout the next 30 years.

The thematic areas include:

- Designated land for human settlement,
- Pedestrian pathways,
- Environment and culture conservation,
- Green growth,
- Commercial,
- Industrial,
- Aviation,
- Agricultural activities.

Furthermore, the revised master plan clarifies specific areas meant for national defense, public infrastructure and services as well zones designated to recycling activities.

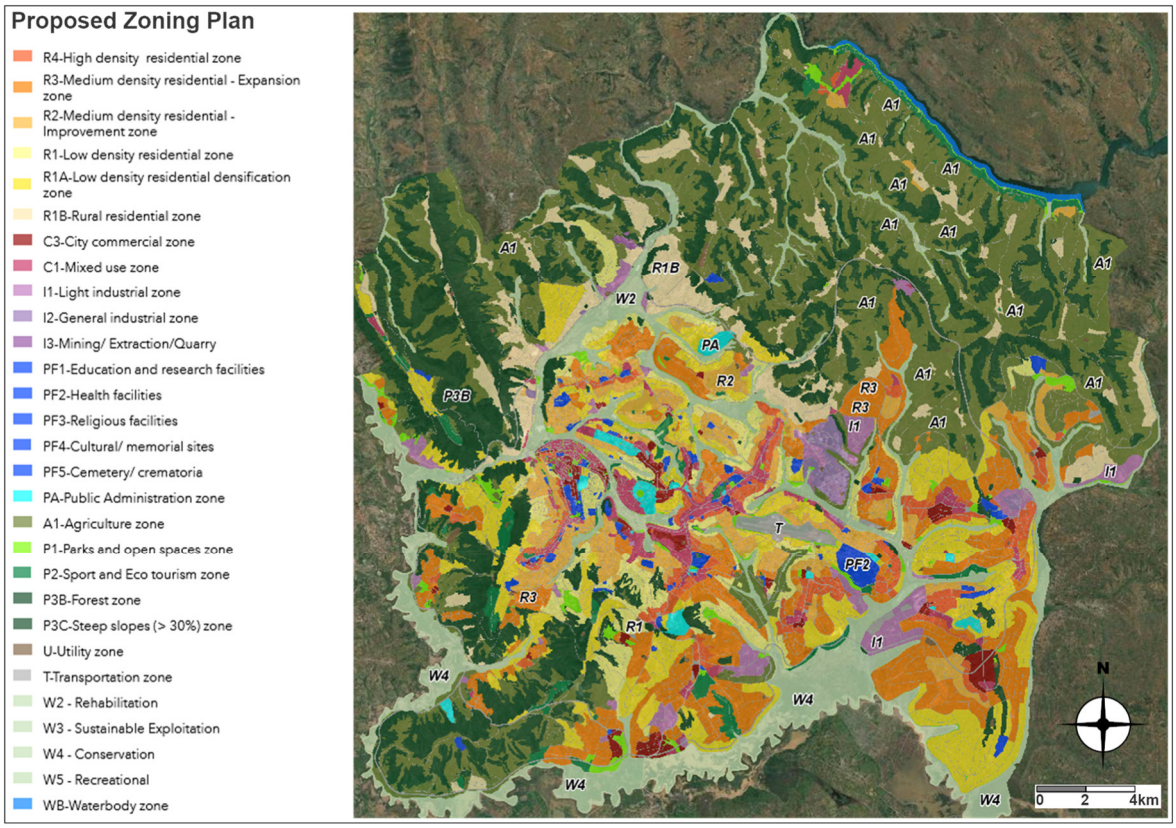
In contrary to the expired master plan which was criticized to be pro-development but pushing away the low-income earners, the revised one has an inclusive character that incorporates all citizens from low to high-income classes. The new plan is conceived to be accommodative and put an end to the problem of affordable houses to city residents, therefore comply with the year 2050 new projections: population of 3.8million inhabitants, household size at 3.8 people, gross density at 5198 people per square kilometer, and employment projection of 1.8 million jobs.

3.3.1. Flexible Zoning Plan

From the old to the new master plan, there have not been total changes to the zoning structure but the regulations behind each zone was revised. The 2020 Master Plan review for the City of was drafted combining international best practices with a bottom-up approach, based on extensive socio-economic data collection and analysis, together with a continued interaction with local and international stakeholders. This process aimed at drafting a highly customized strategy to support Kigali aspirations of become the Centre of Urban Excellence in Africa.

Great attention was put in addressing the issues highlighted in the old Master Plan, introducing a more equitable, flexible, and incremental approach to City development, in line with the UN-HABITAT New Urban Agenda, Sustainable Development Goals and with the latest and more

innovative approaches being currently studied or implemented to guide the rapid urbanization of African Cities. (Master Plan 2050, zoning regulations).



(Source: https://masterplan2020.kigalicity.gov.rw)

Figure 3-5: Kigali city master plan 2020 – 2050 – Proposed Zoning Plan

The new Kigali City Master Plan aims at being more inclusive by facilitating higher degree of social and economic inclusion, allowing for more social and economic mix in the City, favoring small and large investors and facilitating the creation of a large variety of affordable housing solutions, hence supporting the growth of a healthy and well-balanced community.

The review process was designed to address the concerns raised during the first 5 years of implementation, improving the methodological approach and the execution of planning activities, whenever needed, to achieve a more inclusive result.

For instance: (Master Plan 2050, zoning regulations).

(1) A systematic research methodology was applied to the review process with the objective to inform planning decisions. Extensive Primary Data collection was conducted to inform the socio-economic

status quo analysis and the projections. Traffic counts were also conducted to address short-term traffic issues in the City and inform future transport model. All available data and studies were also collected and incorporated into the Plan.

(2) An extensive stakeholders' consultation process was carried out through focused group discussion, stakeholders meeting, and other digital platforms to investigate issues more in detail and find shared solutions.

(3) An intense consultation with international organizations (UN-HABITAT, WORLD BANK, etc.) was conducted to align Master Plan strategies with ongoing and planned activities in the City.

(4) A wide research on world's best practices on regulations (different zoning models), urban policies (land consolidation, incremental development, financing) and affordable development models where conducted to inform the Master Plan. Each of this input was then adapted to the Kigali context and evaluated together with relevant stakeholders.

(5) A new transport and infrastructure model was developed to ensure that the service provision strategy allow for high level of services, while still being affordable to the different income levels and neighborhoods in the City.

(6) New zones and zoning regulations were studied to ensure affordability, flexibility and feasibility of the plan. Minimum Plot size are reduced, plot coverage increased, typologies adapted to ensure incremental development and are now more in line with citizens' purchasing power. Common facilities and public parks are suggested in suitable locations in a more flexible manner.

(7) Mixed use is suggested in most part of the City, allowing the creation of employment opportunities integrated with the neighborhoods, thus allowing for a more inclusive economic development of the communities.

(8) On-street parking is allowed along local roads, collectors and minor arterials and shared parking facilities are encouraged to maximize the use of land and support better parking demand management in the optic of encouraging use of Public and Non-Motorized Transport.

(9) Incrementalism will be encouraged to maximize current investment capacity without hindering future development potential.

(10) Inclusionary zoning for affordable housing will be encouraged and incentivized to increase affordable housing stock for low and moderate-income groups.

3.3.2. Objectives and definition of zoning plan and regulations

The objective of the zoning regulations for the City of Kigali is to provide a clear mechanism for the implementation of the updated Kigali City Master Plan and to direct public and private sector development to follow a clear set of development objectives, definitions, regulations, and guidelines that reflect the vision and concept proposed in the Master Plan. The objectives, definitions and regulations ensure that development is carried out to achieve a logical, attractive, and livable development pattern in the City, safeguard privacy and amenities, and provide opportunities for growth, with enough flexibility to respond to changing business needs and development trends. The regulations place an emphasis on encouraging mixed-use mixed-income development for integrated, well connected, inclusive, and equitable development, that are sustainable and are designed to achieve quality living environment.

Zoning regulates the types of uses, the development intensity, the required density, the setting, and height of buildings on any plot. As such, it serves as an effective planning tool to guide development in a logical and orderly fashion. The Zoning Plan is meant to provide landowners, developers, and stakeholders with a clear picture of what can and cannot be developed on any parcel of land in the City of Kigali's territory.

The Zoning Plan is made up of a zoning map and a set of zoning regulations. The zoning map identifies specific zones within the planning area based on the predominant land use, and the desired intensity, building height and density for that area.

The zoning regulations stipulate the permitted, conditional, prohibited uses, location of a building on any plot, the overall maximum intensity, as well as the building height. Specific regulations related to overall building form, landscaping, development strategy and signage are also stipulated in the Zoning Regulations. Zoning regulations stipulate allowable development for a zone, but flexibility in development is ensured by allowing incentives such as promoting inclusionary zoning, incremental / phased development.

The Zoning Regulations tabulate the uses into three categories: Permitted, conditional and prohibited uses.

- Permitted use: uses that comply with the intended use for the zoning code and can be permitted outright. However, the development shall comply, when relevant, with other context specific additional regulatory restrictions such as urban design guidelines, overlays, heritage, and conservation guidelines.
- Conditional use: Conditional uses are usually activities that may create significant traffic, noise, or other impacts on the surrounding neighborhood. Such identified uses can be permitted

conditionally within a zone following the assessment of City of Kigali's approval. Each zone can allow different but compatible developments that are complementary in terms of use and scale. For example, a small-scale commercial development could be allowed in residential areas to provide convenience for residents to meet their daily shopping needs. Similarly, Civic facilities like schools, day care centers, religious facilities could be allowed in a residential zone, provided the facility meets the parking, noise standards etc. Such conditional uses could be permitted after careful consideration and evaluation by the City of Kigali and may be subject to certain conditions as deemed necessary by the review committee, to ensure that the overall planning intention for any specific is not compromised.

- Prohibited use: uses that are deemed prohibited and include activities that have been found to be incompatible with the zone. For example, heavy industrial uses are prohibited within the residential zones.

(Master Plan 2050, zoning regulations).

Principles guiding the zoning requirements (Master Plan 2050, Zoning regulations):

(i) Integrated Development and Urban Resiliency:

The integrated approach to urban development promotes appropriate growth of cities; ensure sustainable mobility, communities that are more cohesive and a better environment. By looking at the City in a holistic fashion, it strengthens the urban resiliency.

These zoning regulations enhance this approach and help to build the resilience of Kigali providing adequate tools and measures to guide the growth of the City as an urban system, where all infrastructural, institutional, economic, and social components are taken into consideration.

(ii) Inclusivity and community involvement in the planning:

Inclusivity and equity in the planning and development process help create more sustainable cities with people getting the right to fully participate in every aspect of social, economic, political, and cultural life and voice their concerns and aspirations to create thriving neighborhoods and communities.

All developments, shall consider the needs and aspirations of all groups, including vulnerable group and people of all abilities, in the design and implementation process. A participatory and bottom-up approach shall be followed involving and engaging the community in the design, development, and monitoring process.

(iii) Incrementalism and flexibility:

The principle of incrementalism is adopted in these zoning regulations to allow communities, investors, and developers to develop according to their current financial capacities. The objective is to create a flexible environment where all developments happen in an organic manner, without creating financial overexposure and hence hindering the affordability of the development. At the same time, the incremental approach is designed in such a way that future addition to the development would help achieving the desired density for the specific zone in future years. Incremental development also allows developers to better adapt to current and future market conditions, thus reducing investment risk and facilitating access to the market to a larger segment of the population. Incremental development shall be an opportunity to limit ongoing informal development processes and ensure efficient provision of infrastructure and service delivery and rational land use.

(iv) Mixed land use:

As a capital city that is experiencing unprecedented urbanization and population growth and a shift in lifestyle preferences, Kigali displays itself as a prime location to support integrated neighborhood development. Further, the national policies, strategies and various meetings also advocate replacing the current low-rise unplanned settlements into high-density mixed-use developments that caters for affordable multi-family housing. The zoning regulations allow and encourage integrated and mixed-use development within all zones to create higher density, compact and vibrant places for people from all groups and neighborhoods. Neighborhoods shall highlight a blend of residential, commercial, cultural, public facilities, and micro-enterprises, that are accessible and well connected to transit system. This will enhance inclusivity, bring work closer to homes and reduce disparity and social segregation between different groups.

(v) Pedestrian first:

According to Joe Chestnut "Cities around the world are recognizing how essential walkability is for the access, health of their citizens and the economic growth of their cities"[6].

In Kigali, the private vehicle ownership is still in lower limits and majority of the population are either pedestrians or two-wheeler users. This provides a great opportunity to plan for a walkable and healthy City. All planners, designers and developers shall ensure walkable and integrated neighborhoods that links residences to the public facilities, commercial and recreational areas. The Master Plan provides for the City to expand its Non-Motorized Transport (NMT) network to cover the entire City for

[6] Pedestrians First: Tools for a Walkable City (https://www.itdp.org/publication/walkability-tool/)

complete, continuous, and safe walkway and cycle way networks that provide clear protection from motor vehicles and are accessible to people of all groups. Universal designs shall be adopted by removing all physical barriers and providing a safe route for smooth mobility and easy access.

(vi) Transit Oriented Development (TOD)

Transit-oriented development[7] (TOD) presents as the best approach for Kigali to continue keeping the private vehicle ownership on the low, and to avoid unsustainable, car-dependent, and sprawling settlement. TOD is necessary for inclusivity, equity, and long-term sustainability of the cities. The integrated and transit-oriented development bring people closer to activities, work, home, and public space, providing inclusive access for all, to citywide opportunities and resources at the lowest financial and environmental cost, and with the highest resilience to climate change and other disasters. The City shall provide high quality, safe, and reliable mass transit system for a sustainable and equitable development. Mixed-use, integrated, and higher density developments that are well connected with easy walking and cycling connection and in proximity to reliable transit service to the rest of the city are at the base of this master planning effort.

(vii) Sustainable design:

All developments shall be designed and developed with due regards for the environment by incorporating environmentally friendly and sustainable practices in both design and construction of the buildings. It shall be of paramount importance to encourage environmentally responsible buildings that are appropriate for the existing urban fabric.

Subject to review and evaluation of developments in certain zones, and in line with GBMC[8] minimum compliance scoring criteria, the city of Kigali may grant increases in additional floor area, building height or building coverage. This special consideration would be granted for developments that adopt sustainable design technologies or techniques or provide additional benefit to the neighboring communities such as public spaces or recreational areas.

3.3.3. Emphasis on Green Growth

As Kigali city develops and grows in urban areas, there is a continued effort to enhance the greenery, biodiversity and heritage. There have been concerns that Kigali city is developing too rapidly and it is losing its greeneries and historical heritage. The revised master plan looked at those

[7] Transit Oriented Development (https://www.itdp.org/library/standards-and-guides/tod3-0/)

[8] Rwanda Green Building Minimum Compliance System (https://www.primature.gov.rw/index.php?id=2&no_cache=1&tx_drblob_pi1%5BdownloadUid%5D=695)

concerns to incorporate a balance by a sustainable growth. Since the global competition have become very high, the master plan leaves an open door for reinvention and creativity to beautify the overall city fabric in order to continue moving forward and staying relevant.

Urban green spaces provide ecosystem benefits to cities, ranging from maintenance of biodiversity to the regulation of urban climate. However, throughout the implementation of the expired master, urban development have often given rise to dramatic changes in urban land use. In some areas, there have been removal of the natural green caver and replaced by built-up areas, replacing natural surfaces with impervious built-up surfaces and hence changing the land surface's thermal and radiative properties. The conversion of natural vegetated landscapes into impervious surfaces causes a shift in the urban climate known as the Urban Heat Island (UHI). Consequently, without short to long-term mitigation measure, Kigali city inhabitants would be exposed to environmental hazards and risks.

In the Master Plan, we have put in place various plans. The revised master plan considered building the capacity of individuals, communities, institutions, businesses, and systems within Kigali city to survive, adapt, and grow no matter what kinds of chronic stresses and/or acute shocks they might experience (100 resilient cities, 2017).

3.4. Kigali city transformation

The very first physical plans concerned a single hill, by rectangular grids pattern along the hillcrest and its gentle slopes of the hillside. By that time, all buildings were rectangular shaped single-story. There were four types of walling materials: cement blocks, burnt bricks, mud blocks and wood. Roof shapes varied among three types: gable roof, hip roof and shade roof; covering materials either were asbestos cement sheets or burnt clay tiles.

With more than 80% of the global GDP generated in cities, sustainable urbanization has every potential to contribute to sustainable growth by increasing productivity, while allowing innovation and creativity (World Bank, 2017). While the Rwanda Gross National Income per capita increased three-fold from 2000 to 2017, the share of exports in GDP rose from 6% in 2000 to 18% in 2017 (Turok, 2019). Importantly, GDP has been growing between 6% and 8% annually since 2003, and it on record to be one of the highest rates in the world (World Bank, 2017).

On the social front, there has been significant achievements in social progress. For instance, the proportion of people living below the poverty line decreased from 57% in 2006 to 39% in 2017 (World Bank, 2017).

From the above considerations, the government has embraced urbanization as a vehicle to catalyze Rwanda's transformation from an impoverished rural society to a prosperous modern economy.

Importantly, the modernization agenda has largely focused on improving spatial planning and land-use management for an efficient urban growth.

(1968 photo, source: Kigali city archives, roads network highlighted by the author)

Year 1968
- 1: Main roundabout
- 10 to 18: Commercial
- 38: military academy
- 2,3,4: Administration
- 19: Military and police
- 41: first informal settlement area
- 6,7,8: Residence of high government officials
- 20,21: Catholic schools and church
- 42 and 43: native farmers
- 39,40: school and hospital
- 22 to 37: Planned residences

(Extracts of current situation, author's photos - January 2020)

2020 situation
- 2, 3, 4, 6, 7, 40', 10', 14, 16, 19, 20, 21 : Developed
- 23, 28, 36, 37: mixed use
- 38: University of Rwanda campus
- 2, 8, 40, 15, 17,22 : Demolished for re-development
- 29 to 31 and 33 to 35: combined and demolished for extension of the state house
- 41 to 43: dominated by informal settlements
- 32: central bank
- 10 to 13: Upgradeable business area

Figure 3-6: Kigali city center from beginning until recently

The Kigali City Master Plan 2013 and its revised version launched in 2020 underpins this agenda, detailing proposed land uses and zoning plans to ensure a responsive future urban development. Since master plan implementation, there has been a tremendous transformation of the central business district, as highlighted on Figure 3-6, to accommodate a diversity growing retail business and services as well as increasing pressure of ICT-based enterprises.

Impressive policy measures have been put in place to keep the city of Kigali green and clean. For instance, the city government banned the use of non-biodegradable plastics and designated a day each month for all residents in maturity age to clean the city and the surroundings. Nowadays, there is no litter on Kigali streets because there is a daily city cleaning routine carried out by private companies. In the year 2008, the UN-Habitat awarded its Scroll of Honor to Kigali city for its slum and urban amenities upgrading, particularly for refuse collection and the provision of housing, water and sanitation. In the year 2015, Kigali city was selected as one of six African cities out of 67 cities worldwide for the 100 Resilient Cities initiative of the Rockefeller Foundation. The foundation helps cities to address urbanization, climate change and globalization challenges through infrastructure development that can cope with population growth (UN Magazine, 2016).

Chapter 4 Research Design and Methodology for the Empirical Study

This section details the research design, process and strategies of this study. It also enlighten the guiding principles for the selection of case study precincts, respondents selection as well the reliability and validity of data collected therein. Moreover, this chapter explains the methodologies for data collection their analysis techniques. Two different informally settled precincts eligible for onsite upgradability, as per the Kigali city master plan, are the objects of this study. From the two study areas, we collected data concerning the same indicators but varying in data types (qualitative, quantitative) and analysis methods.

4.1. Research Design and Strategy

This section deals with the conceptual structure within which this research was conducted. According to Yin (1994), "the logic that links the data to be collected and the conclusions to be drawn to the initial questions of the research should be clearly spelt out at this stage of design". Furthermore, he argues, "the purpose of research design is to avoid situations where evidence could be collected but without addressing the research questions in place". Moreover, Kothari (2000) defines a research design as "the arrangement of conditions for collecting and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure".

This research seeks to discover the implication of socio-economic standpoints of informal settlements' households on housing typologies, public infrastructure, services and utilities. A Case study approach is adopted in this study because it is well suited in bridging the gap between the qualitative and quantitative methods (Johansson, 2005). According to Yin (1993), there is a need of emphasizing on different sources of evidence for an empirical inquiry on a phenomenon. Through case studies, a researcher directly interact with concerned respondents while studying a phenomenon. Therefore relying on field realities rather than assumptions. From its introducing part to its core objective, this research is based on a multi-case study with multiple units of analysis consisting on either an individual or a group of people or objects.

By this research strategy, it is possible to compare between the study cases by evaluation of variations and similarities/dissimilarities from the same research indicators. Even if both quantitative and qualitative evidences combine for the whole data set, this study's main approach is predominantly quantitative. On one hand, qualitative evidence was solicited for compiling the general sentiment of the concerned communities about their level of satisfaction for a given public infrastructure, utility or service. On the other hand, quantitative evidences were generated from a structured data collection,

based on specific and standardized units of measurements for concerned survey indicators. Both quantitative and qualitative evidences coordinated together to fulfill targeted objectives of this study from sample areas.

From a combination of variety of documentation, self-observations and interviews to optimize the validity and reliability of the survey outcomes, this study makes it possible to highlight the real-life situations of concerned communities. The exploratory nature of this study enables asking questions on 'how', 'what' and 'why' about a contemporary set of events over which the investigator has little or no control (Yin, 1994). All questions involved in this research converge to pre-defined set of indicators meant to generate scientific-based evidences towards an overall deep and systematic comprehension of the status quo of necessary functions within the study precincts.

4.2. Selecting Case Study precincts

4.2.1. Selection basis

This study was conducted in Kigali, the capital city of the republic of Rwanda. Chapter 2 (2.1 and 2.2) above discusses the general status of Rwanda and Kigali city in terms of informal settlement indicators. As the central hub of administration, industries, trades and ICT services, Kigali city have been a central target of rural-urban migrants since its creation, making it an interesting choice for a study on informal settlements' historical proliferation. According to National Institute of Statistics of Rwanda (NISR, 2017), among the 13 main cities and urban centers in Rwanda , Kigali counts six times the population of the second largest city (Rubavu).

As discussed in chapter one, about 80% of Kigali city population lives in informal settlements, among which 32% were recommended for onsite upgrading and the remaining be relocated. Kigali city is therefore an interesting study site for onsite upgradability of informal settlements.

4.2.2. Guiding principles for study precincts selection

The choice of the study areas was purposive after deliberative viewpoints guided by the main objective of this research. The selected study cases were therefore considered to be of intrinsic interest to this study (Johansson, 2005); as they reveal the historical expansion nature of informal settlements in Kigali city, both in occupancy rates and changes in typologies. A background knowledge and a long experience of the author living in Kigali city, combined to guide the choice of the relevant study areas. Two informal settlements with different locational and historical contexts were selected for this study. Furthermore, the exploratory nature of this study on specific physical and socio-economic

indicators and the influence of the central business district to each area enlightened the selection of the two precincts among many candidate areas. Table 4-1 below compares the two selected study precincts with respect to specific selection guidelines.

Table 4-1: Study areas selection guidelines

Selection viewpoint	Study precincts	
	First (1)	Second (2)
Master plan directives	Onsite upgradable	Onsite upgradable
Settlement history	Aged about a century	Aged about 4 decades
Dwellings density and typologies	Density likely to exceed the acceptable maximums, historic to nowadays typologies	Moderate density, recent decades' typologies
Occurrence in targeted survey indicators	All available	All available
Distance from CBD and its influence on daily life	Adjacent to CBD, host of most CBD's manpower	About 4 kilometers away, mixed low to medium incomes employees and traders.

(Source: author's compilation)

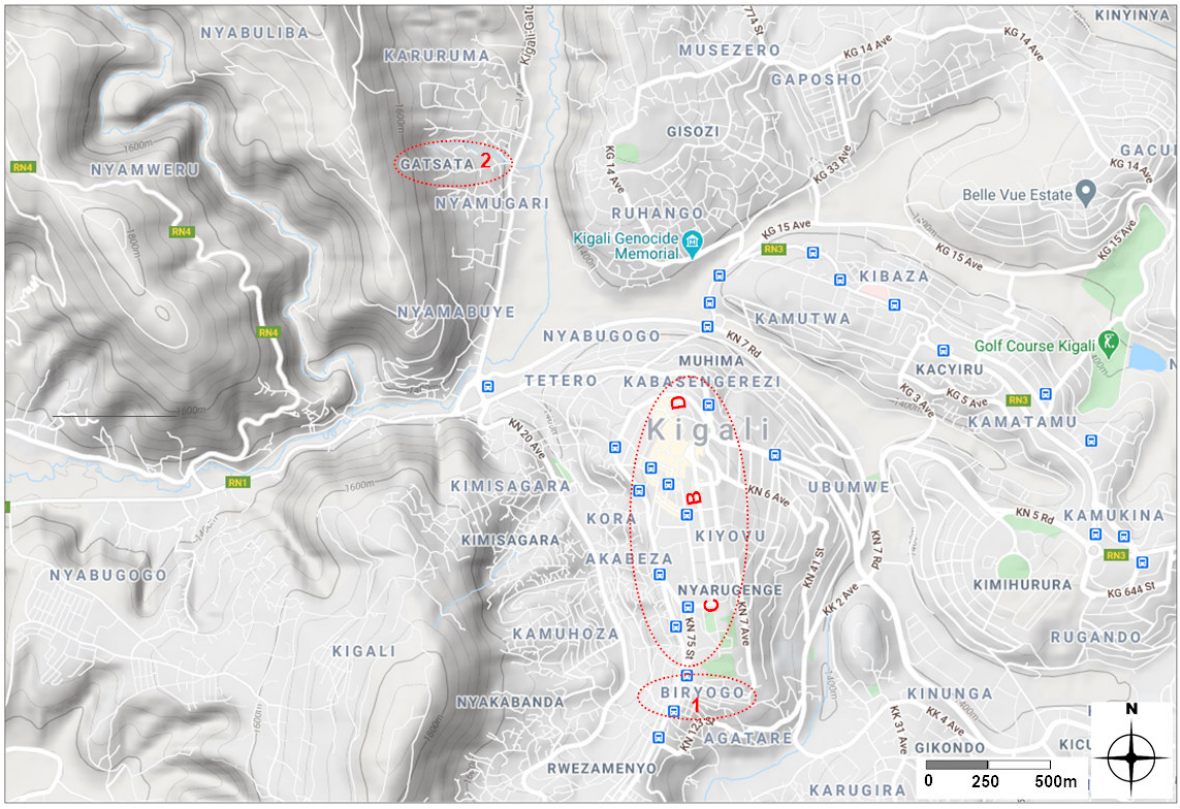


Figure 4-1: Study areas location from CBD (source: Google-terrain image, comments: author)

4.2.3. Fieldwork time framing

The filed work was carried out throughout years 2016 to 2018. Due to time constraints of data collectors, only available half of summer vacation, in addition to limited research budget we anticipated to split the field works within a reasonable time span. However, for research validity, it was made sure that data for a specific indicator be collected within the shortest time possible and without interruptions.

4.3. Methodological approach

This research work output is a result of sequential steps from the idea conception to presentation of results analysis outcomes in writing, the following stages combine to form an itinerary to the final work output.

(1) Formulation of idea concept and brainstorming
(2) Review of previous research results and possible gaps in information
(3) Selecting the case study areas based on pre-assumed research targets
(4) Formulations of questionnaires related thereto
(5) Test field survey
(6) Questionnaires reviews based on field experience, estimation of time and budget
(7) Field surveys and data entry
(8) Analysis of data and documentary evidence
(9) Research outcomes reporting

Inspired by Kothari (2000), Figure 4-2 below illustrates the encountered steps in research design and processing.

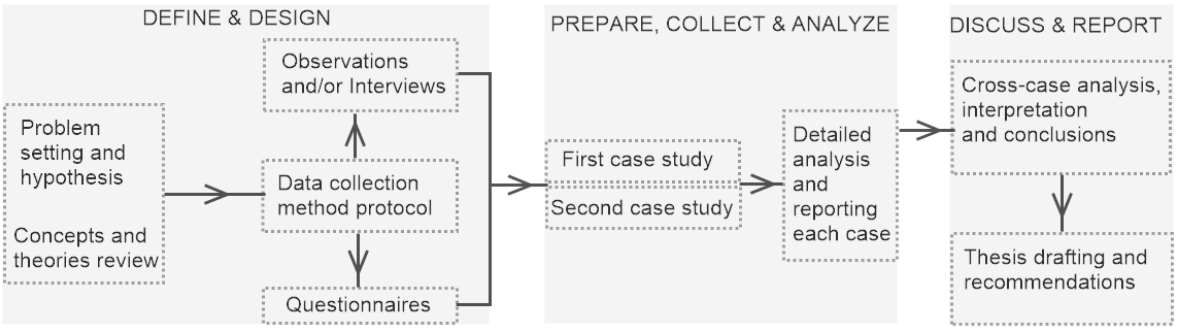


Figure 4-2: Research design and processing (source: author's illustration)

4.4. Data collection techniques from different sources

The overall research findings is a combination of primary and secondary data types, both focused to the context and the meaning of this study's objectives. As the urban poor settlements is a complex issue whose concerns involve in different institutional stakeholders, this approach of data collection stands itself appropriate for a deep analysis of socio-economic conditions of informal settlements inhabitants, representing an overwhelming majority of Kigali city overall residents.

On one hand, by a combination of different techniques of data collection with respect to the targeted groups of respondents and/or interviewees, primary data were collected by either one or more of the following methods:

(i) Questionnaires fill in by households or target institution involved therein

(ii) Physical observations

(iii) Documentary surveys

(iv) Open discussions or systematic interviews with target individuals or groups on specific issues requiring special attention like public services and/or utilities providers, garbage collection companies, local spiritual leaders, to mention but a few.

On the other hand, we obtained secondary information by literature reviews for two main objectives:

(1) Raising the awareness of gaps in common knowledge related to this study's research theme, in order to avoid unnecessary waste of time and financial means by repeating previous similar studies

(2) Supplementing the interviews and discussions with independent sources by a resourceful documentary analysis.

The subsections below discuss the specific reasons behind the consideration of every data collection technique and the specific utility for this study.

4.4.1. Documentary review

Purposively reading the previous research reports on the same study areas and find the gap(s) that requires specific detailed research, for the overall interest of the concerned communities.

While a recent study suggested the on-site upgrading approach (Institute for Energy and Environmental Research, Kigali city and UN-Habitat, 2015); there are no prompt details on key parameters for housing status, accessibility networks and sanitation situation. These three parameters are the most common challenges for the urban poor as highlighted by Joshi Deepa (2020) in a comparative study among informal settlements in Bangladesh, Kenya and India.

The exploratory nature of this study relied only on the existing information records from relevant institutions to make conclusions and recommendations. Therefore, this study spotted those gaps to carry out a research based on fresh feedback answers from concerned communities.

4.4.2. Open discussions or systematic interviews with target individuals or groups

Throughout this research, it was held interviews with different professional public and/or private bodies as well as individuals in their official or personal capacities. Most frequently, the interviews cessions took the form of open conversations beyond well-structured questionnaires. Interviews with key officials in concerned municipalities whereby the study areas are administratively located were considered very useful for this study by revealing the short to long-term plans and proposed solutions to raised problems during interview. Well placed in strategic positions for communities' related surveys, interviewees enlightened the trends of ongoing onsite informal upgrading initiatives. Being involved in the communities' routine challenges, the responses from interviewees complemented the fields' surveys data for generating unbiased data-driven evidences.

4.4.3. Interviews with residents

As a communities' centered study, this research was designed to get the most resourceful information from residents of the concerned study areas, either tenants or owners. In order to give enough time for preparedness to the pre-assumed respondents, it was made sure that they receive the questionnaires printouts at least one week in advance for them to take a good time to read, understand and prepare for relevant responses.

Field surveys encountered some challenges from people who showed little regard to the questionnaires, either asking for incentives or not willing at all to lose their time in responding. However, the strategy of face-to-face interactions to respondents with questionnaires in hands enhanced the response rate and eased the exercise of field data collection.

4.4.4. Physical observations and measurements

In combination with onsite fields surveys, data collectors also carried out physical observations, required measurements as per the questionnaires, mapping and photographing of current situations, as well as any other necessary inputs deemed resourceful to the study's objectives.

These physical collections and measures guided the author to make a data-driven scientific detailing on existing public infrastructures and services like:

(1) Roads quality, width and accessibility distances to households;

(2) Storm and wastewaters drainage systems dimensions and their capability to serve the concerned communities;
(3) Solid and liquid wastes collection and disposal;
(4) buildings sizes, stability and construction materials, plots coverage ratios and densities of dwellings;
(5) Family size and occupancy ratio with respect to available building spaces;
(6) Estimated distances to water sources, public transportation, schools hospitals and other daily routine necessities. To mention but a few.

4.5. Sampling techniques and sample size

Although the data collection technique (as discussed above in section 3.4) is the same for both case study areas, the choice of sampling technique slightly differ case to case for a case guided by the aim and the expected outputs from data analysis.

4.5.1. First case study area

For the first case study area (shown on Figure 4-1 above), data were collected by on-site measurements, observations, and questionnaires. We selected survey samples by stratified random sampling (David Walonick, 2007), whereby we divided the whole population (households) into groups of comparable characteristics. Then, within each group, we selected a random cluster sample, keeping the proportionality between the sizes of samples to the size of the groups. The total number of households from the chosen random cluster samples summed up 401. Because of time and financial constraints, the population was too large to carry out a comprehensive socio-economic survey and analysis of all of the households. Therefore, we applied a statistical methodology for computing the appropriate sample size with help of Yamane's formula (Yamane T., 1973) and we found 200 households as a representative population sample.

Yamane's formula for computing sample size is stated:

$n = N / (1+Ne^2)$

Where:

- n: corrected sample size;
- N: population size (401)
- e: margin of error, e = 0.05.

Applying the above stated parameters into the formula, gives a corrected sample size of 200 households[9].

From first impression, an observation reveals that the settlement structure of the study area have been following a certain clustering order due to historical patterning as well as socio-economic conditions and increasing housing demand. Guided by this observation, we collected data into various numerical variables. Data were collected systematically, starting from the housing characteristics, accessibility situation and finally to sanitation conditions.

4.5.2. Second case study area

Referring to David S. Walonick (2007), the sampling method adopted for this case is the "non-probability sampling". The same as the first study area, data were collected by on-site measurements, observations, and questionnaires. This area have been selected by Kigali city for trial grant of land ownership, prior to the onsite informal settlement upgrading. Therefore, all lands were registered to the legally bound owners in first run of land registration process. This fact influenced the choice of a non-probability sampling method for data collection.

Therefore, each member of the population (each household in the context of this research) has 100% chances of being selected. In other words, each household "must be selected" and survey topics apply for all in the same manner. In this regards, all 217 households (hosting 1508 people) circumscribed in delimited study boundary were surveyed door to door.

4.6. Data analysis

Data analysis seeks to make a sense or scientific evidence out the records from data collection. In this regards, this study varied the methodologies for data analysis in order to understand different phenomenon in the case study areas, prior to drawing relevant conclusions from the facts of a case. With Targeting to answer the research questions and achieve the research objectives, we performed a number of operations for summarizing and organizing collected data in appropriate manner.

Each study case's data were separately analyzed in order to identify unique patterns and interrelationships among the survey indicators for that single case.

[9] After the deletion of cases with missing data, further processing was accrued out with 178 cases with full data for all survey indicators.

4.6.1. First case study

In order to highlight possible relationships among different entities of collected data, we relied to Principal Components Analysis (PCA) to reduce its dimension to a small set that still contains the information in the large set. We took the decision of using the PCA as data processing method after preliminary data examination. Regarding the sample size, the number of observations (178) in this research met the requirement to be factor analyzed. Generally, the minimum is to have at least five times as many observations as the number of variables to analyze, and the more acceptable sample size would have a 10:1 ratio[10] (Joseph F. et al, 2014).

We carried out more advanced statistical tests to assume that enough structure does exist for our data to be factor analyzed. In this regards, we checked the Measure of Sampling Adequacy (MSA) to quantify the degree of inter-correlations among the variables and the appropriateness of factor analysis. We found a MSA of 0.875, qualified as meritorious[11] to carry out our data analysis by PCA. After checking the reliability of analyzing our data by PCA, we instructed the processing software to extract eight clusters based on k-means clustering algorithm as well as the size and characteristics of our data. In this regards, based on rules and regulations of PCA, we extracted four factors and eight clusters that summarize the hierarchical socio-economic settlement formations of the study area.

[10] In this research, the ratio between the number of observations and number of variables is12:1

[11] MSA classification: 0.80 or above is meritorious; 0.70 or above is middling; 0.60 or above is mediocre; 0.50 or above is miserable; and below 0.50 is unacceptable. The MSA increases due to either one of the following: the sample size increases, the average correlations increase, the number of variables increases, or the number of factors decreases.

4.6.2. Second case study

For this case study, as the data per indicator were either qualitative or quantitative or the mixture of both, data processing was done separately for each indicator by an appropriate method with respect to data type. Thereafter, we processed to crosschecking among the indicators of to draw out their interdependency relationships.

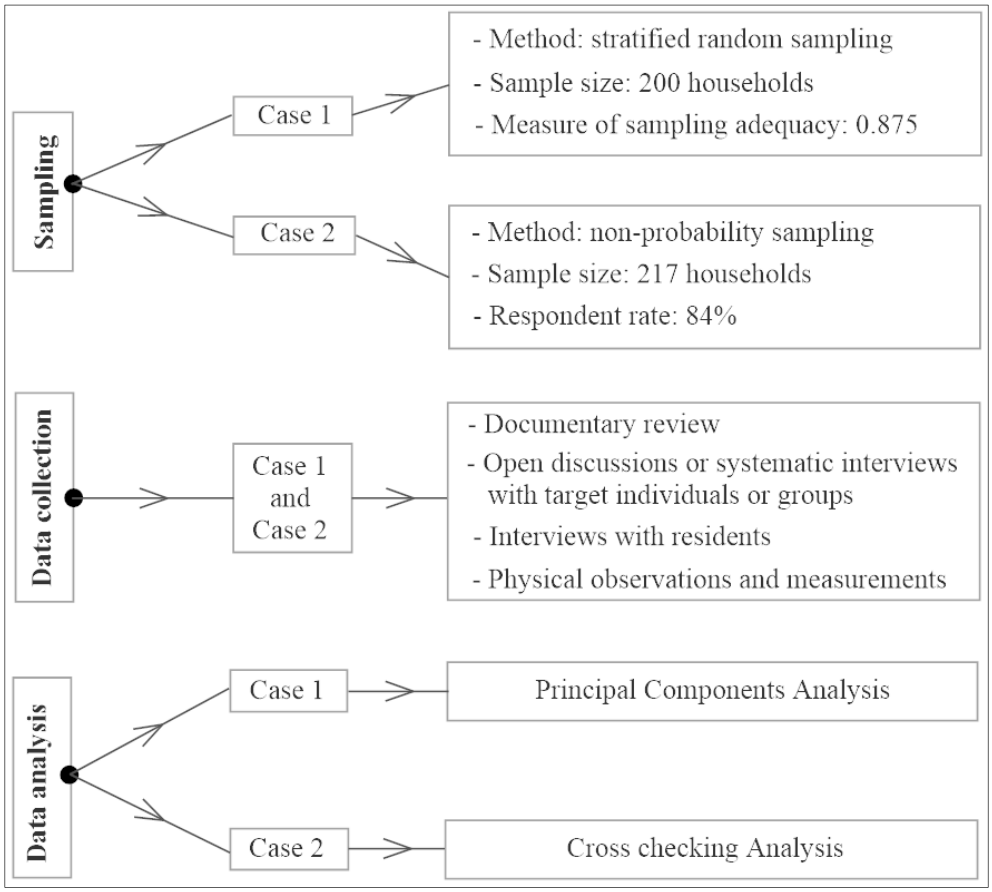


Figure 4-3: Research process flowchart

4.7. Reliability and internal validity

According to Alreck P. and Settle R. (1995), “reliability is taken to be the degree to which the survey results are free from random or systematic error”. For a study to qualify as reliable, its process must be repeatable and prove similar results. Furthermore, Saunders M. et.al. (2007) argued, “The data sources should be critically assessed and ways for their reliability evaluated”. In this research, the selection of study cases were based on valuable reasons and survey indicators involved therein

were based on a consistent scientific significance set on international standards and previous related research works.

Before field works on either case study, it was designed a database compilation formats for a systematic daily entry and storage of freshly collected data. The reliability of the information got from respondents is based on the fact that it was face-to-face collected with spontaneous responses, with ample clarifications of conscious and pre-trained data collectors where some respondents (due to their educational backgrounds) seemed to be confused by some questionnaires terms. For more trust from respondents, native locals, well known and familiar with respondents, assisted data collectors to create a friendly climate during data collection process. Before the final field works, the principal researcher (author) trained the research assistants (data collectors) both in theories in two seminar cessions, and in practice by two trials field work. The two preparedness exercises proved valuable in enhancing the principal researcher and data collectors to map and familiarize with both the research fields realities the respondents' behaviors.

Concerning the internal validation, Saunders M. et.al (2007) argued, "Research findings are about what they profess to be about". Therefore, this study relied on multi-sourced evidence (discussed and detailed in section 4.4) to ensure an internal validity of research findings.

As earlier discussed, the early preparedness cessions both in seminars for questionnaires mastering, and on fields for practical trials, coordinated together to avoid possible deviations from the research objectives.

Chapter 5 Findings from Case Study Areas

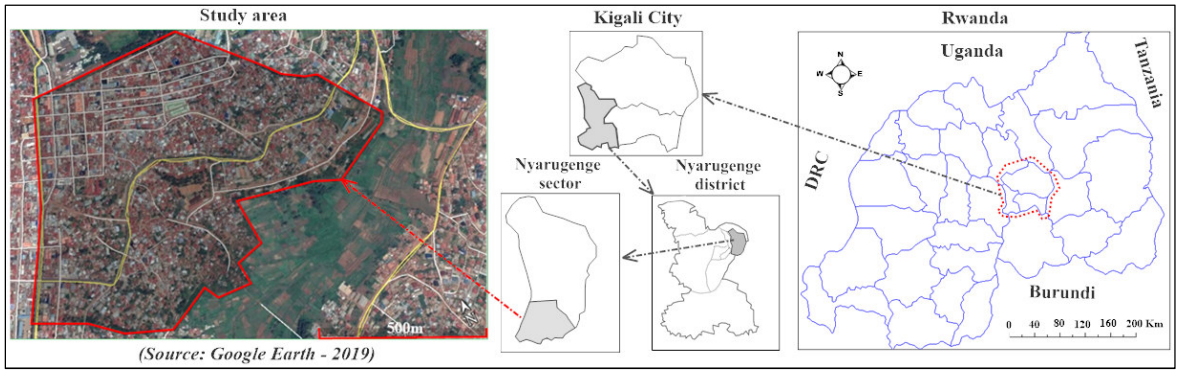
5.1. Case Study Areas introduction

While both case study areas share the same main characteristics of being onsite upgradable informal settlements precincts, they differ from their locational context, historical background as informal settlements, socio-physical features as well their influence on the central business district or vis-versa.

5.1.1. First case study

(i) Background

The study area, whose administrative location is shown on the Figure 5-1 below, is one of the suburbs directly adjacent to the Central Business District. With a density of 4,605 inhabitants/km^2 by 2017 (National Institute of Statistics of Rwanda, 2017), the area is one of the most densely populated in Rwanda[12].



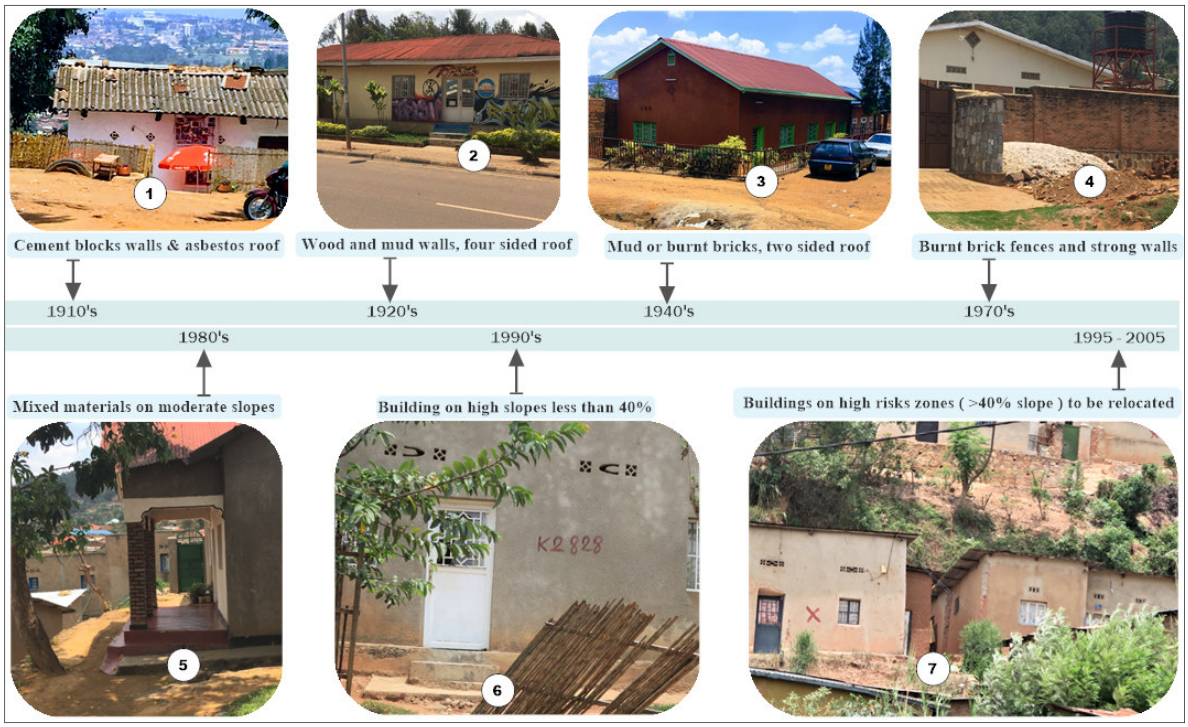
(Author's illustration)

Figure 5-1: First case study area location

Due to its strategical location closer to the central business district, the area was the first informally settled in the history of the Kigali city. Pioneer settlers of the area were local employees of the governing colonial regime, followed later by medium, small size as well informal business traders all buying fractions of lands from native farmers and gradually pushing them away.

[12] According to the National Institute of Statistics of Rwanda, the overall national population density by 2017 was 495 inhabitants/km^2 whereas the density of Nyarugenge sector, where the study area is located, was 4605 inhabitants/km^2 in the same year.

The uniqueness of the settlement history of this study area, from the early twentieth century until a decade ago, is highlighted by a variety of building typologies and materials, as shown on Figure 5-2



(Author's illustration, Source of photos: author's field survey)

Figure 5-2: Building typologies throughout the settlement history

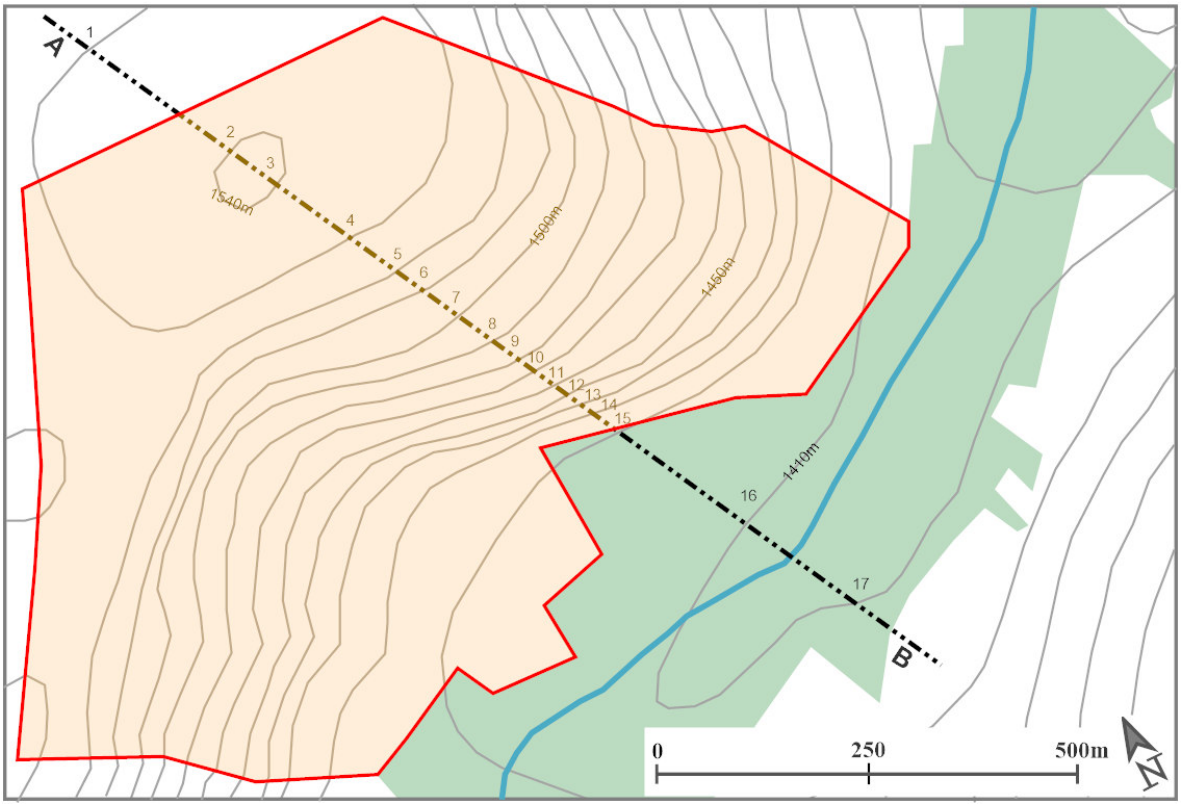
The strategic location of this area led it to become the cradle of unplanned settlements since the early age of Kigali city until recently. Therefore, the precinct's historic unique character motivated our choice for a research sample to understand the complexity of informal settlements throughout the historical evolution of Kigali city.

As it is generalized for Kigali city, this study area has a highly varying topography in elevation above mean sea level (MSL), ranging from 1540 meters to 1410 meters. Figure 5-3 below, shows that most of the buildings (69%) are located on slopes greater than 20% whereas about 11% among them are built on high risks zones[13]. Most of buildings on sloppy ground relates to typologies 5, 6 and 7 on Figure 5-2 above.

Moreover, according to the longitudinal profile from the section AB (Richard, 2004) through the study area (Figure 5-3 below), the high percentage of buildings on high slopes occupy a small area

[13] The Government agencies in charge of human habitat in Rwanda consider the ground slopes of 30% and beyond as high risks zones inappropriate for human settlement.

(from point 7 to 14 of the profile AB, Figure 5-3a below) compared to buildings on flat and gentle slope terrain. Therefore, it reflects a high concentration of dwellings units on sloppy ground than on gentle slope terrain.



(Author's illustration)

Figure 5-3: Topography of first study area

(ii) Existing socio-economic conditions

The study area is predominantly residential with random commercial shops along the access roads and footpaths. Some houses are mix-used as residence and small-scale home-based business, like hair salons, tailoring, boutiques, to mention but a few. While the World Health Organization (1988) suggested the minimum margins for space and density requirements, 78.3% of total plots fall in the range of $200m^2$ – $300m^2$, whereas the remaining 21.7% plots are $300m^2$ and above.

(Source of photos: author's field survey)

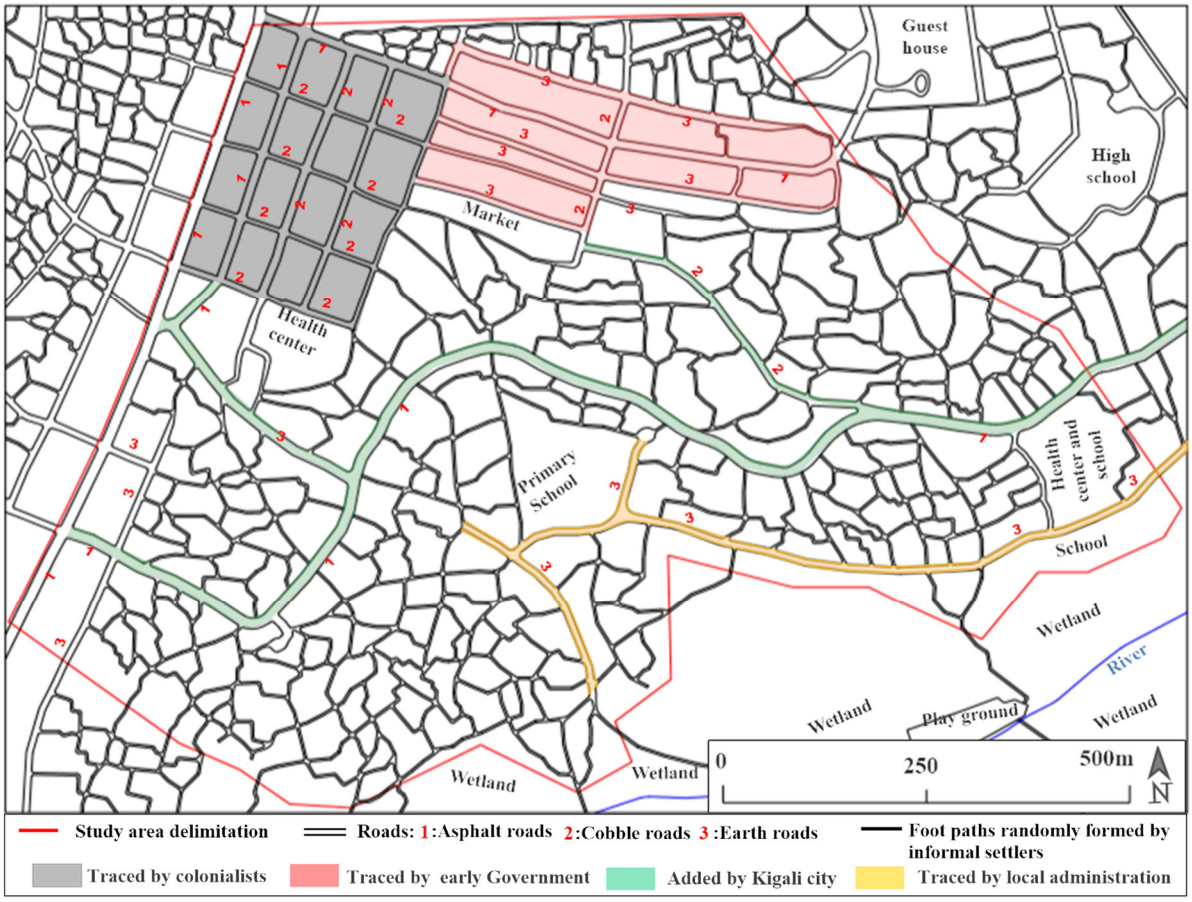
Figure 5-4: Accessibility scenarios in the study area

The wetland at the foot of the study area is dominated by cultivation of short-term crops and dairy farming. Due to the unplanned settlement, 70% of dwellings have no vehicular access, as noticed from Figures 5-4 and 5-5, with poor conditions footpaths eroded by storm water.

Overall, the mobility in the study area is highly dominated by randomly distributed and irregular in size footpaths. Scarce bitumen paved roads are supplemented by cobble paved roads (cheaper in construction cost and easier maintenance but provide low level of service) and earth roads (irregular in sizes, muddy in rain season and dusty in dry season and mostly damaged by soil erosion and runoff water after rain). The current mobility network is a combination of different historical backgrounds. Referring to the Figure 5-5:

- Early colonialists traced the roads network of the zone shaded in black to serve the residences of their servants.

- Early government after the independence created the roads within the red shade, to serve the residences of military officers of the newly nearby built military camp.
- The local government administration created the roads network colored yellow to serve the health center, the two schools as well as the agricultural farms in the wetland.



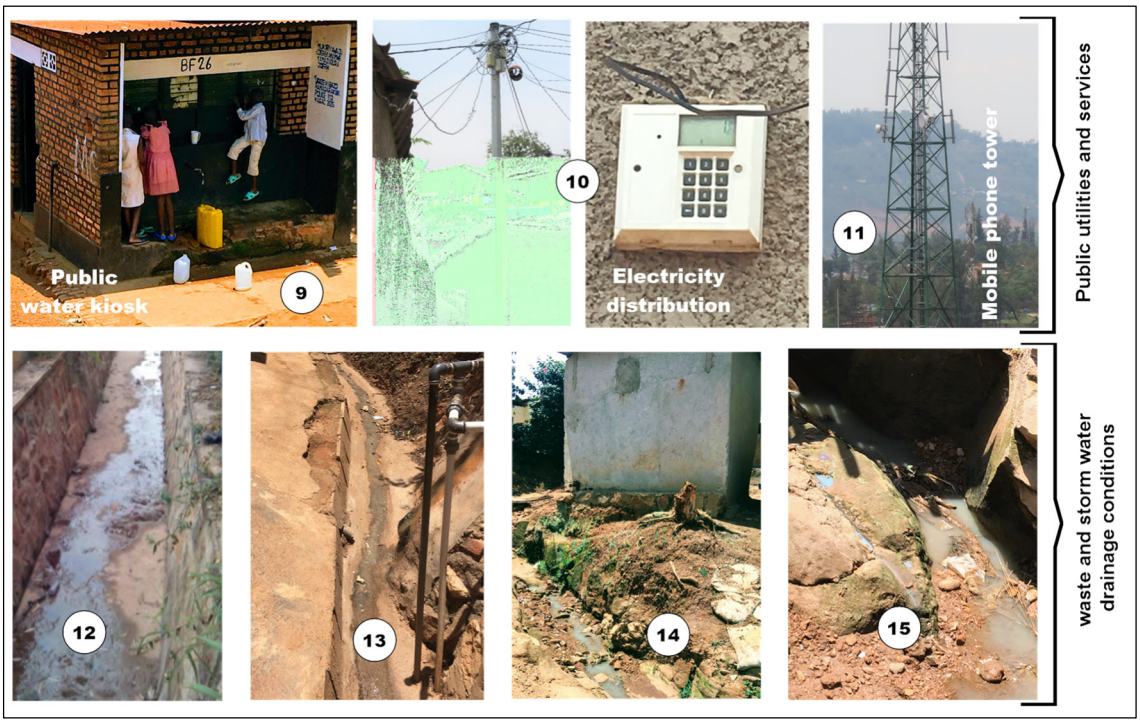
(Author's illustration)

Figure 5-5: Accessibility networks throughout history

- Owing to its ongoing efforts to upgrade on-site the area, the city of Kigali opened the roads network colored green to serve as not only a central distributor corridor, but also easy accessibility to the market and the health center.
- Landowners (residents or institutions) created some short access roads, whereby they dealt privately to buy a strip of land according to availability or the access width needed.

- The irregular and randomized footpaths networks are the direct results of a highly disordered plots layout. The more informal settlers fragmented the precinct, the more footpaths augmented at a high rate, each household struggling to find a way for its accessibility.

Concerning the public services and utilities, the importance of adequate water supply and sanitation services as drivers for social and economic development, poverty reduction and public health, are fully acknowledged in Rwanda's flagship policy documents and political goals.



(Source of photos: author's field survey)

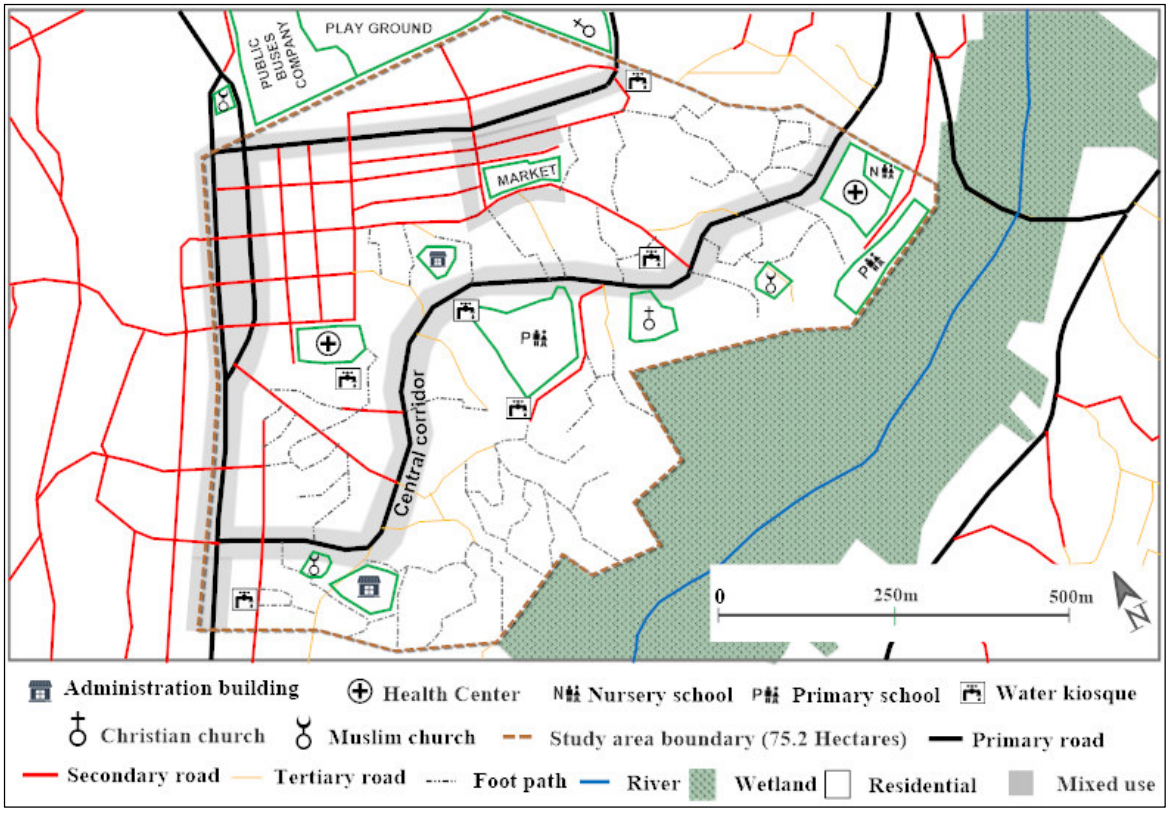
Figure 5-6: Public utilities and services

Throughout the study area, 77.2% of dwellings own private water connection from the main water supply pipe. However, there is a routine daily water shortage and cutoffs and residents mostly rely on public water kiosks (image 9 on Figure 5-6). Other sources of water for domestic use include water vendors, borehole and river water.

Regarding the drainage of wastewater and storm water, only 24% of the total water drainage network is improved. Considering the sloping character of this area, the storm water becomes a big challenge in heavy rain season, causing the soil erosion, landslides and sometimes loss of human lives due to total or partial collapsing of buildings.

About the electricity supply, medium and low voltage electrical lines serve the study area; 76% of residents have access to electricity used mainly for lighting and plugging home appliances like

television, radio, refrigerators and mobile phones charging. However, the lighting does not extend to streets and footpaths most of which are dark alleys after nightfall. This further explains a high level of poor accessibility in the area.



(Author's illustration)

Figure 5-7: Existing socio-economic conditions

Apart from poor access streets and footpaths, residents face troubles to reach their homes when it is dark at night due to lack of public lights and scarce private lights. Moreover, the mobility becomes almost impossible after rain because of high velocity runoff, mostly following the footpaths due to scarce rainwater drainage trenches. Figure 5-6 above highlights the status of public utilities and services in the study area.

Figure 5-7 summarizes the existing socio-economic conditions analysis throughout the concerned area. Apart from their primary functions, schools, churches and mosques yards and/or play fields provide the only public spaces for residents' socio-cultural entertainment and gatherings. In addition to primary routine health services, the health centers organize regular counseling and training on both public health and reproduction health to alleviate both high risks of communicable disease

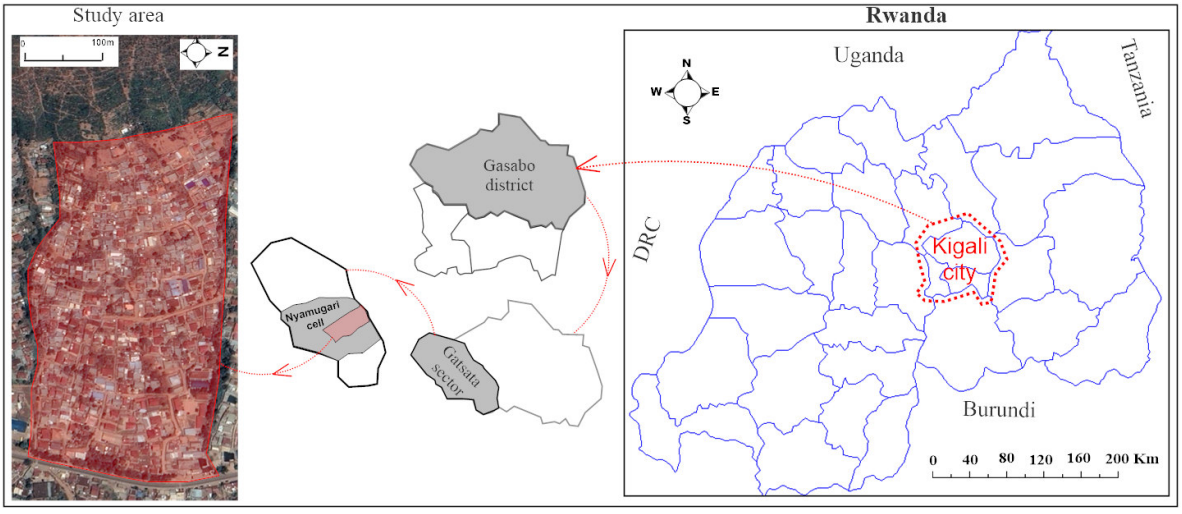
propagation and rapid population increase. Due to frequent water shortage and/or cutoffs, water kiosks supply water to majority of residents.

About the economic standpoint, the study area has three main key actors: (i) the market and its neighboring mixed-use zone are the economic hub hosting various formal and informal businesses like selling clothes and shoes, fresh foods, restaurants, sewing worships, reparation workshops, street garages for cars and motorcycles, to mention but a few. (ii) The central corridor road, with a mixed-use character, is also a host of different income generating activities like neighborhood boutiques selling routine home necessities, shaving saloons, fresh vegetables from the nearby wetland, fast food restaurants, to mention but a few. (iii) The wetland's farms produce different kinds of fresh tropical vegetables in all seasons of the year (in dry season the river's water is used to irrigate the farms). Thereby creating a kind of permanent jobs for farm workers and regular income for farmers.

5.1.2. Second case study

(i) Background

The survey was carried out in an informal residential district located north-west of Kigali city, as shown on the Figure 5-8 below. By the time of creation of the city by Germany colonialists in early twentieth century, the district was left out of the Kigali city's circumscription, devoted to agriculture activities by native farmers.



(Author's illustration, area image: Google Earth)

Figure 5-8: Study area location

In early 1980s, the Government of Rwanda decided to include the district within the Kigali city area. By that time, considerable portion of agriculture lands were already converted into informal

dwelling proliferation sites, due to the high rate of housing demand caused by the rural-urban exodus that followed the industrialization of the city.

The district has been subject of gradually increasing informal settlements since a half-century ago with a considerable decrease within last twenty years, due to the strict prohibition of illegal settlements. A panoramic view at the district reflect a disordered mix-up of building typologies, as referenced of the Figure 5-10 below, ranging from high standing story houses to critical state mud houses (most often highly risky shelters by their structural conditions).

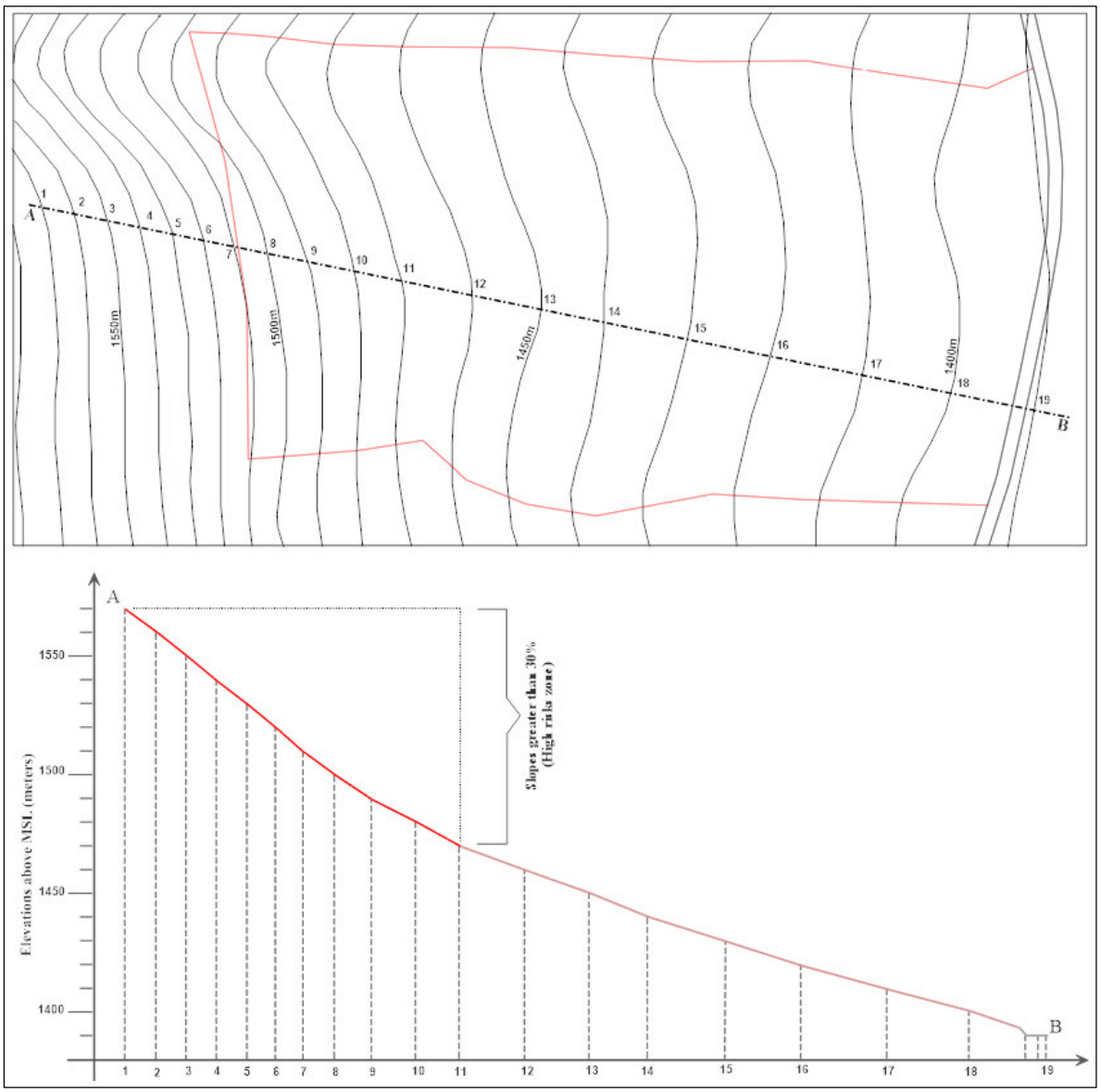


Figure 5-9: Study area topography

As shown on the Figure 5 – 9 above, the district is a foot of a steep mountain and subjected to environmental and ecological degradation, caused by people seeking both construction materials and firewood. These actions contributed to a considerable increase of erosion intensity, sometimes washing away mud houses on its passage.

Nevertheless, despite the above mentioned this study precinct have been selected among the pilots areas for legalization of national wide lands registration campaign. In this context, all portions of lands, either built or not, have been legally registered to owners[14] and a regular monitoring is carried out to prevent further illegal constructions.

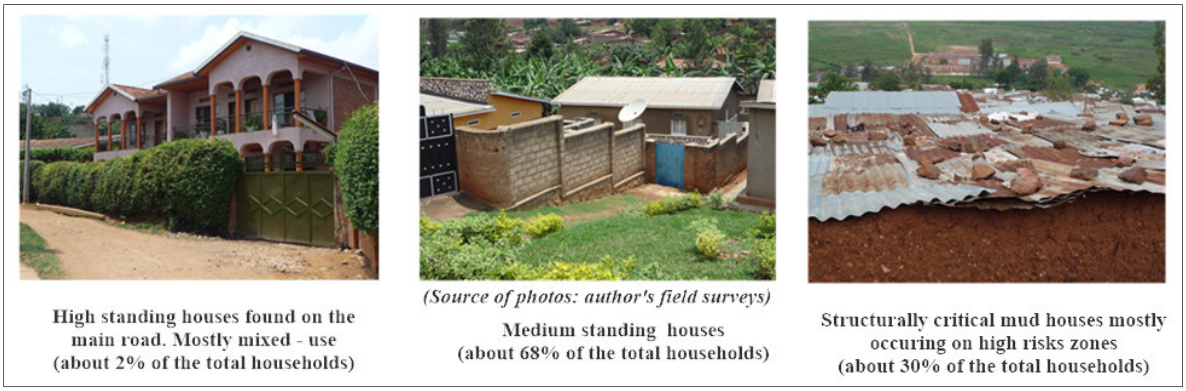


Figure 5-10: Most occurring building typologies

(ii) Existing socio-economic conditions

By the time of the surveys, the district was hosting 217 dwellings totaling 1508 inhabitants. This district has been illegally settled before and after its incorporation within the Kigali city circumscription until two decades ago with a strict law enforcement, prohibiting illegal housing activities.

The district is densely populated with an average family size of five members, with peak sizes up to ten members. Social and economic activities are scarce in the district; the only available nursery-primary school complex is not able to accommodate all children at school age to acceptable minimum pupil/teacher ratio. The district has no official public market apart from unregularly gathering of informal traders mostly vending fresh vegetables and fruits.

Concerning public health, there is only one small health post for primary aids cares. The district location is at high risk of malaria transmission due to mosquitoes bleedings in the nearby wetland.

[14] The land ownership issued is the right to own for a period of ninety-nine years.

Poor hygiene related communicable diseases are also likely to emerge anytime, especially in dry seasons, due to poor disposal of wastewaters.

Sport and leisure facilities are almost inexistent because highly condensed dwellings have left no open spaces for community gathering. Routine socio-cultural and other community assembly take place on the school playground or churches halls depending on their availability.

As highlighted on the Figure 5 – 11 below, the mobility network throughout the district is highly dominated by irregular and unsafe footpaths, whereby motorcars can access only about 25% of individual houses. Service streets are randomly distributed and most of them in critical conditions mostly characterized by irregularity in width, lack of side drainage, poor surface conditions and excessive slopes at some portion causing mechanical failure of vehicles.

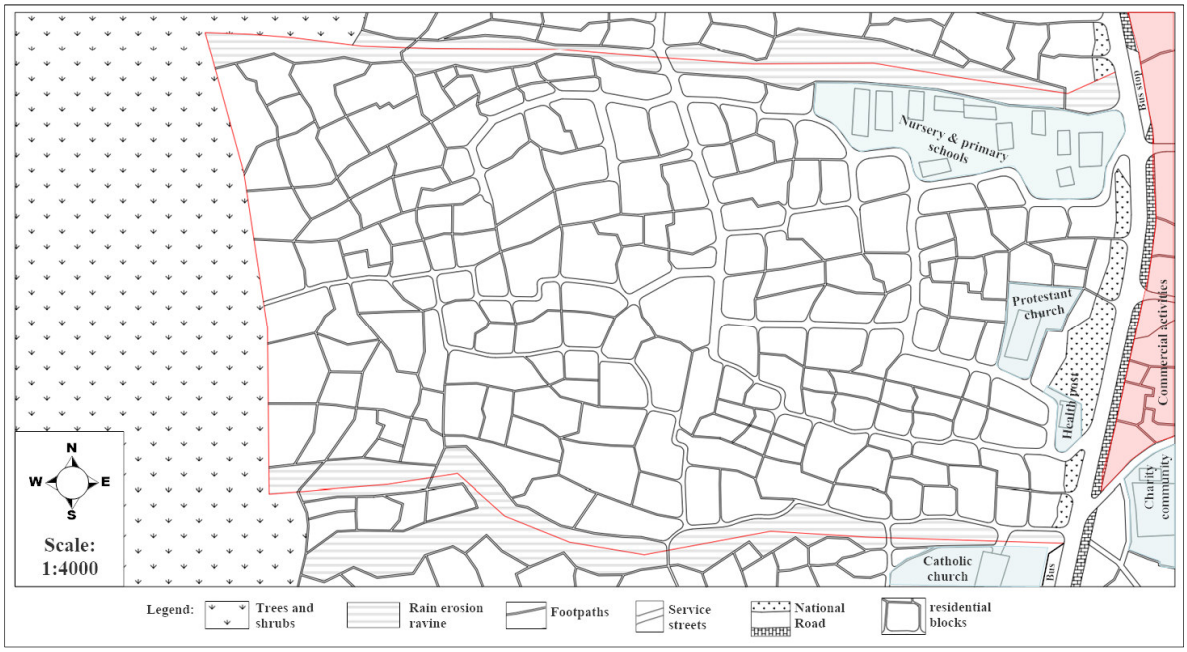


Figure 5-11: Existing socio-economic conditions

In addition to being in critical states due to long time usage depreciations (as shown on the Figure 5-12 below), public utilities such as piped water supply, wastewaters and rainwater drainage system and electricity supply have been overloaded by rapid population increase that far away surpassed the supply capacity.

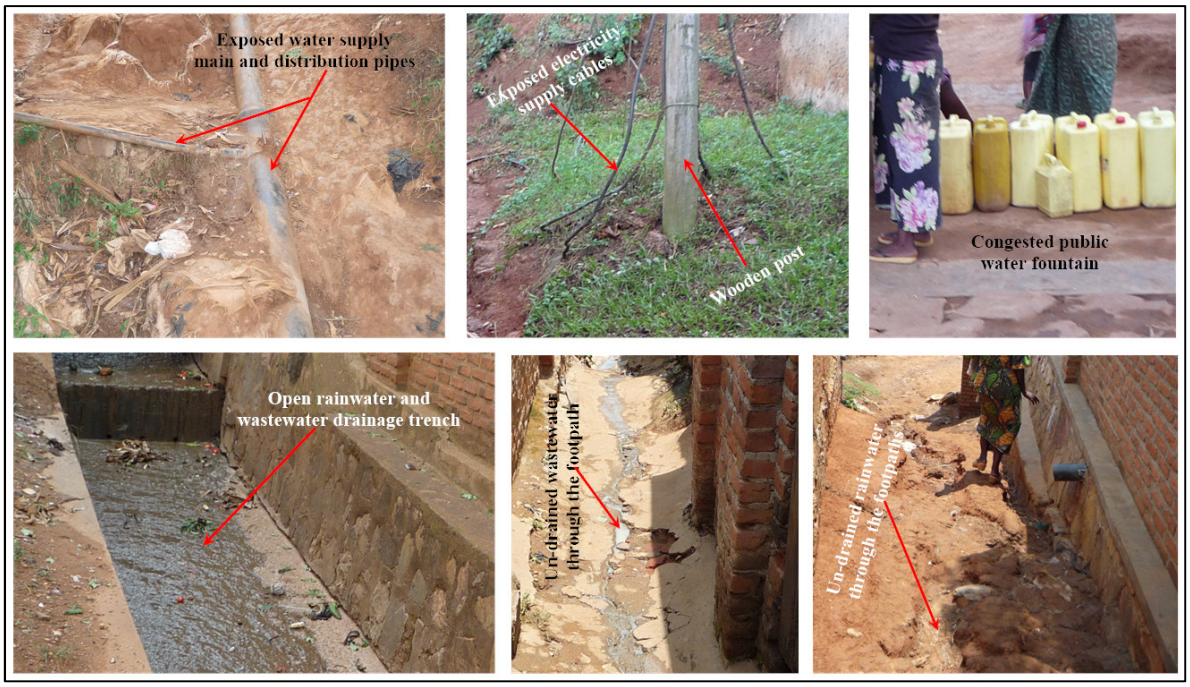
This research revealed that the daily quantity of water for domestic uses is about $34m^3$, representing only one third of the daily needed quantity, according to the minimum acceptable standards as recommended by the World Health Organization. It is also to mention that the district's

water tank storage capacity is nearly half of the daily-required quantity, which makes it impossible to secure enough water storage to serve the community in case of shortage, especially in dry seasons.

Domestic electricity challenges are not only based low connectivity level, but also to low voltage unable to run some useful and routine electrical appliances. According to this research, the main reasons of non-connectivity are related to either financial constraints (69%) or technical problems (31%).

Whereas the district generates an estimated amount of 23m^3 of wastewater daily, there is no adequate system for conveyance and disposal of this daily load. At some points it infiltrates into soil and, after saturation, creates wastewater ponds, which becomes mosquitoes breeding sites. Hence, malaria and much other water bone diseases proliferation.

Considering total solid wastes generated per day in the district, organic wastes (58 m^3) triple inorganic ones (21m^3). However, despite their huge quantities, the disposal of organic wastes becomes easier since good quantity of them is transformed into agriculture manure or fire briquettes.



(Source: author's field surveys)

Figure 5-12: Public utilities status

5.2. Results from data analysis

Housing reflects social, cultural and economic situation of any society and it affects the health, welfare, social attitude, psychological and economic productivity of an individual person (Julia J. Mundo-Hernández, et al., 2014).

Moreover, according to the World Health Organization, there are interrelated dimensions that need to be considered when carrying out a housing analysis (WHO, 2011):

- The dwelling: in terms of its construction, materials and interior quality;
- The immediate built environment including infrastructure and transportation;
- The community: which relates to the social environment, characteristics of the residents and local community services.

Based on the above statements, we collected data related on housing characteristics and its surrounding built environment data in order to understand the socio-economic standpoint of the community in the study areas

5.2.1. First case study

Referring to the main objective of this research for the study area, we collected all data in metric indicators in order to assess possible correlation scales among them. In this regards, we preferred the R-type factor analysis whereby we used the correlations among variables matrix as the basic data input. Table 5-1 below shows the extracted correlation coefficients among variables.

A visual inspection of the correlation matrix reveals that there are enough substantial number of correlations[15] to carry out factor analysis

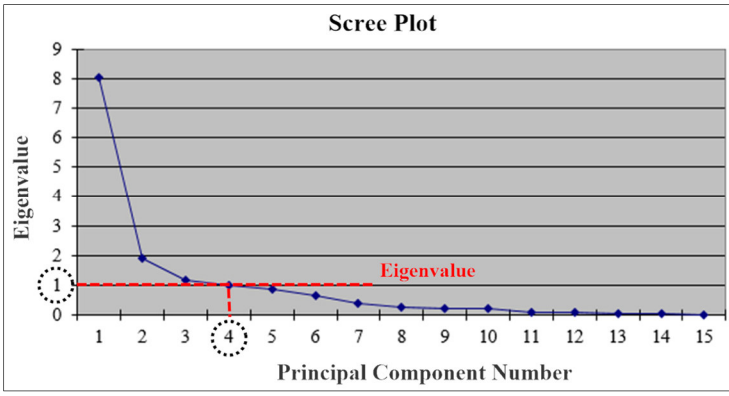
Table 5-1: Correlation among variables

VARIABLES	Open space (%)	Number of trees	Main building area (m2)	Number bed rooms	Family size	House age (years)	Exterior opening (m2)	Foundation depth (cm)	Structuralcracks (No)	Wall width (cm)	Distance to nearest access (m)	Access width (m)	Daily water use (l)	Wastewater/day (l)	Distance to sewer (m)
Open space (%)	1.0000														
Number of trees	0.2324	1.0000													
Main building area (m2)	0.4303	0.1704	1.0000												
Number bed rooms	0.3289	0.1629	0.8940	1.0000											
Family size	0.0556	0.1259	0.1947	0.2151	1.0000										
House age (years)	0.9569	0.1967	0.3436	0.2455	0.0777	1.0000									
Exterior opening (m2)	0.1463	0.1017	0.5071	0.4628	0.0215	0.0974	1.0000								
Foundation depth (cm)	0.3411	0.2193	0.8275	0.7886	0.1829	0.2699	0.4723	1.0000							
Structuralcracks (No)	-0.3821	-0.1695	-0.7396	-0.6781	-0.1385	-0.3340	-0.4063	-0.8099	1.0000						
Wall width (cm)	-0.2965	-0.1512	-0.7487	-0.7195	-0.1346	-0.2389	-0.4459	-0.8530	0.7411	1.0000					
Distance to nearest access (m)	-0.2745	-0.1391	-0.6897	-0.6540	-0.1497	-0.2245	-0.4018	-0.7224	0.6726	0.8709	1.0000				
Access width (m)	0.1570	-0.0164	0.5845	0.5644	0.1232	0.1224	0.3631	0.5339	-0.5412	-0.7382	-0.8240	1.0000			
Daily water use (l)	0.2578	0.1209	0.6335	0.5977	0.1276	0.2255	0.3824	0.5771	-0.5633	-0.7771	-0.8627	0.8045	1.0000		
Wastewater/day (l)	0.2405	0.1288	0.5922	0.5667	0.1274	0.2157	0.3660	0.5529	-0.5373	-0.7457	-0.8348	0.7874	0.9785	1.0000	
Distance to sewer (m)	-0.2661	-0.0983	-0.6545	-0.6064	-0.1105	-0.2142	-0.3847	-0.6707	0.6559	0.8013	0.9283	-0.7650	-0.8084	-0.7806	1.0000

[15] According to the book entitled "Multivariate Data Analysis, seventh edition" by Joseph F. et al., the visual inspection should reveal enough substantial number of correlations greater than 0.30

(i) Extraction and naming of factors

Figure 5-13 below shows the scree test's plot whereby only four factors have eigenvalues greater than one[16] and explain a cumulative variance of 80.68%. These factors will represent the structure of the variables in the analysis.



Total variance explained

Component	Eigen values		
	Total	Variance	Cumulative
1	8.049611	53.66%	53.66%
2	1.894089	12.63%	66.29%
3	1.152478	7.68%	73.97%
4	1.005826	6.71%	**80.68%**

Figure 5-13: Number of factors and total variance explained

Shown below, in Table 5-2, are factors loadings. They indicate the degree of correspondence between the variable and the factor, with higher loadings making the variable representative of the factor, therefore helped in naming the factors.

Table 5-2: Factors loadings

Variables	Components			
	1	2	3	4
Open space (%)	0.431456568	0.839953531	-0.275686591	-0.031530977
Number of trees	0.200033683	0.365662991	0.320406613	0.345094527
Main building area (m2)	0.865897879	0.136988192	0.256581663	-0.151445496
Number bed rooms	0.821306133	0.059315597	0.318964637	-0.118801367
Family size	0.195402036	0.077527226	0.423218554	0.742890472
House age (years)	0.369890486	0.846311177	-0.32681334	0.015944773
Exterior opening (m2)	0.52800384	-0.053819063	0.301072965	-0.408099261
Foundation depth (cm)	0.854618671	0.079850977	0.321723332	-0.145746665
Structuralcracks (No)	-0.808842684	-0.126843139	-0.186009044	0.149773306
Wall width (cm)	-0.918186895	0.103614789	-0.027869012	0.037120827
Distance to nearest access	-0.920668405	0.190299783	0.154209667	-0.097241174
Access width (m)	0.802233527	-0.321511635	-0.247151268	0.09138235
Daily water use (l)	0.867807887	-0.219324182	-0.287688042	0.166977249
Wastewater/day (l)	0.841180106	-0.225985101	-0.300931104	0.189674704
Distance to sewer (m)	-0.875088696	0.18832593	0.180569501	-0.057357942
Factors	**Better housing conditions**	**Old houses in large plots**	**New houses in poor conditions**	**Big families houses**

[16] With component, only the factors having eigenvalues greater than one are considered significant; all factors with eigenvalues less than 1 are considered insignificant and are disregarded.

Table 5-3 shows the clusters scales and their average values to principal components.

We decided the clusters names based on careful check of all factors loadings, starting with the first variable on the first factor and moving horizontally from left to right, looking for the highest loading for that variable on any factor. We repeated the process and checked all eight clusters loadings to the four factors.

A visual check on Table 5-2 above shows that:

- The component 1 has higher positive loadings on following variables: building area, number of bedrooms, foundation depth, access width as well daily water used and wasted. All these conditions reflect large strong houses with good accessibility to public utilities and services. This component is mostly composed by new modern houses owned by high-income people.
- Component 2 records higher positive loadings on open space and house age variables; this denotes the character of old houses built on large plots. This component is characterized by old style houses mostly built in large plots during colonial period by local colonialists' employees.
- Component 3 shows a moderately high negative loading on house age as well as on public utilities and services. These conditions reveal newly built informal houses in located in areas with poor public infrastructures and services.
- Component 4 has the highest positive loading on family size and records too small positive loadings to public infrastructures and utilities. Moreover, this component loads mostly negative to plot size and building area as well as house structural stability.

The variable "number of trees" has neither higher positive nor negative loading on any principal component; this tells us that there have been no orderly or planned trees planting in the study area.

Table 5-3: Clusters' loadings to principal components

Cluster	Scale	Better housing conditions	Old houses in large plots	New houses in poor conditions	Big family houses
		PC1	PC2	PC3	PC4
1	36	-0.882998674	0.47968178	1.187209281	0.321558009
2	18	-1.26551916	0.905403118	-0.495215354	-1.163304813
3	37	3.468158945	-0.572334968	0.157675938	0.554931827
4	18	2.111436654	-1.130141723	-0.891194712	-0.388230135
5	12	-1.086442048	3.109529645	-0.822263567	0.340543212
6	26	-1.95919189	-1.004466027	0.534052379	-0.452027929
7	16	-5.422271469	-1.100662161	-0.861409974	0.637118841
8	15	2.598146234	0.957700069	-0.923586684	-0.447242138

In order to assess the significance of the extracted factors, we checked their normality, as shown on Figure 5-14, compared to the normal distribution:

- The first factor has a flatter distribution and slightly skewed on the left side;
- Factor 2 is slightly skewed on the right side;
- Both third and fourth factor follow the path of the normal distribution graph with some minor deviations.

Therefore, from a statistical standpoint, all the four factors are significant enough for the observed correlations.

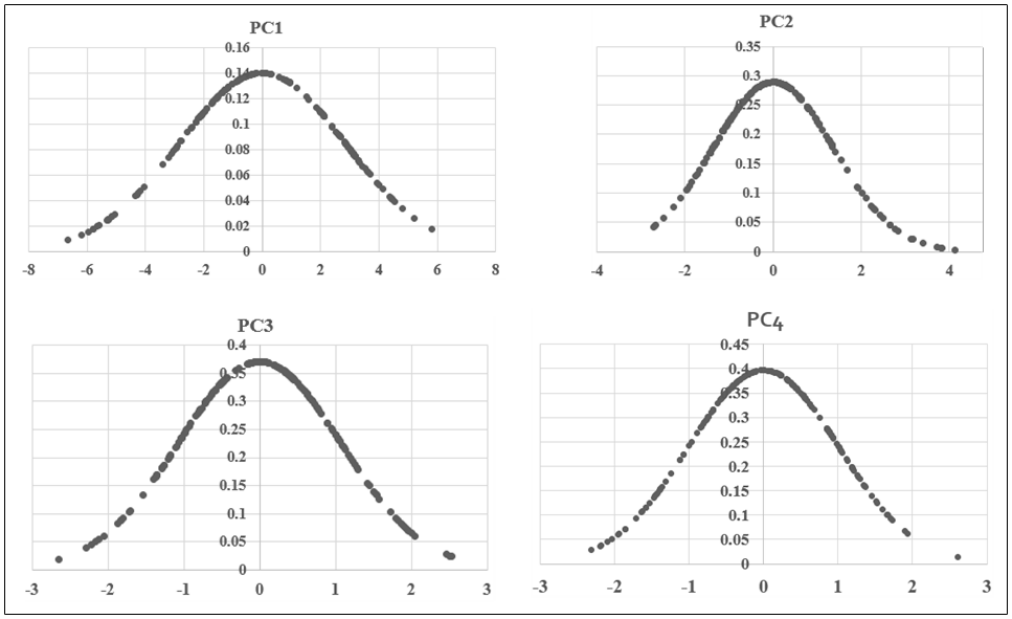


Figure 5-14: Normality of principal components

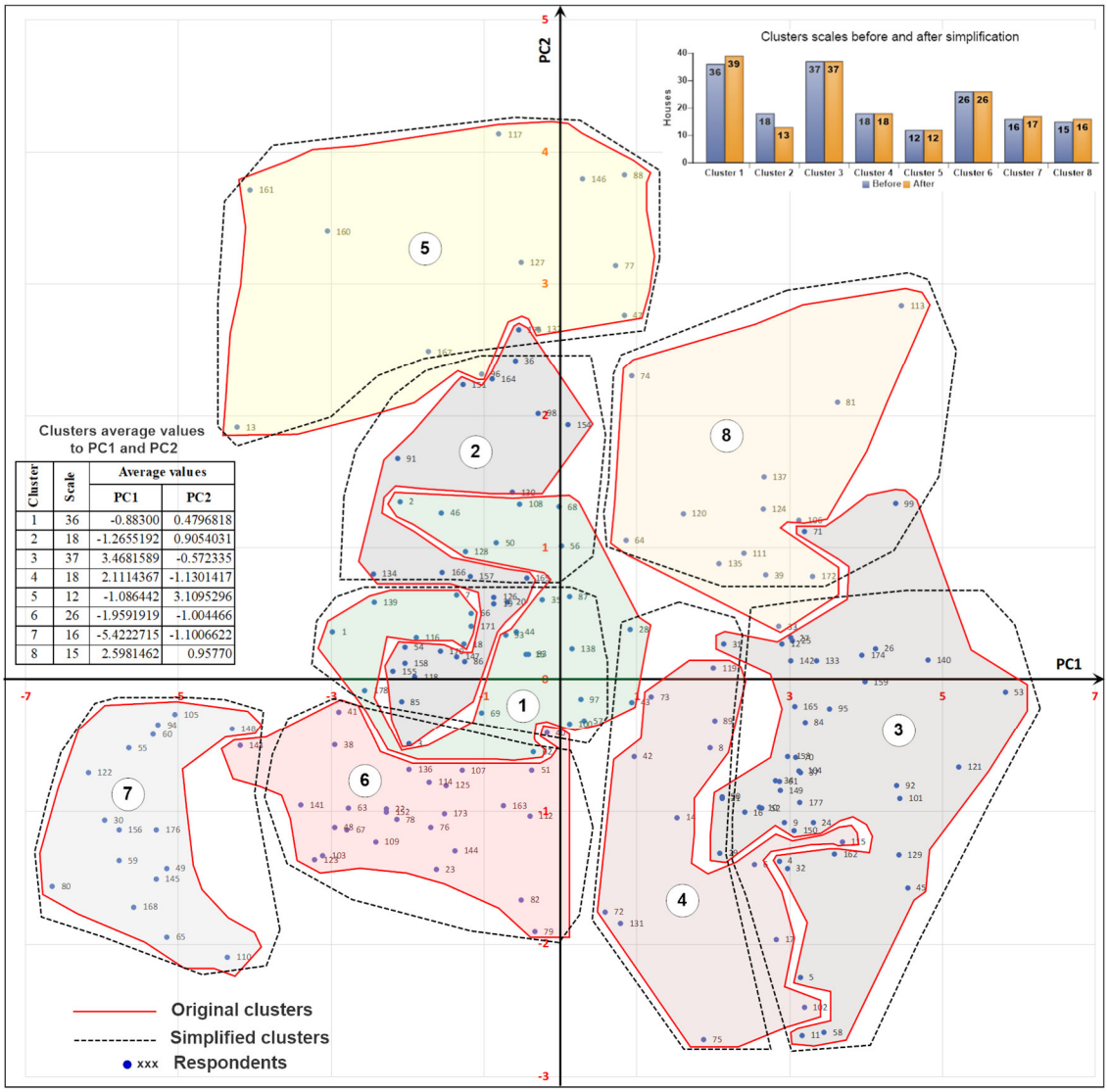
(ii) Determination of clusters memberships

"The primary objective of cluster analysis is to define the structure of the data by placing the most similar observations into groups. The procedure must group those observations that are most similar into a cluster, thereby determining the cluster group membership of each observation for each set of clusters formed" (Joseph F., et al., 2014). In this research, a data processing tool[17] did the sorting of the most similar observations (households) into eight groups (clusters).

[17] Excel Tokei 2006 by SSRI, https://www.ssri.com/co_profile/

Thereafter, we did a scatterplot representation of all 178 observations and we looked at each observation's membership (from the sorting done by the software) among the eight groups to trace what we termed as "original clusters", as shown on Figure 5-15 below.

In order to delimitate different clusters based on different respondent's memberships, we considered their two-dimensional distribution with respect to the first two principal components as illustrated on Figure 5-15.



Cluster	Scale	Average values	
		PC1	PC2
1	36	-0.88300	0.4796818
2	18	-1.2655192	0.9054031
3	37	3.4681589	-0.572335
4	18	2.1114367	-1.1301417
5	12	-1.086442	3.1095296
6	26	-1.9591919	-1.004466
7	16	-5.4222715	-1.1006622
8	15	2.5981462	0.95770

Figure 5-15: Scatterplot of 178 observations (households) based on the 15 clustering variables

Focusing on practical, not statistical, significance and having a sample size[18] greater than 100, also considering significance as the criteria, we can assess the loadings as follows:

- Factor loadings between ± 0.30 and ± o.40 are considered to meet the minimal level for interpretation of structure.
- Loadings ± 0.50 or greater are considered practically significant.
- Loadings exceeding 1.70 are considered indicative of well-defined structure and are the goal of any factor analysis.

(iii) Clusters naming

In order to find representative and meaningful names of clusters, we firstly grouped related variables into sub-sets, each one defining a specific character. Table 5-4 below shows the subsets. After grouping related variables into sub-sets, we calculated the average values of houses sharing same membership to clusters and for all variables. Table 5-5 summarizes the resulted values.

Table 5-4: Subsets of variables

Subsets	Variables		Subsets	Variables
House age	House age		Ventilation and aeration	Building area, Exterior openings
House scape	Open space, Number of trees		Interior comfort	Number of bedrooms, Family size
Construction materials[19] and structure	Foundation depth Structural cracks, Wall thickness		Accessibility	Distance to nearest access , Access width
Sanitation	Daily water use, Wastewater /day, Distance to sewer			

Table 5-5: Average values of clusters' members

Clusters		House age	House scape		Ventilation and aeration		Interior comfort		Construction materials and structure			Accessibility		Sanitation		
		House age (years)	Open space (%)	Number of trees	Main building area (m2)	Exterior opening (m2	Number bed rooms	Family size	Foundation depth (cm)	Structural cracks (No)	Wall thickness (cm)	Distance to nearest access (m)	Access width (m)	Daily water use (l)	Waste water /day (l)	Distance to sewer (m)
Average values	1	12.61	27.07	2.82	70.71	2.93	3.00	6.43	51.07	1.46	25.50	24.75	1.79	82.14	59.29	24.00
	2	20.00	38.94	1.39	62.28	2.89	2.44	3.11	44.72	1.61	25.61	27.06	1.67	72.78	50.56	24.44
	3	15.30	30.27	2.35	84.54	3.51	3.78	6.35	61.08	0.38	22.16	5.78	5.01	192.43	145.95	8.27
	4	12.89	26.72	1.17	74.33	3.06	3.28	4.00	54.44	0.94	22.83	7.00	4.49	172.78	127.22	8.61
	5	37.17	59.92	2.33	62.83	2.58	2.50	5.17	34.58	2.00	26.33	28.17	1.56	83.33	60.00	31.00
	6	5.00	11.43	1.26	59.78	2.87	2.39	4.96	41.96	2.04	25.83	27.57	1.70	70.43	49.78	27.78
	7	3.67	5.60	1.00	39.40	2.07	1.27	4.73	0.00	4.33	29.53	40.73	1.27	55.33	38.67	38.00
	8	28.93	50.47	1.87	81.20	3.40	3.33	4.47	56.33	0.60	23.13	8.53	3.93	162.67	117.33	9.00

[18] Guidelines proposed by the Multivariate Data Analysis book, seventh edition.

[19] In Rwanda informal settlement context, thicker walls refer to wood and mud, whereas thinner wall correspond to either burnt clay bricks or cement blocks.

With respect to our research objectives, we designed a cluster analysis solution to interpret the clusters, understand the characteristics of each one, and develop a name or label that appropriately defines its nature. A cluster being a set of observations with similar predefined characteristics, given names below highlight the general status of households within each cluster with respect to essential functions, as recommended compulsory by the United Nations Human Settlement Program (2010). Those functions are: durable housing, accessibility, not overcrowded, access to improved water, improved sanitation and security of tenure (in case of Kigali city, all lands are legally registered to tenants). In order to classify and name clusters with respect to their average values to variables, we used guidelines values[20] as summarized in Table 5-6.

Table 5-6: Guidelines values for clusters naming

GENERAL GUIDELINES			CLUSTERS CHARACTERISTICS							
			1	2	3	4	5	6	7	8
House age: (years): The age impact depends on the construction materials and the structure conditions			Moderate	Old	moderate	moderate	Old	New	New	old
House scape (building coverage ratio %): 100-70:poor , 69-50:moderate, 49 and below:good			62.9%: moderate	61.1%: moderate	68.1%: moderate	73.3%: poor	40.2%: good	88.2%: poor	94.4%: very poor	49.5%: good
Ventilation and aeration (% of openings to building area): 0 – 9: poor, 10 – 20: moderate, Above 20: good			4.1%: poor	4.6%: poor	4.2%: poor	4.1%: poor	4.3%: poor	4.8%: poor	5.3%: poor	4.2%: poor
Interior comfort (people/bedroom): <2: comfortable, 2-3: tolerable,>3:unbearable			2.1: tolerable	1.3: comfortable	1.7: comfortable	1.2: comfortable	2.1: tolerable	2.1: tolerable	3.7: unbearable	1.3: comfortable
Construction materials and structure										
Wall thickness (cm)	**Foundation (cm)**	**Cracks (number)**								
22-24: burnt bricks or cement blocks, 24.1-26: mud blocks, Above 26cm: wood and mud	0: critical, 30-49.9: shallow, 50 and above: deep	0-1: strong, 1.1-1.9:stable, 2- 3: instable, >3:critical	Stable mud blocks	Stable mud blocks	Strong burnt bricks	Strong cement blocks	Stable mud blocks	Instable mud blocks	Critical wood and mud	Strong cement blocks
Accessibility										
Distance (m)		**Width (m)**								
<10: easy, 10 -20: moderate, >20-30:difficult, >30: critical		<1.8:tiny, 1.8-3.5: narrow, >3.5: wide	Narrow access	Tiny access	Wide access	Wide access	Tiny access	Tiny access	Tiny access	Wide access
Sanitation										
Water/capita/ day	**Wastewater/ family**	**Distance to sewer (m)**								
<20:survival, 20<W<70: good, >70: better	<100:low, >100: high	<10:short, >10: long	12.8 L : survival sanitation	23.4 L: good sanitation	30.3 L: good sanitation	43.2 L: good sanitation	16.1 L: survival sanitation	14.2 L survival sanitation	11.7 L : survival sanitation	36.4 L: good sanitation

[20] Some values are international standards while others are suggested by building codes, codes of practice and/or thumb rules from experience.

After crosschecking the clusters' average values to the standards and/or guidelines, we decided the appropriate name to each cluster as follows:

- Cluster 1: Mud blocks houses on narrow access and survival sanitation.
- Cluster 2: Mud blocks houses on a tiny access and good sanitation.
- Cluster 3: Burnt bricks houses on wide access and good sanitation.
- Cluster 4: Cement blocks houses on a wide access and good sanitation.
- Cluster 5: Old mud blocks houses on a tiny access and survival sanitation.
- Cluster 6: Instable mud blocks houses on a tiny access and survival sanitation.
- Cluster 7: Critical wood and mud houses on tiny access and survival sanitation.
- Cluster 8: Old cement blocks houses on wide access and survival sanitation.

(iv) Distribution of clusters

The pattern on figure 5-16 shows most occurring clusters in different zones of the precinct, which is what we termed as "dominated". From uphill to downhill, there is a high variation in slopes (as previously highlighted on figure 5-3).

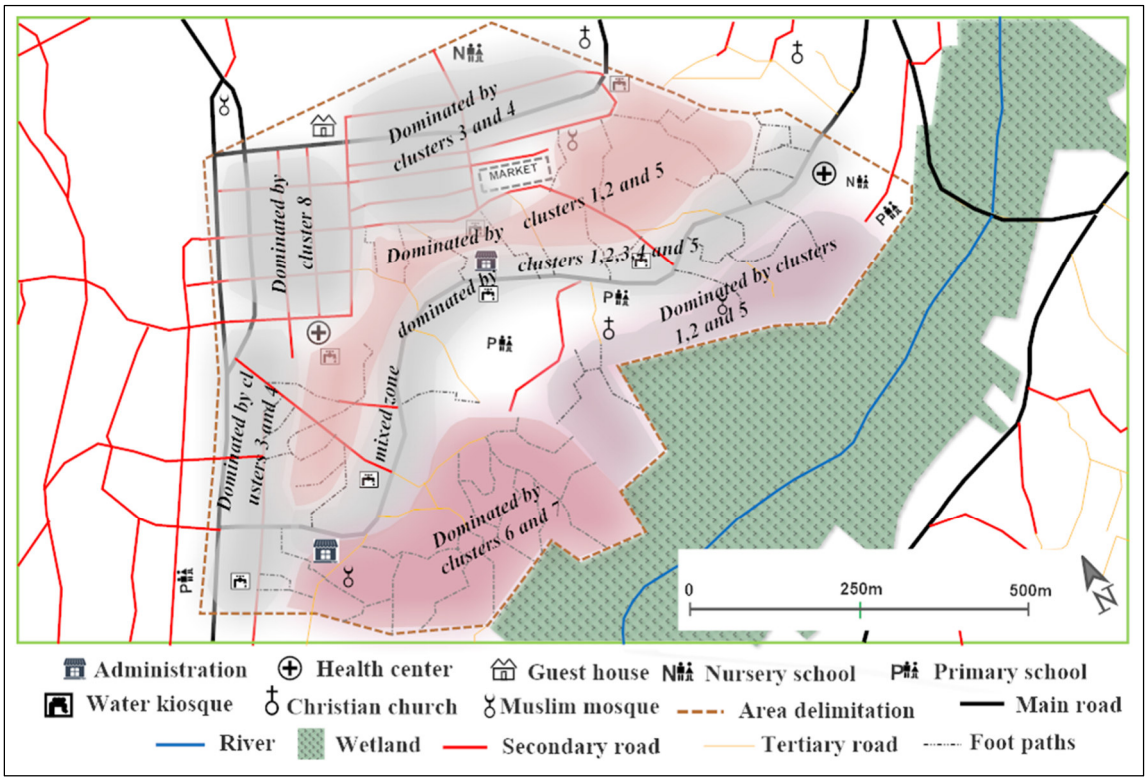


Figure 5-16: Clusters distribution pattern

Historically, the settlement on this area started on flat terrain on the hillcrest along the road from the city center; alongside this road there are still very old building styles built during colonial regime mostly built in cement blocks or burnt bricks and roofed by asbestos sheets.

Due to continuous pressure on residential housing demand, caused by the economic growth and development of the CBD, the land value dramatically increased pushing away low income residents towards steep slopes of the hillside, mostly dominated by mud blocks houses.

Following the itinerary of the main road passing all along the middle of the hillside, there is a mixed use of both residential and commercial building; the land value in this zone is increasingly rising up since the construction of the road six years ago.

The west side zone of the hill towards the wetland has steep slopes, hence settled mostly by very low-income people living in structurally critical houses.

(v) Relating clusters to income classes

By the time of data collection, the Government of Rwanda used to categorize its citizens into six major income classes[21] as described in Table 5-7.

Table 5-7: Major income classes

Income class	General descriptions	Monthly net income range (US dollars)
1	Homeless, beggars, no hope of life and wishing to die rather than living miserably.	Not applicable
2	Living in small and risky houses, no regular job, malnutrition, families with out-of-class children, cannot afford medical care.	Less to 100
3	Living in small houses, informal jobs with little incomes, undernourishment, poorly educated children, poor medical care.	Between 100 and 300
4	Own a low-cost house, can afford children education until high school, can afford basic medical care, have enough income for survival, have some bank savings.	Between 300 and 1,000
5	Own a decent house, run a medium scale business or senior officials with high salaries, can employ other people.	Above 1,000 to 5,000
6	Class 6: Living in villas, owners of factories, industries, commercial and/or consultancy companies, high-income people who can afford their desired lifestyle.	Above 5,000

[21] Every five years the Government of Rwanda update the classification of all countrywide households into different income groups, based on pre-defined socio-economic indicators.

Apart from income classes 1 and 6, as described above, the study area is a host of the four remaining classes.

Figure 5-17 points out the relationship between the clusters and income classes. The figure highlights the relationships between clusters, as previously named and major income classes described in Table 5-7.

A cluster or group of clusters matches with its corresponding income class, based on housing conditions from both clusters' names and income classes' description.

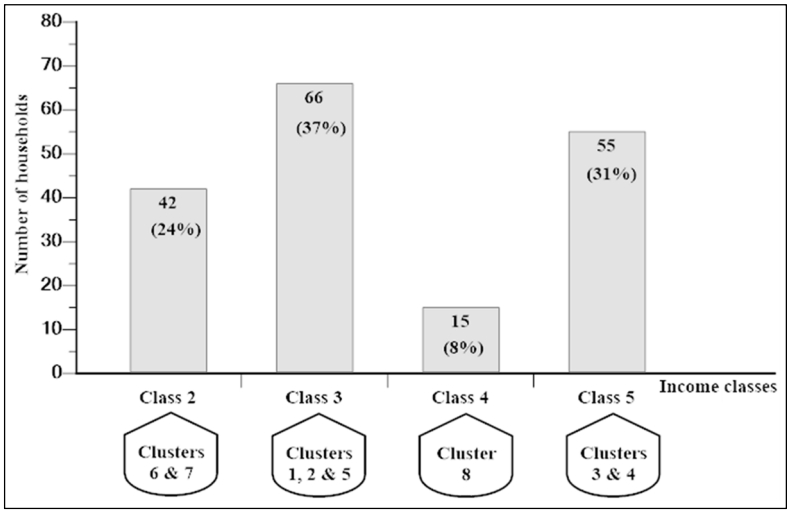


Figure 5-17: Relationship between clusters and households income

(vi) Interrelationships among indicators

Table 5-8 below contains the average values of different clusters to different variables. We obtained these values by calculating the mathematical averages of all members included in a given cluster.

Table 5-8: Clusters average values to key variables

Clusters		Open space (%)	House age (years)	Number bed rooms	Family size (number)	Foundation depth (cm)	Structural cracks (number)	Wall thickness (cm)	Distance to nearest access (m)	Access width (dm)	Daily water use (l)	Distance to sewer (m)
Average values	**1**	27.07	27.07	3.00	6.43	51.07	1.46	25.50	24.75	17.90	82.14	24.00
	2	38.94	38.94	2.44	3.11	44.72	1.61	25.61	27.06	16.70	72.78	24.44
	3	30.27	30.27	3.78	6.35	61.08	0.38	22.16	5.78	50.10	192.43	8.27
	4	26.72	26.72	3.28	4.00	54.44	0.94	22.83	7.00	44.90	172.78	8.61
	5	59.92	59.92	2.50	5.17	34.58	2.00	26.33	28.17	15.60	83.33	31.00
	6	11.43	11.43	2.39	4.96	41.96	2.04	25.83	27.57	17.00	70.43	27.78
	7	5.60	5.60	1.27	4.73	0.00	4.33	29.53	40.73	12.70	55.33	38.00
	8	50.47	50.47	3.33	4.47	56.33	0.60	23.13	8.53	39.30	162.67	9.00

Switching the above tabular values to linear graphs representation, we came up to the scenario shown on Figure 5-18 below.

Clusters tend to group together into different blocks each of them following a regular pattern towards different variables.

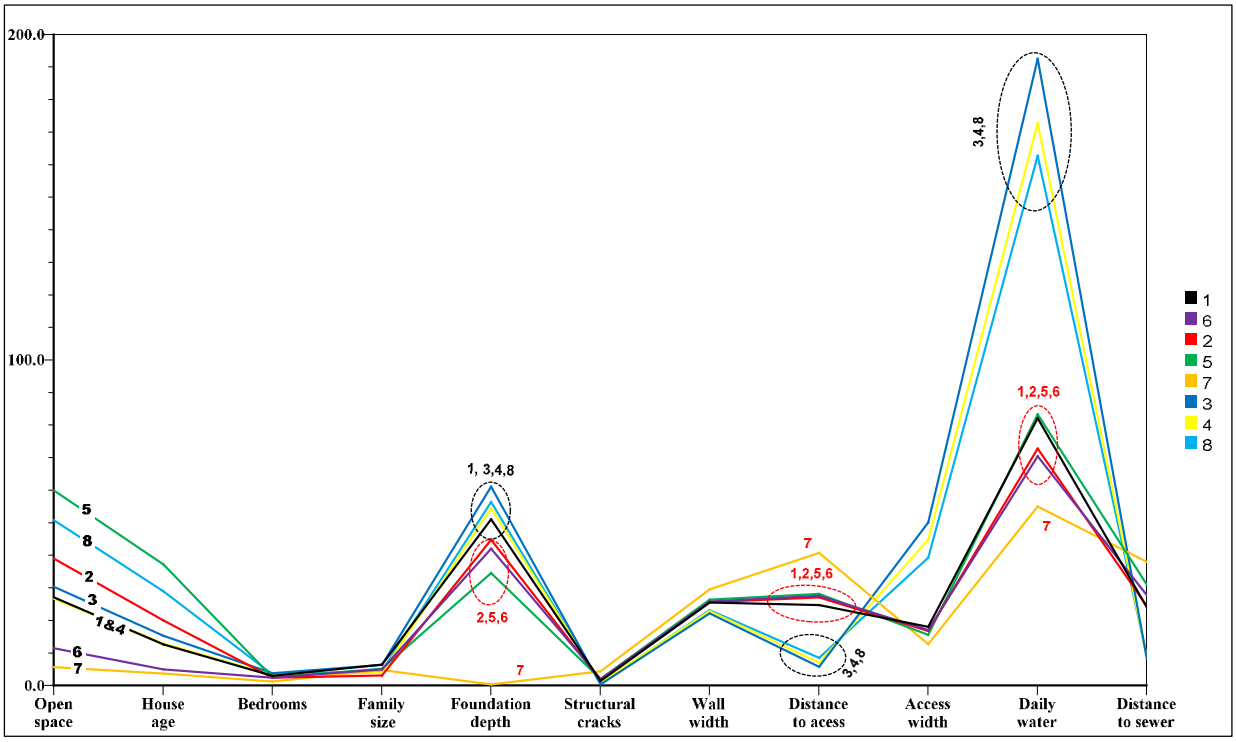


Figure 5-18: Clusters grouping to key variables

From the Figure 5-18 above, old houses (clusters 2, 5 and 8) have larger open spaces whereas newly built houses (clusters 6 and 7) have smaller open spaces. The same figure also shows that the houses in mud blocks built along tiny access (clusters 2, 5 and 6) have shallow foundation and, consequently, bear high structural damages (Table 5-6). In contrast, from the same table, houses with deeper foundation (clusters 1, 3, 4 and 8) present mere insignificant structural damages.

From building characteristics variables, a clear grouping of clusters can be noticed: (3,4,8), (1,2,5,6) and 7 alone.

The groups patterns did not came out by simple coincidence: the triplet of clusters 3, 4, and 8 is mostly composed by houses with deepest foundations, strongest construction materials, located to the shortest distances from the widest roads and using the highest daily water quantity.

The quartet of clusters 1, 2, 5, and 6 mostly composed by houses built by mud blocks on shallow foundation, located a bit far from norrow roads and whereby the daily water quantity is for survival use conditions.

The cluster 7, composed of wood and mud houses without foundation and structurally critical, has a personal behavior of scoring the poorest and mostly critical conditions for both accessibility and sanitation conditions.

5.2.2. Second case study

In this study area, the surveys were carried out door to door and most of respondents were the responsible persons of households, the first questionnaire questions were designed to understand the demographic structure of respondents.

(i) Respondents details

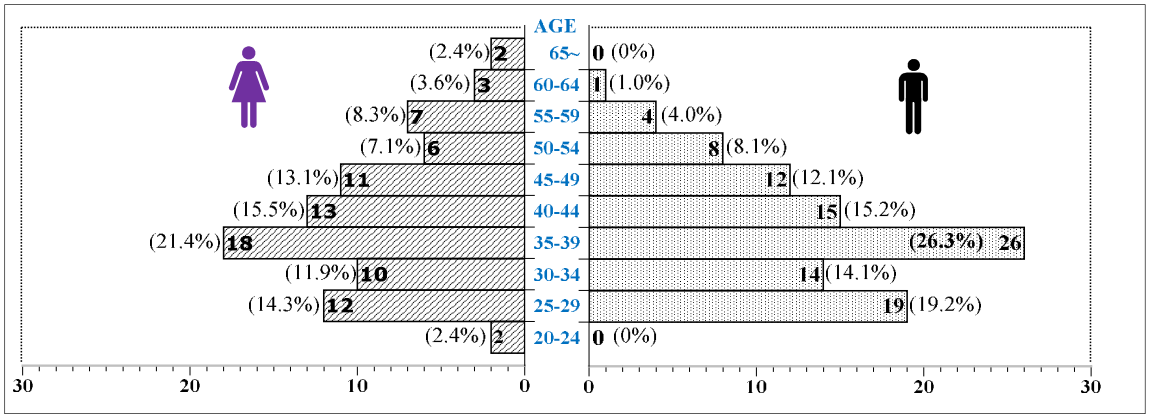


Figure 5-19: Respondent's gender by age

According to Figure 5-19, one hundred sixty four respondents (90%) fall under the age of 55 years; while Table 5-9 shows that the rate of employment of people under the age 55 years (126 out of 166, or 76%) is around three times higher than the rate of unemployment (40 out of 166, or 24%).

From Table 5-9, 95% (174 out of 183) of the district lands are registered to owners; and from the same table, 86% (157 out of 183) lands are registered to active aged people under 55 years. Observation again at Table 5-9 reveals that 80% (79 out of 104) of owned houses fall in hands of middle-aged people under of 50 years old.

Table 5-9: Community statuses by age groups

Age	Employment status		Total
	Employed	Unemployed	
20-24	0	2	2
25-29	26	5	31
30-34	17	7	24
35-39	32	12	44
40-44	21	7	28
45-49	18	5	23
50-54	12	2	14
55-59	7	4	11
60-64	1	3	4
65~	0	2	2
Total	134	49	183

Age	Land status		Total
	Registered	Unregistered	
20-24	2	0	2
25-29	31	0	31
30-34	23	1	24
35-39	40	4	44
40-44	25	3	28
45-49	22	1	23
50-54	14	0	14
55-59	11	0	11
60-64	4	0	4
65~	2	0	2
Total	174	9	183

Age	House ownership		Total
	Owned	Rented	
20-24	0	2	2
25-29	10	21	31
30-34	14	10	24
35-39	24	20	44
40-44	15	13	28
45-49	16	7	23
50-54	12	2	14
55-59	7	4	11
60-64	4	0	4
65~	2	0	2
Total	104	79	183

By combining above results, it is observed that the pressure on housing demand by active aged people has been among main causes of informal dwellings proliferation. In other words, the high rate housing demands and the lack of properly defined housing policies resulted to the high growth of informal settlement.

(ii) Houses structure and interior units

While the foundation[22] is the principal house's supporting structure, Figure 5-20 shows that 67% of houses within the study area are either supported by weak foundations or 'no foundation'[23] at all. Either case is sensitively subject to house damages from simple wall cracks to complete collapse.

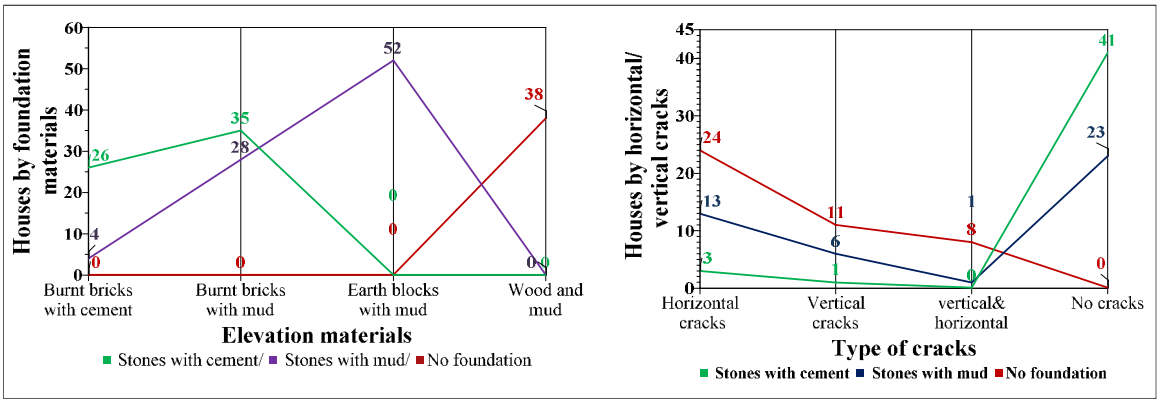


Figure 5-20: Walling materials and structural failures

[22] For simple residential houses in informal dwelling, most common foundation type consists of stones with cement and sand mortar (or mud mortar for low-income people who do not afford the cost of cement). A two cm thick cement layer (or plastic sheet in some cases) is laid between the foundation and wall to prevent foundation's moisture ascending in the wall. Structural failures in foundation are transmitted in the wall, ranging from simple to severe cracks or sometimes complete collapse.

From Figure 5-20, a good number of houses are walled by wood[24] and mud paste. Those houses can relatively stand securely for a time span between 12 to 20 years (T. L. Highley, 1995), after which woods are partially or completely deteriorated by termites and/or other woods damaging parasites, so that the house remains standing only on mud. This fact is proven from the figure, whereby wood and mud walled houses (no foundation cases) present around double cracking values for vertical and horizontal cracks (13 and 6 for blue graph against 24 and 11 for red graph) compared to those supported by stone and mud foundations.

For no foundation houses, the common practice is to sharpen wood trunks at one end and driving them into soil by pressure, or in cylindrical holes dug by manually operated tools. Vertical wood walling trunks are framed together by horizontal wooden sticks by steel nails or ropes. Thereafter filling the framework with mud paste.

From the figure, it is also noted that:

- All houses with stones and cement foundation are elevated by burnt brick,
- 62% of stone and mud foundations are elevated by earth blocks wall and
- All 'no foundation' houses are walled by wood and mud paste.

Referring to the Figure 5-21, more the foundation is shallow or do not exist more walls will crack and vice versa. The same figure also reveals that there are no records of excessive settlements among houses supported by stones with cement foundation type.

It is therefore concluded that a strong foundation acts as a bridge to imposed charges on weak soil locations.

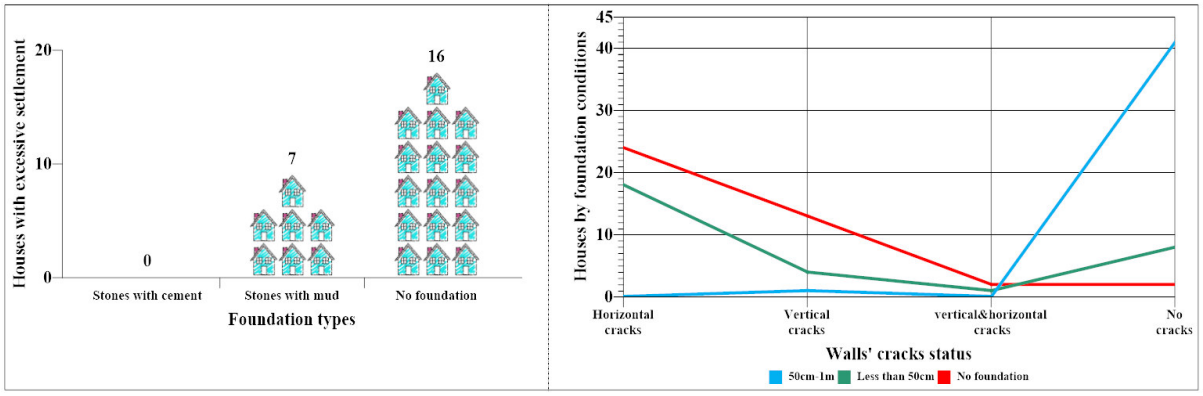


Figure 5-21: Foundation types and structural failures

[24] Wood walled houses have no foundation structure; wood members are sharpened at one end and vertically driven into soil. These vertical members are then linked together by horizontal wood stick by either nails or ropes. This framework is then filled out with mud.

Concerning the interior areas subdivisions, from Figure 5-22, the most occurring bedrooms number is three (3) and, from the same survey, the most occurring family size number is six (6); this makes an average of two people per bedroom.

However, there are some extreme cases where more than three people, as shown by the same figure, share one bedroom.

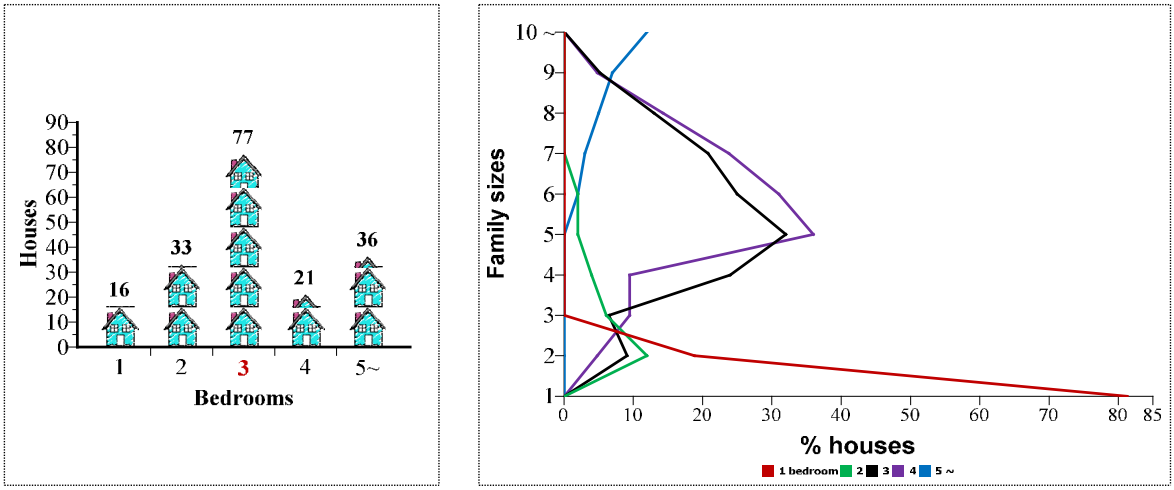


Figure 5-22: Bedrooms per household and by family size

According to Table 5-10, weakly walled and weakly supported houses are the most deprived of kitchen and bathroom units. An explanation to this scenario relies on the fact that those houses typologies belong to low-income residents whose economic standing cannot afford expensive construction finishes of kitchen and sanitary units.

Table 5-10: Households' interior units by construction materials[25]

Contruction materials		Existence of kitchen and bathroom							
		Kitchen				Bathroom			
		YES		NO		YES		NO	
		Number	%	Number	%	Number	%	Number	%
Walling	Burnt bricks	72.0	63.3	3.0	8.1	68.0	71.6	4.0	7.4
	Mud blocks	38.0	33.9	6.0	16.2	23.0	24.2	19.0	35.2
	Wood and mud	2.0	1.8	28.0	75.7	4.0	4.2	31.0	57.4
	Total	**112.0**	**100.0**	**37.0**	**100.0**	**95.0**	**100.0**	**54.0**	**100.0**
Foundation	Stones and cement	40.0	35.7	8.0	21.6	48.0	50.6	6.0	11.1
	Stones and mud	49.0	43.8	12.0	32.4	43.0	45.3	11.0	20.4
	No foundation	23.0	20.5	17.0	46.0	4.0	4.2	37.0	68.5
	Total	**112.0**	**100.0**	**37.0**	**100.0**	**100.0**	**100.0**	**54.0**	**100.0**

[25] The bedroom exists for all residential houses regardless the type of the construction materials

(iii) Classrooms and church halls occupancy rate

Table 5-11 summarizes the results from the interviews held with the school and church leaders. While standards (Kenneth T., 2000) recommend about twenty students per classroom, the table shows that both kindergarten and elementary classrooms count an average of more than fifty students per classroom.

The level of enrolment in kindergarten (only 45% of children eligible to kindergarten age) is still too low, as it should be 100% according to the national educational policy goals. The high enrolment levels recorded in the elementary school the direct results of government decision that made the basic education free but compulsory in order to achieve the education for all, as one of the sustainable development goals. Yet, however, there are still unschooled children despite the national policy.

On the other hand, table 5-6 shows the church density is around 4 persons/m^2; this density is very high when compared to standards that propose a density of 0.6m^2/person for cathedral seating arrangement.

Table 5-11: School and church occupancy rates

Nursery and elementary schools				
Level	Available classrooms	Number of pupils	Classroom size (sq. meters)	Enrolment level (%)
Nursery	12	743	120	45
Elementary	16	832	90	92
Church hall				
Number of believers	Total hall area (sq. meters)		Available seating area (sq. meters)	
1600	500		350	

(iv) Sanitation indicators

Table 5-12 summarizes the quantities for domestic water uses within the study area. By subtracting water used for toilet flushing[26], a quantity of around 23m^3 of wastewater is generated every day throughout the study area. As there is no adequate system for conveyance and disposal of this daily load, at some points, it infiltrates into soil and after saturation wastewater, ponds become channels of waterborne diseases proliferation.

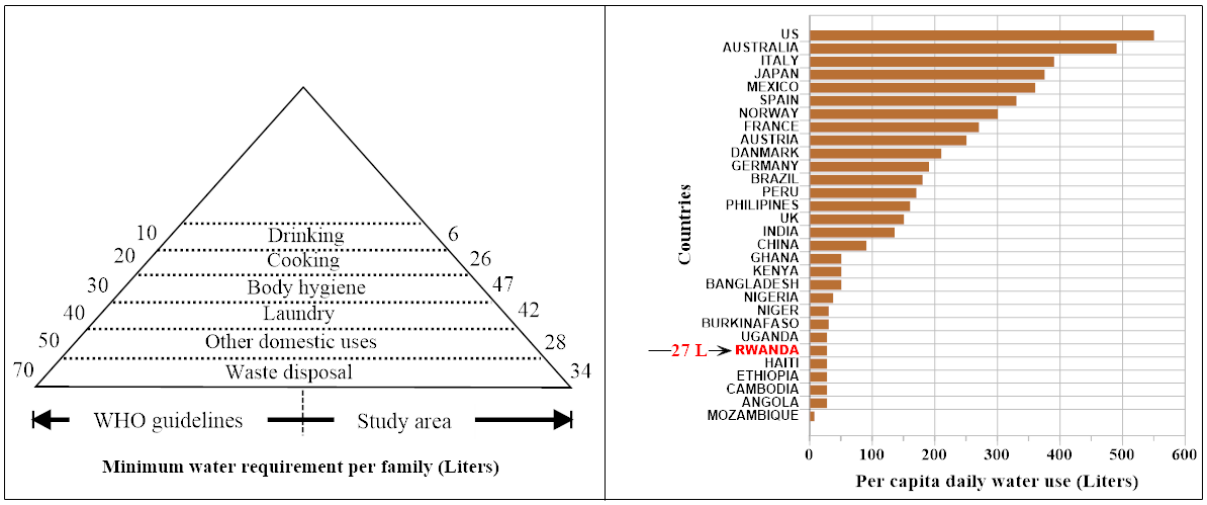
[26] Water flushing toilets throughout the study area work the septic tank system whereby the wastewater infiltrates into soils by soak away pit and the remaining sludge stocks is a separate tank.

Table 5-12: Domestic water use quantities in the district

Uses	Kitchen	Laundry	Bathing	Toilet	Drinking	Other
Quantity(L)	4,840	7,770	8,540	6,190	1,164	5,040
Total(L)	33,544					

Per capita daily water use in the study area is about 22 L, broadly allocated as follows:

- Hygiene: 67% equivalent to 15 liters
- Kitchen and drinking: 18% equivalent to 4 liters
- Other domestic uses: 15% equivalent to 3 liters



(Author's illustration, data source: field survey results, WHO open source data)

Figure 5-23: Daily domestic water use quantities

Considering the minimum water requirements per family as recommended by the World Health Organization (Figure 5-23), and comparing them to those in the district, it is observed that:

- WHO recommends around double quantity used in the district for waste disposal. This big difference rely on the fact most of latrines in the district are non-water type, and water is used principally for kitchen related water demand.
- The quantity of water allocated to domestic uses other than laundry, body hygiene, cooking and drinking is almost half of the quantity recommended by WHO, this is due to the fact that most of informal households do not have gardens and/or other water demanding belongings like swimming pool, cars, animals, etc.

- Water used for body hygiene, laundry and kitchen is slightly higher than the quantities recommended by WHO. The main reason behind is the family size whose average within the district is six (6); hence, increasing water related routine needs.

Further observations at Figure 4-23 show that the average per capita daily water use in Rwanda (27 L, which is among the lowest as shown by the figure) is greater than the study area average (22 L). This difference highlights that the water supplied in the district is far away less than that demanded. The main cause of this alarming situation is an uncontrolled population increase that overpassed the water supply capacity that was initially allocated to few native farmers.

Concerning the solid wastes generated within the study area, they can be grouped in two categories: organic (mostly food related wastes) and inorganic (plastic and metal wastes). Private company workers collect masses of wastes door to door on weekly basis.

From the Figure 5-24, most wastes quantities are organic type and principally composed by food related wastes. The nature and quantity organic wastes generated is subject to vary from time to time depending on the agriculture seasons and most occurring food products on the local market.

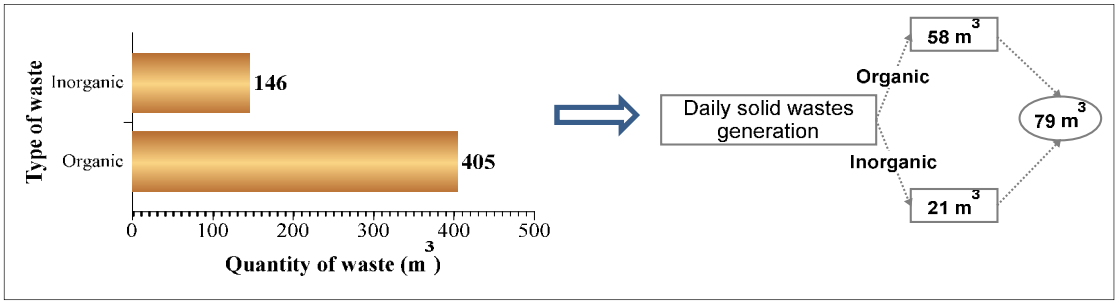


Figure 5-24: Weekly and daily solid wastes generation

Considering the total solid wastes generated daily in the district, organic ones (58 m^3) triple inorganic wastes (21m^3). However, disposal of organic wastes, despite their huge quantities, is easier since good quantity of them is transformed into agriculture manure or fire briquettes[27]. Therefore creating jobs and partially solving a challenging problem of cooking energy.

[27] In order to reduce the deforestation by firewood as the main source of cooking energy, environmental concerned organizations initiated the conversion of organic wastes into fire briquettes that are cheaper in cost compared to traditional charcoal and more environmentally friendly alternative. This technique also prevents extra disposal cost charges of a good quantity of organic wastes.

(v) Public infrastructure and services

1) Transportation

The mobility of people, goods and services is still a challenge throughout the district; existing roads and service streets are not only randomly distributed as shown on the Figure 5-25, but also in critical conditions in most of cases.

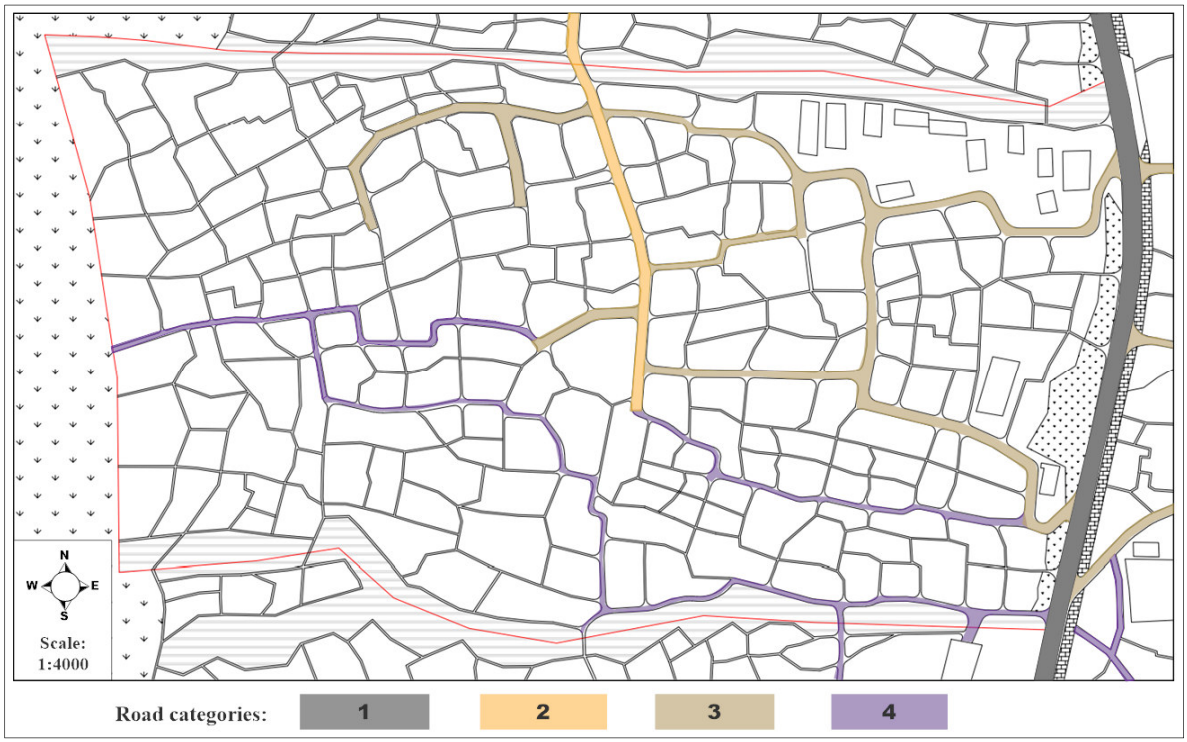


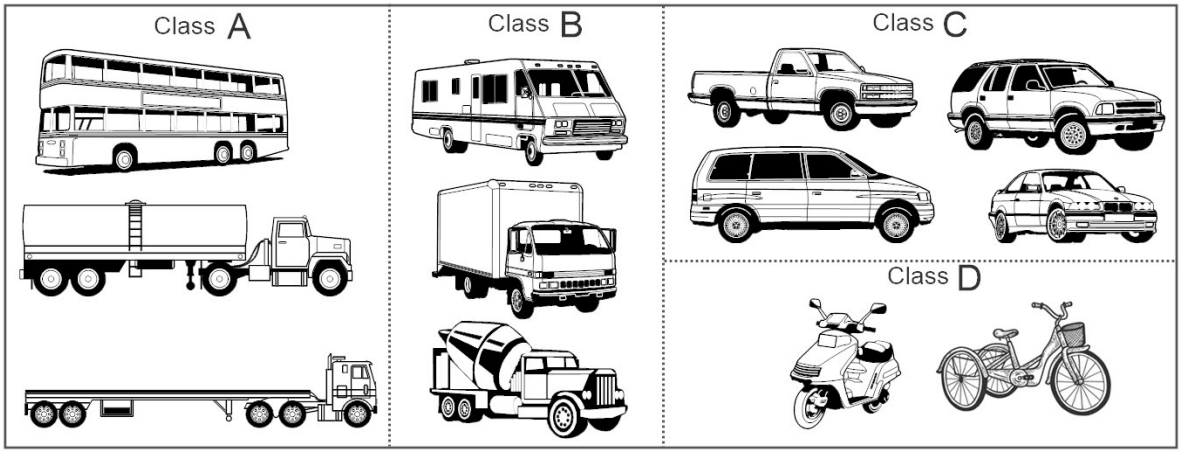
Figure 5-25: Roads and streets categorization

Apart from the national road[28] passing by the east side of the study area, the following features generally characterize the network:

- Snaky shaped
- Dead ended
- Sleepily in rain seasons
- Dusty in dry seasons
- Poor or lack of rainwater runoff drainage
- Sloppy

[28] Commonly known as the "North Corridor" that links Rwanda to Mombasa (Kenya) port

Accessibility by vehicles options throughout the district may be classified into five classes as shown on the Figure 5-26.



(Author's illustration)

Figure 5-26: Vehicle accessibility options

From the Table 5-13 below, following observations are deduced:

- Only one road (the international road passing on the eastern side) can accommodate all vehicle classes.
- Road category 2, which is the only one within the district that can be accessed by buses and service trucks, is the shortest.
- Due to their slopping character, the roads category 3 can only be accessed by passenger cars.
- Roads category 4, which is sloppy and tiny, can only accommodate bikes and short span tricycles.

Table 5-13: Possible traffic matrix

Road categories	Possible vehicle classes			
1	A	B	C	D
2	B	C	D	
3	C	D		
4	D			

As this study area is located a bit far from the central business district, most residents commute by bus for work and other daily routine.

According to this study, from Figure 5-27, daily lost time per capita is estimated below (in minutes) for one way[29] (going to work) basis:

- Travelling time from home to road: 14 minutes
- Waiting time at the bus stops: 28 minutes
- Journey time from bus stops to bus terminal: 25 minutes

According to the above data, lost time per week per capita in opening days is estimated to five and half hours; and by the same logic more than two working days would be lost per month considering the official working time from 7am to 5pm.

Figure 5-27 summarizes the transport by bus related timing issues.

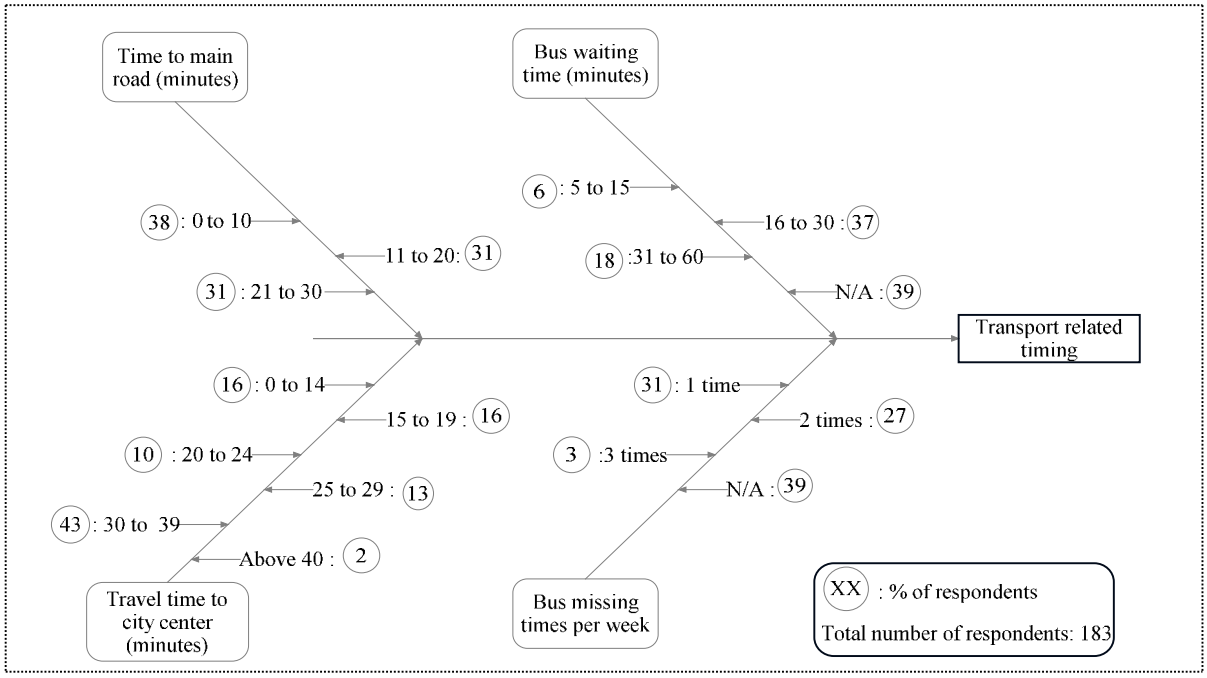


Figure 5-27: Public transport timing indicators

From the above data, lost time per week per capita in opening days is estimated to five and half hours; and by the same logic, more than two working days would be lost per month considering the official opening hours from 7am to 5pm.

[29] One-way basis was considered in time estimating because outside the surveyed district there are many other parameters influencing the time in direct or indirect ways.

Concerning the quality of service delivery in public transportation, the Figure 5-28 summarizes the results of analysis of the four basic indicators, namely:

- The density or crowding rate,
- The frequency or the punctuality of buses,
- The safety to accidents or other related harms,
- The cost.

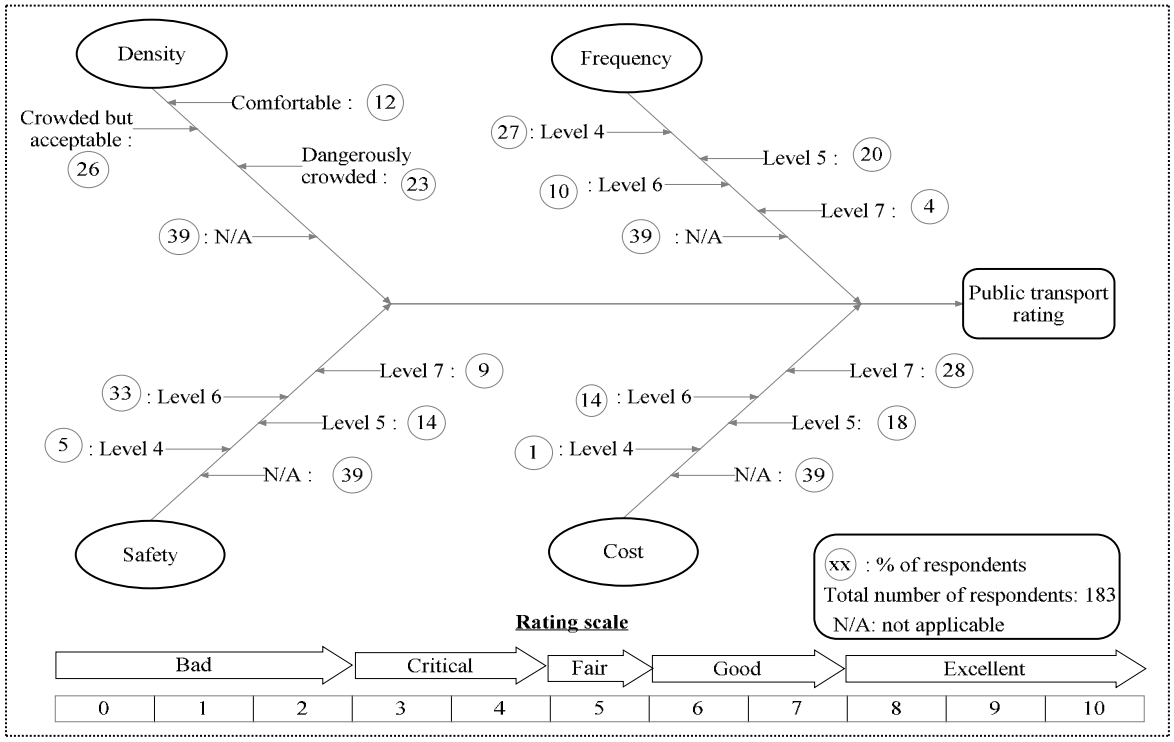


Figure 5-28: Public transport quality rating

The above results on the Figure 5-28 are summed up in the Table 5-14 below. According to the respondents' opinions, the first challenge in public transportation is the frequency of buses, in other words transport service offer is far away to satisfy the demand.

Table 5-14: Public transport services rating

Service	Ratings (% of respondents)					Majority
	Bad	Critical	Fair	Good	Excellent	
Frequency	-	27	20	14	-	Critical
Safety	-	5	14	43	-	Good
Cost	-	2	18	42	-	Fair

The traffic police unit now carefully checks the crowding in buses, which was a huge problem to commuters some years ago. The principle is that the number of passengers (including bus staff) must not exceed the number approved by the insurance company.

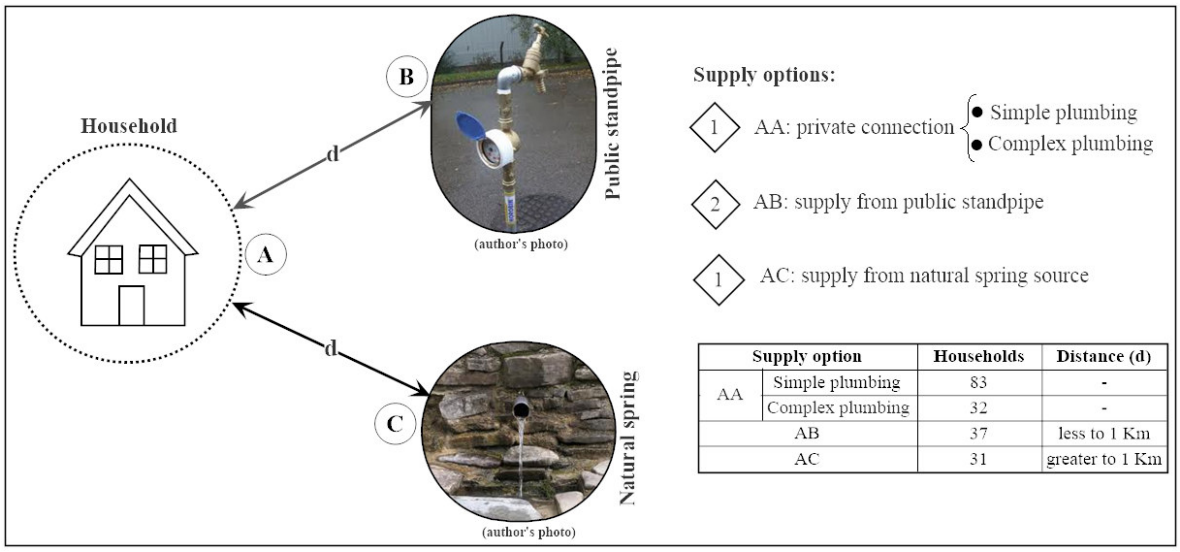
Transport safety used to be a problem with old buses that have been causing mechanical failure related traffic accidents. This issue was solved by imposing a biannual technical control for all buses involved in public transportation.

Concerning the transportation costs, they are regularly regulated by the in-charge government's agency, commonly known as RURA (Rwanda Utilities Regulation Agency).

2) Water supply

By the time of the field surveys, on one hand the quantity of water required in the district to meet the minimum required standards was estimated to 90.5m^3, whereas the public piped water storage tank capacity was 50m^3.

On the other hand, according to surveys, estimated quantity used daily was 33.5m^3. These results show that water used throughout the study area is almost one third of the daily quantity required for minimum acceptable standards, as recommended by the World Health Organization. It is also to mention that the district's water tank capacity of storage is nearly half of the daily-required quantity. Figure 5-29 summarizes the options of water supply and the number of households concerned by each option.



Supply option		Households	Distance (d)
AA	Simple plumbing	83	-
	Complex plumbing	32	-
AB		37	less to 1 Km
AC		31	greater to 1 Km

Figure 5-29: Water supply options

According to the figure 5-29, the most popular water supply option is the *simple plumbing private supply*[30] type covering 45% of district's households. Medium-income people who can afford the preliminary installation fees mostly prefer this supply option.

Concerning the *Complex plumbing*[31] option of water supply, it is mostly the case in high standing houses, as it requires high cost for both installation and monthly bills. Public standpipe option offers less working distance for people who cannot afford private water connection; however it is also a paying option and poor people who cannot afford it have no other choice than going to natural spring with a long walking distance.

From the Figure 5-30, most respondents choose water source according to water availability. This fact highlights frequent water shortage and cutoff that makes it unavailable most of times.

Water quality, which, logically, should be the first condition, is ignored when water becomes scarce. Direct consequences from uncontrolled water quality affect not only users but also the surrounding community through transmission and propagation of different water related diseases.

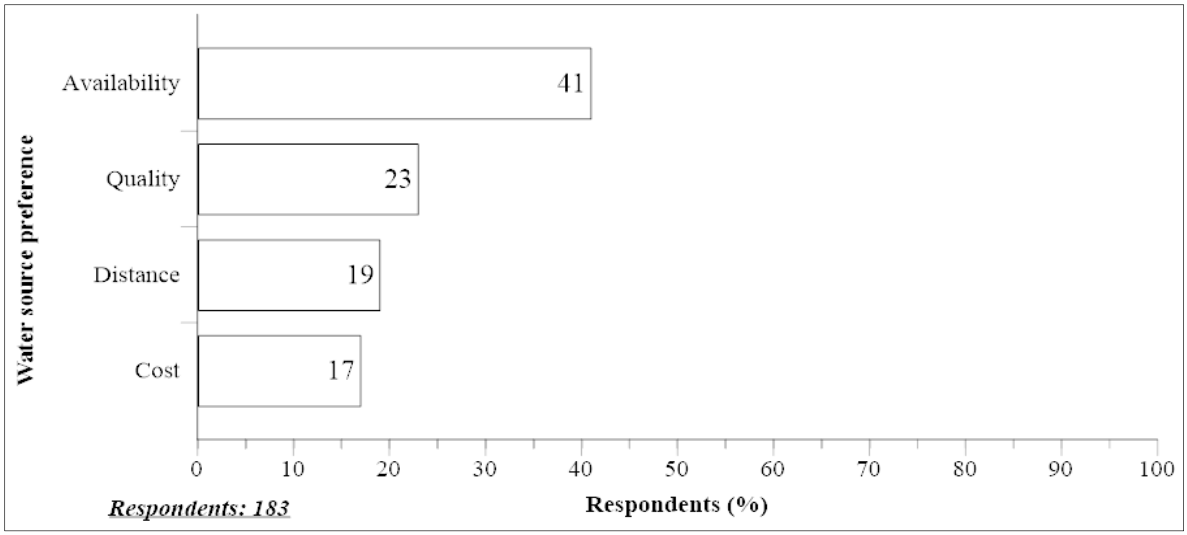


Figure 5-30: Water source conditions

Water cost is basically fixed by the supplying company. However, during periods of water shortage, the cost of water from vendors becomes very high. Most residents experience water shortage

[30] Simple private water connection consisting of a water tape with recording meter standing outside of the house, there is no water connection in different house units (sanitary, kitchen, etc.).

[31] Water is conveyed in different house units. Most of times a water tape is provided outside for routine water uses like garden watering, car washing, etc.

once a week, this is mainly caused by technical maintenance or filter cleaning from the water treatment plant. Advice is to store enough water at home to cover the period of technical cutoff or shortage.

However apart from technical issues, there are areas of the district where there is a daily shortage mostly during peak hours (5-7 am/pm). This situation is caused by the reduction in water pressure during high water demand shifts. Hence, houses located at lower ground level are continuously supplied by gravity.

Most residents prefer water availability from 5am to7pm with emphasis on three periods:

- 5-7am: bath, shower, breakfast preparation, houses cleaning, garden watering, etc.
- 11am-1pm: lunch and other related preparation activities (dish washing, etc.)
- 5-7pm: for dinner and other evening water needs (bath, shower, clothes washing, etc.)

From the Figure 5-29 above, residents averaging 20% have to walk more than 1Km to reach the water spring point; moreover they have to wait long time to get access to water because the spring source is most often crowded. Presently water is accessed from house private tape (no distance) up to two kilometers distance. From the survey, residents say that a distance up to half kilometer would be reasonable.

People who have to collect water from long distances are vulnerable in different ways:

- Long walking distance with heavy water weight (20 to 40 liters of water per person).
- Most alarming situation concerns children under maturity age who are forced to carry heavy weight beyond their physical capacities. Moreover, most of them are children in school age using school hours for water collection.
- Long waiting time at spring water source in days of water shortage in the district.

3) Grid electricity supply

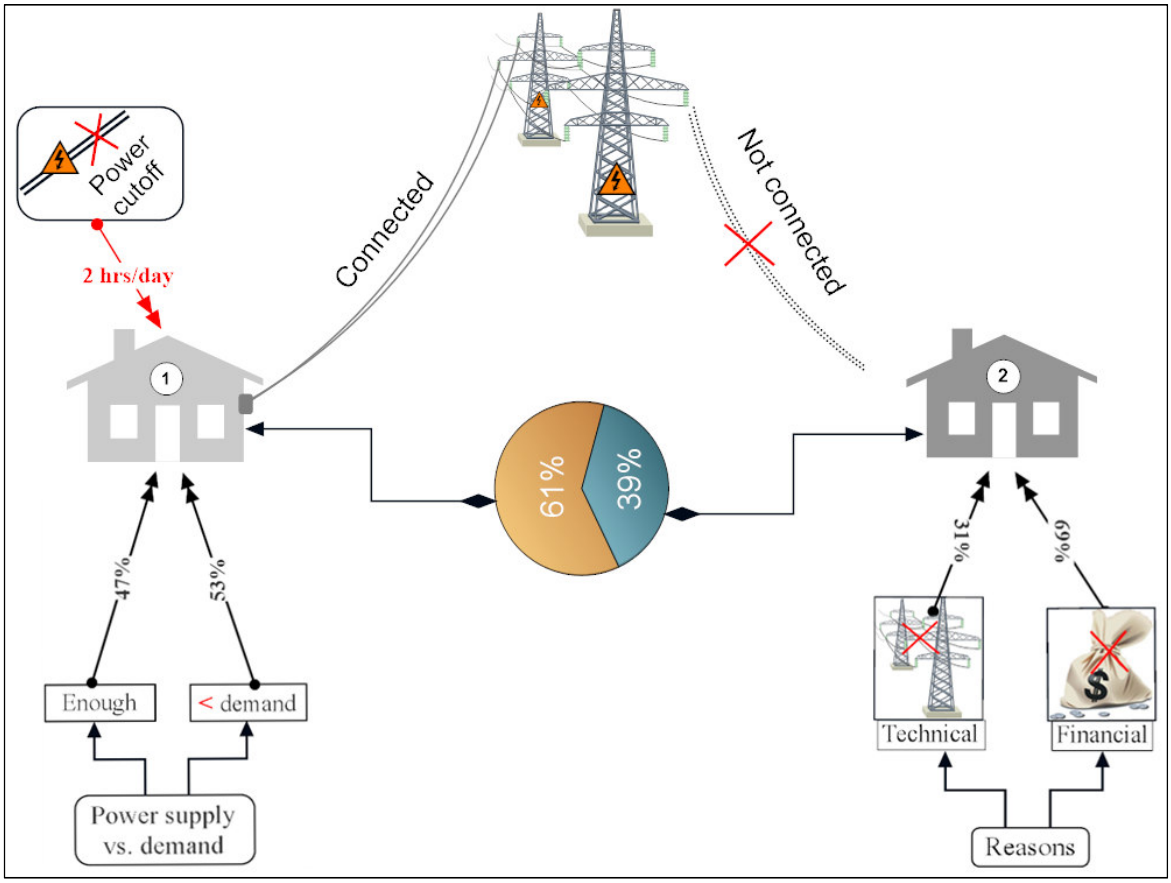
Concerning the connection to the grid electricity, it is one of the most challenging public utilities in the study area. In addition to low connectivity level, there is also a problem of low voltage unable to run some routine domestic electrical appliances.

As shown on the Figure 5-31, two main reasons are the cause of non-connectivity:

- Financial problems come first with a rate of 69%.
- Technical problems (lack of electrical line around residence) are the cause of non-connectivity at a rate of 31%.

In addition to the low connectivity coverage, there is also a huge problem of non-satisfaction in power for connected households, especially in peak hours of electricity demand (6-10 pm).

Moreover, there is a daily power cutoff of two hours decided by the electricity supplying company to share evenly available power capacity throughout the consumers.



(Author's illustration)

Figure 5-31: Connectivity to grid electricity

On the other hand, 53% reveal that the electrical power available is far away to meet their daily needs. This group is principally composed of people leaving in high cost houses with high intensity electricity consumers.

(vi) Public infrastructures and utilities interrelationship

From the Table 5-14, households that can be accessed by commonly used vehicles (C and D classes) make a total of 114 and, as shown by the same table:

- Households accessible by 2 and 3 car types and connected to water sum up 95
- Those accessible by same car categories and connected to electricity totalize 92

Table 5-15: Public infrastructures and utilities interrelationships

Accessibility options	Households	
	Number	%
A. International transporters	15	8.2
B. Service trucks and buses	46	25.1
C. Passenger cars	68	37.2
D. Cycles	26	14.2
No access	28	15.3
Total	183	100

Utilities connectivity	Accessibility options by vehicles			
	International transporters	Service bus and trucks	Passenger cars	No access
Water	13	39	56	7
Electricity	15	41	51	5

$$\left(\frac{95}{114} = 0.83 \quad \frac{92}{114} = 0.81\right)$$

From the table, in terms of probability:

- Chances of a households accessible by cars to be connected to water are 83%.
- The same household will have the chances of 81% to be connected to electricity.

In conclusion, these high and very closer probability values denote the street as the key infrastructure to other main public utilities, especially for water pipes and electrical lines that normally follow the street's itinerary.

Chapter 6 Comparison of findings by cross cases analysis

In this section, a comparison is made between the two study areas about the status of the existing conditions in terms of the essential functions as pre-described by the UN-Habitat, which are also the key factors for onsite upgrading of informal settlements. Therefore, the comparison emphasizes on the following indicators: structural quality/durability of buildings, locational conditions of dwellings, sufficiency or not in living area, access to improved water for domestic uses, access to improved sanitation facilities, people and vehicular mobility conditions and security of tenure vis-à-vis the land or dwellings.

6.1. Dwellings conditions

6.1.1. Foundation

A building's foundation is a crucial element in holding the structure above it and ensure that the building remains upright. When a foundation is inexistent or poorly constructed, it can cause serious risks to the inhabitants and the neighborhood as a whole. Therefore, it is essential that the foundations are taken seriously while assessing the buildings' stability and safety.

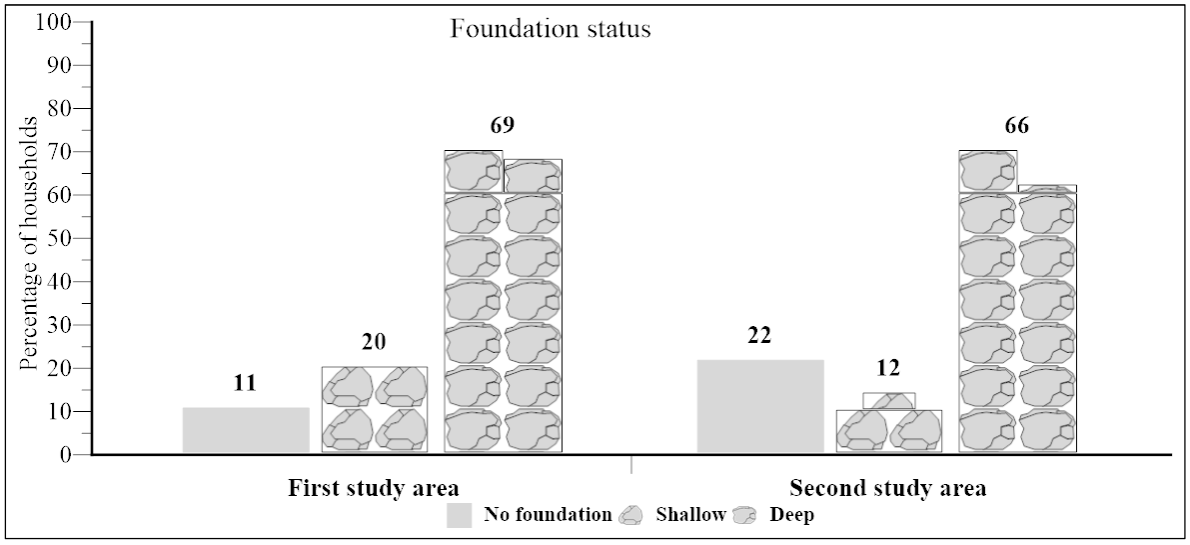


Figure 6-1: Foundation depth

As shown on the Figure 6-1, the two study areas show a dissimilarity in the proportions of buildings with weak or no foundation at all, whereby the second study area doubles the first one for both the total absence of foundation and the weak foundation values. This dissimilarity is mostly due to a large sloppy area (Figure 6-5) qualified as "high risks zone" whereby the majority of weak building are found.

6.1.2. Walling materials

As observed on the Figure 6-2, the construction with mud blocks is the most commonly used in both study areas. This construction method is cheaper and does not require skilled workmanship. Mud blocks are laid on the construction site and allowed to dry out for about a week before usage.

In contrary, the construction with burnt clay bricks or cement blocks is not affordable by most of dwellers due to its high cost in both the masonry elements and the biding mortar. Both bricks and blocks are hauled from the manufacturing sites, most of times far away from the construction sites with a high cost of transportation. Moreover, the construction with burnt clay bricks or cement blocks requires expensive skilled workmanship.

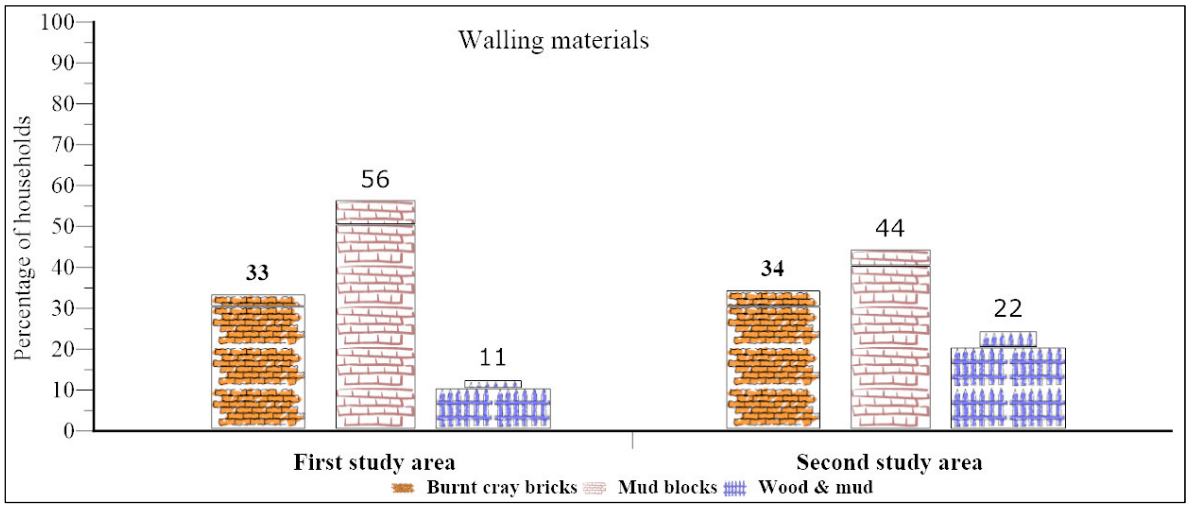


Figure 6-2: Walling materials

Observation from Figure 6-1 and Figure 6-2 reveals that the percentage of no foundation houses equals the percentage of houses with wood and mud walling from both case study areas. The second study area doubles the first one in this walling type due to high number of households in high risks zones whereby this construction typology is the mostly commonly used.

6.1.3. Structural stability

From the settlement history of both study cases as informal settlements, the first study area is about five decades older than the second one. Therefore, the depreciation of buildings is pronounced by more structural damages in the first study area.

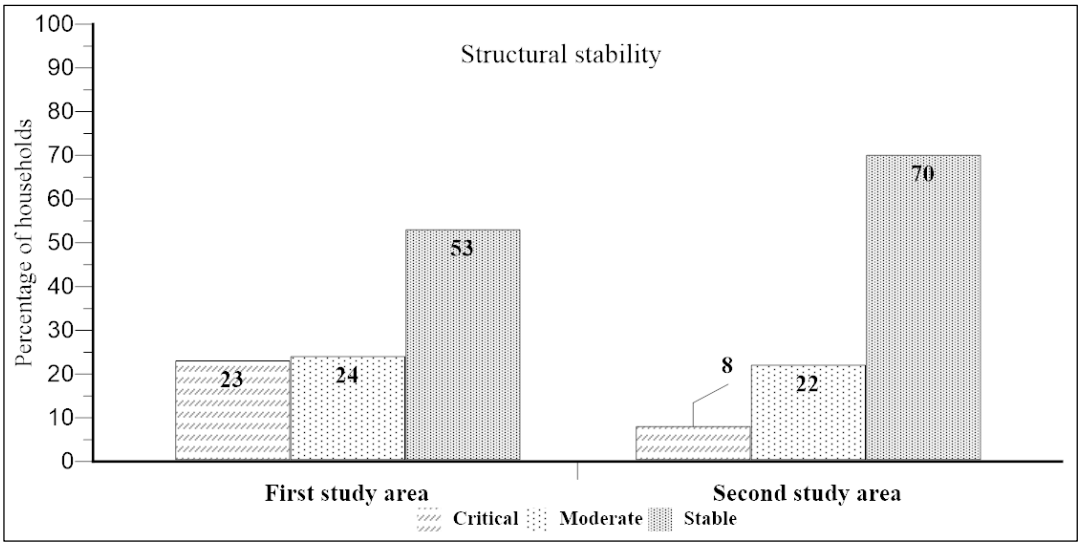


Figure 6-3: Structural stability[32]

6.1.4. Interior space occupancy

From the Figure 6-4, the two study cases have an almost equal average in family size. However, the first study area doubles the second one in the average number of bedrooms per family size. This is mostly due to many small houses built on the high risks zone whereby the births control measures are scarce.

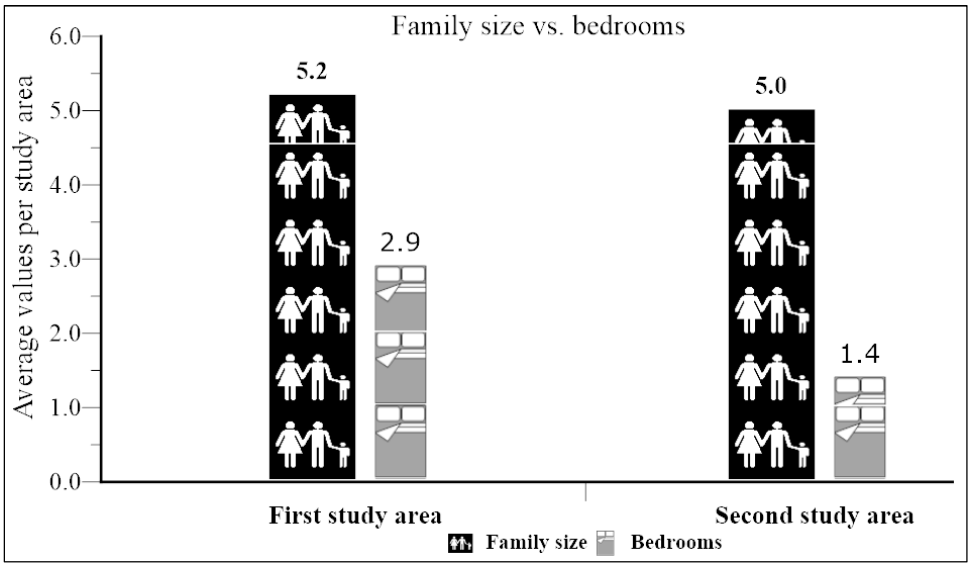


Figure 6-4: Interior space occupancy

[32] Assessed by checking the presence/non-presence of structural cracks throughout the walls. Cracks may be horizontal, vertical or in both directions.

According to the UN-Habitat guidelines[33] about the interior space requirements, the second study area is crowded with an average of about four people per bedroom. Whereas the first study area with an average of about two people per bedroom remains within the range of acceptable margin.

6.2. Topographic conditions

From the figure 6-5, the second study area triples (11.2% versus 30.2%) the first one in the proportions of non-durable and health endangering houses. According to the government's guidelines, ground slopes of 30% and greater as well as areas adjacent to wetlands are considered as high risks zones, therefore inhabitable by humans.

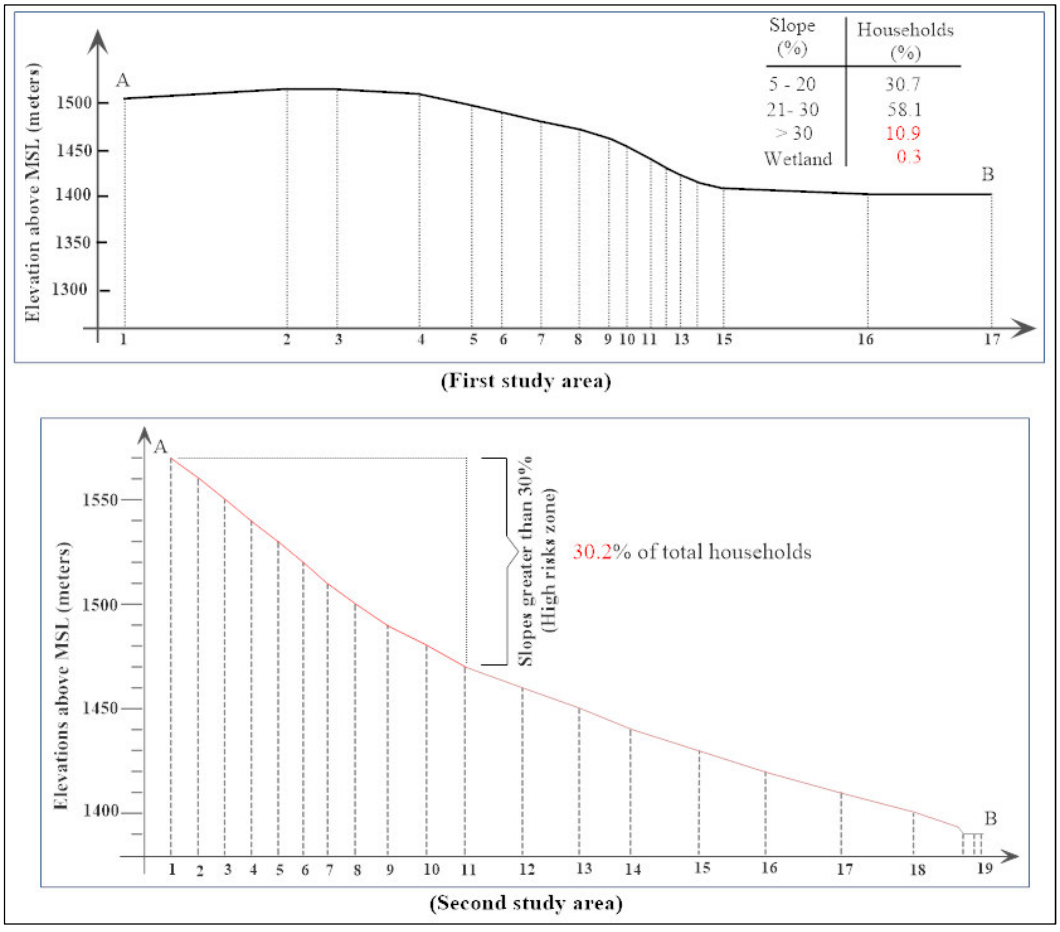


Figure 6-5: Topographic conditions

[33] UN-Habitat practical guide recommends a maximum of three people per one bedroom.

6.3. Accessibility conditions

Observations at the Figure 6-6 reveals that the proportions of accessible and inaccessible households by cars from both study areas are almost the same (50% versus 54% accessible, 50% versus 56% inaccessible by cars).

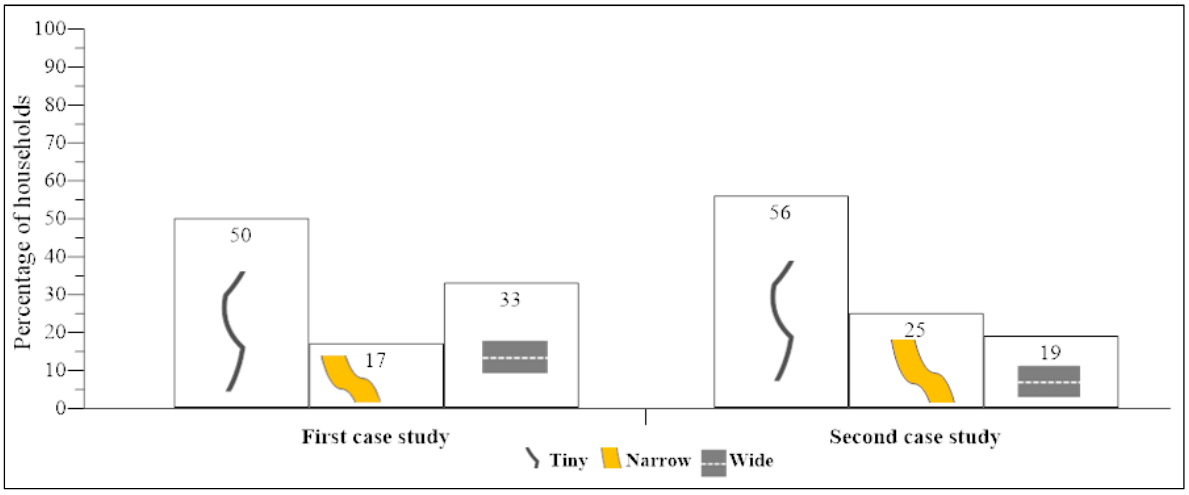


Figure 6-6: Mobility options[34]

6.4. Water supply and wastewater disposal

6.4.1. Per capita daily water use

From the Figure 6-7, although the majority of residents in both study areas score below the recommended minimum by the World Health Organization, the first study area suffers more in water supply shortage. According to interview held by the researcher with local authorities in this area, the supply capacity have never been updated since 1980's while the size of the population increased by more than twenty times from the same period.

[34] Referring to the guidelines from the RTDA, this study considered a width of less than 1.8 meters as tiny, between 1.8 and 3.5 meters as narrow, and above 3.5 meters as wide.

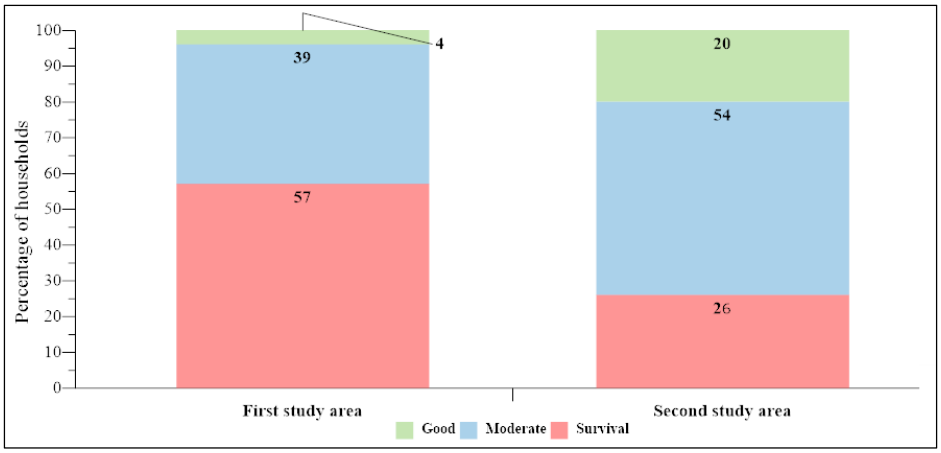


Figure 6-7: Daily water use per capita[35]

6.4.2. Wastewater and sewerage

Wastewater disposal is a big challenge in both study areas. As shown on the Figure 6-8, the number of households without access to sewerage system scores 70% and above households. This situation not only poses public health threats but also raises up endless dispute among residents who fail to retain their wastewaters within their compounds and leak to surrounding neighborhoods.

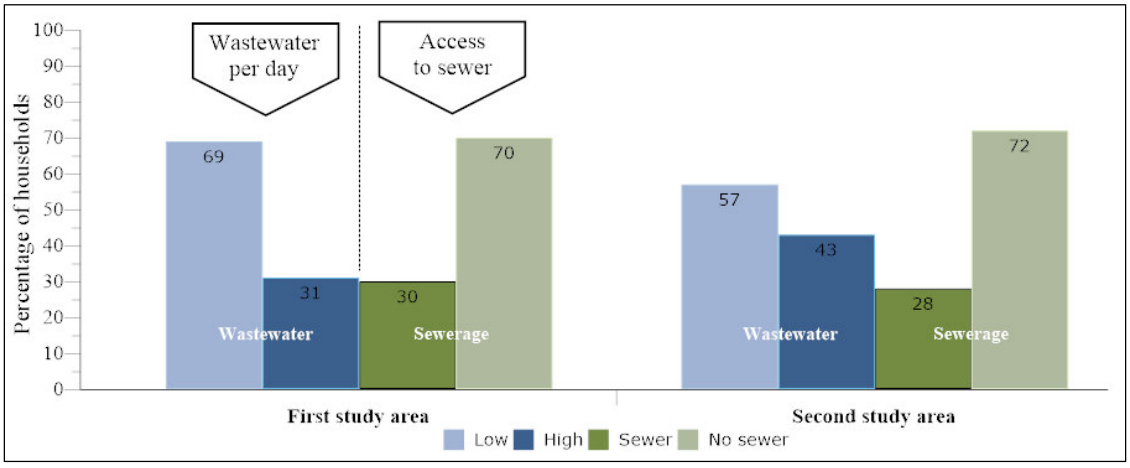


Figure 6-8: Wastewater and sewerage[36]

[35] Referring to the WHO standards and the WASAC guidelines, this study considered a daily per capita water use quantity less than 20 liters as survival, between 20 and 60 liters as moderate, above 60 liters as good

[36] Referring to WASAC guidelines, this study considered an emission in wastewater less than 100 liters per day as low, otherwise high.

6.5. Connectivity to electricity

From the Figure 6-9, both study areas record lower connectivity ratios compared to the overall Kigali city connectivity of 82%. The second study area records the lowest connectivity due to many households located on high risks zone, whereby the electricity supply is not allowed. In addition to the main challenge of accessibility that hinders the spread of power lines throughout the community, there is also a problem of power shortage and frequent cutoffs, as discussed earlier in section 4.

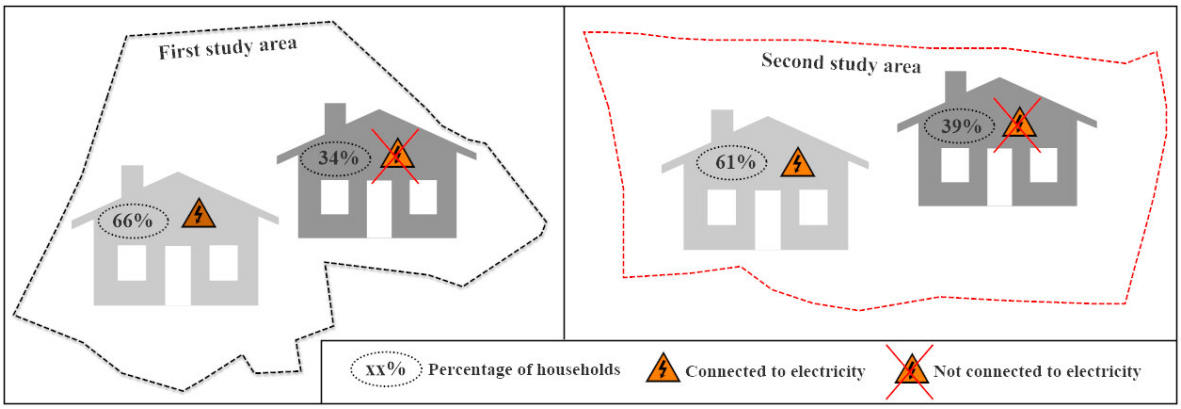


Figure 6-9: Connectivity to electricity

6.6. Existing socio-economic facilities and opportunities

The differences in the locational context of the two study areas cause a difference in socio-economic opportunities between their residents.

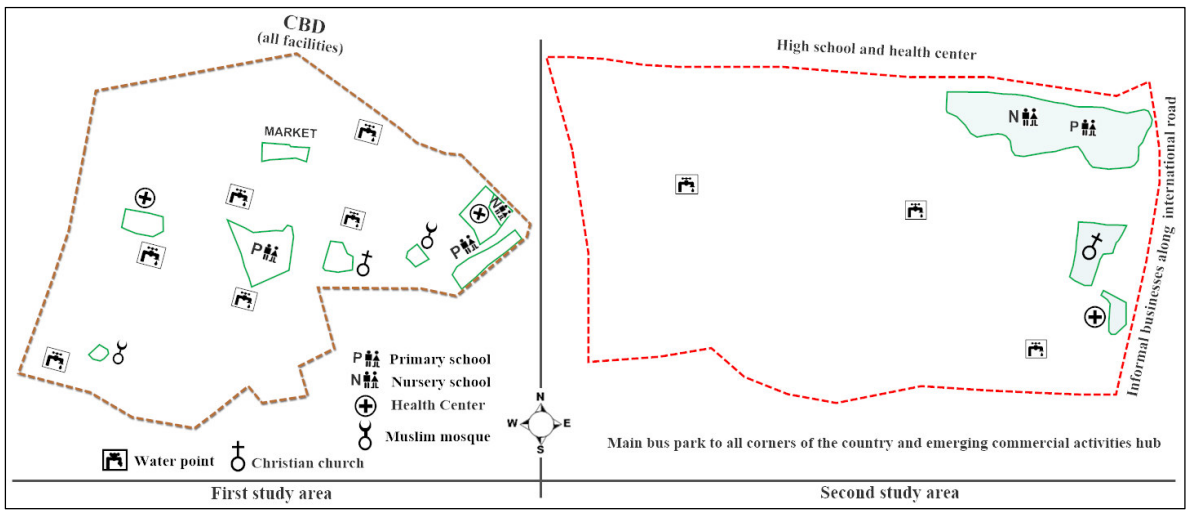


Figure 6-10: Existing socio-economic facilities and opportunities

As shown on the Figure 6-10, the strategic location of the first study area on the proximity of the Kigali city's Central Business District offers more advantages to the residents who can easily access the socio-economic facilities offered by the CBD. Residents from this study area can easily go to CBD by walk for their daily routine like working, shopping, medical services, schools, to mention but a few.

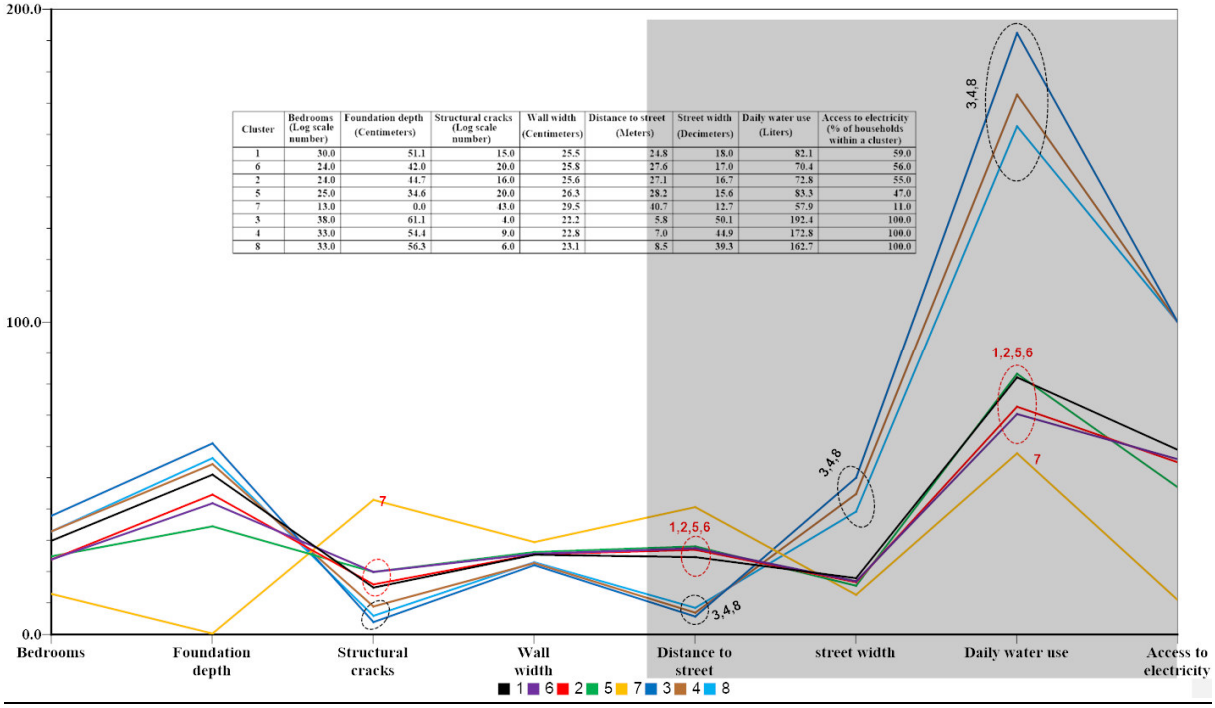
In contrary, residents from the second study area need to commute by public transportation services (as discussed earlier in section 5) for their daily needs from the Central Business District. The public transportation is not reliable especially in pick hours when many people are in its need (morning and evening for the start and the end of a business day). Some residents prefer to walk a distance of about four kilometers to CBD. Nevertheless, this study area has an advantage an international road on its east side as well the main bus park and an emerging commercial hub on its south side.

6.7. Security of tenure

Since the year 2009, the Department of Lands and Mapping in Rwanda launched the national wide regularization of land tenure, an exercise that was concluded in 2013. Since then, the residents in informal settlements, including both study areas, have seen their portions of land legally and financially secured. Landowners can rely on their ownerships as a collateral security to negotiate long-term loans from the commercial banks. In addition, landowners have a right to be expropriated to the market price if any public or private development project want to seize their property.

6.8. Infrastructures and utilities interrelationships

Results from the Figures 6-11 and 6-12 reveal that the more a household is accessible by vehicular traffic the more it has a high probability to be well accessed by the basic utilities and services.
From these results, the households divide into three major blocks. The first includes easily accessible and structurally stable households with good sanitation conditions. The second block encompasses the majority of mud blocks houses, on narrow streets and survival sanitation services. The last block englobes structurally critical houses and mostly built in high-risk zones subjected to landslides in heavy rains, their hazardous accessibility inflicts them very poor sanitation status.



Cluster	Bedrooms (Log scale number)	Foundation depth (Centimeters)	Structural cracks (Log scale number)	Wall width (Centimeters)	Distance to street (Meters)	Street width (Decimeters)	Daily water use (Liters)	Access to electricity (% of households within a cluster)
1	30.0	51.1	15.0	25.5	24.8	18.0	82.1	59.0
6	24.0	42.0	20.0	25.8	27.6	17.0	70.4	56.0
2	24.0	44.7	16.0	25.6	27.1	16.7	72.8	55.0
5	25.0	34.6	20.0	26.3	28.2	15.6	83.3	47.0
7	13.0	0.0	43.0	29.5	40.7	12.7	57.9	11.0
3	38.0	61.1	4.0	22.2	5.8	50.1	192.4	100.0
4	33.0	54.4	9.0	22.8	7.0	44.9	172.8	100.0
8	33.0	56.3	6.0	23.1	8.5	39.3	162.7	100.0

Figure 6-11: First study area's infrastructure-utilities interrelationships

Accessibility options	Households	
	Number	%
A. International transporters	15	8.2
B. Service trucks and buses	46	25.1
C. Passenger cars	68	37.2
D. Cycles	26	14.2
No access	28	15.3
Total	183	100

Households utilities connectivity	Households accessibility options by vehicles			
	International transporters	Service bus and trucks	Passenger cars	No access
Water	13	39	56	7
Electricity	15	41	51	5

$$\left(\frac{95}{114} = 0.83 \quad \frac{92}{114} = 0.81\right)$$

Figure 6-12: Second study area's infrastructure-utilities interrelationships

6.9. SWOT analysis for onsite upgradability of the study areas

Table 6-1: SWOT analysis for onsite upgradability

Strengths	**Weaknesses**
➢ Security of tenure - Financial resources: land can be used as collateral security to access the long-term lease bank loans. - land value: continuously increasing since two decades ago ➢ Strategic locations as physical resources: both study areas are strategically located: the first one closer to the CBD, the second one on international highway, national bus park and an emerging commercial hub. ➢ Fewer slums than informal settlements, According to UN-Habitat's indicators and thresholds for defining them. ➢ Human resources: Active population: more than 90% of the population in both study areas is aged between 20 and 50 years.	➢ Sanitation: - Lack of drainage and disposal for wastewaters - Insufficient water supply worsening hygienic conditions ➢ Accessibility and openness: - Unsecure and tiny footpaths, mostly eroded by storm water - High dwellings density ➢ Infrastructure and facilities: - Lack of streets for basic services - Lack of storm water drainage worsening an already fragile situation. - Scarcity of water and electrical supply mains ➢ Security: at dark nights, the security of people is compromised by lack of lighting on snaky and narrow footpaths with dangerous obstacles. ➢ Fire hazards: caused mainly by fire woods while cooking in tiny and easily inflammable houses.
Opportunities	**Threats**
➢ Eligibility to onsite upgrading: both study areas are reserved by the Kigali City Master Plan for onsite upgradability ➢ Informal settlements upgrading projects and initiatives: the government of Rwanda, in collaboration with international and local organizations, initiated the pilot projects for informal settlements upgrading. ➢ Mortgage loans availed at low interests rates for land owners to upgrade their dwellings ➢ Public Private Partnership initiatives: This partnership intervene in diverse socio-economic deals, including housing and roads, which initially seem to be a heavy burden to the government alone.	➢ Weather: - Loss of human lives due to undrained storm water in heavy rain season. - Buildings' roofs snatched away by strong winds, mainly due to the lack of wind corridors. ➢ Public health: Infectious diseases from outside that can easily spread throughout the study areas due to poor sanitation conditions. ➢ Topography: steeply terrains subjected to frequent landslides during heavy rain seasons.

Considering this SWOT analysis outcomes and based on this study's findings, the most convenient strategy that can work to eliminate weaknesses while alleviating the threats is to "open service streets" throughout the inaccessible spots in order to engage the participation of the concerned communities. Service streets would serve as not only a mile stone for the onsite upgrading projects, but also as a link for integration within the neighborhoods and the overall city's development plan.

Chapter 7 Simulation analysis of onsite upgrading towards a sustainable community

This simulation is due to showcase the possibility and feasibility study of the onsite upgrading of informal settlements. It is limited to suggesting the creation of streets throughout the study area, guided by the existing mobility rhythm and order of the neighboring community, as shown on Figure 7-1, by modeling of two scenarios to assess the on-site resettlement capacity as well as its implementation feasibility under the Public Private Partnership. In the first scenario, only one central linear corridor collector street is created, whereas in the second scenario a total on-site redevelopment is considered.

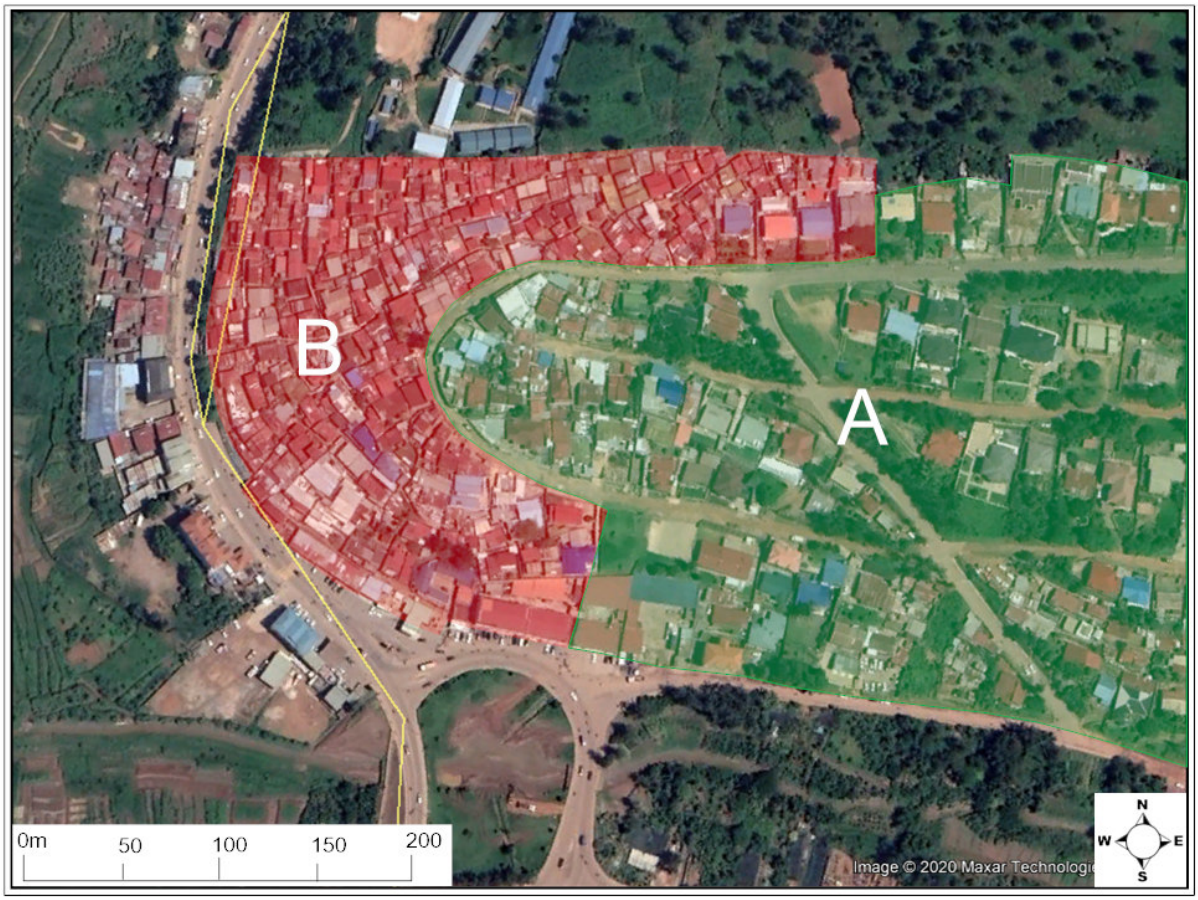


Figure 7-1: Survey communities

7.1 Methodology

In the sake to understand the situation of the necessary functions (mobility, cleanliness, and service networks) in the study area "B", as shown on Figure 7 - 1, we carried out parallel surveys (John, 2018). The same questionnaires and interviews questions were used within the same period in two neighboring communities "A"[37] and "B" with same locational and physical contexts.

With households being the target respondents, we counted the total number of dwelling units (DU) in community B and we identified 383, this was decided it to be our population size. As we based our research method on comparison, we took the same size of dwellings units from the community B.

Due to time constraint and financial limitations, we convened to reduce the population size to get a reasonable sample size (Paul and Stanley, 1999) correlated to our time and available funds. In this regards, we relied on the Daniel's formula (Naing, Winn and Rusli, 2006) for proportioning the sample size with respect to the population size.

Daniel's formula:

$n = N*X / (X + N - 1)$

Where:

- $X = (Z\alpha/2)^2 * p*(1-p) / MOE^2$,

Z: is the critical value of the normal distribution at α/2 (for this research as the confidence level was taken to be 95%, then α is 0.05 and the critical value is 1.96).

MOE: is the margin of error,

P: is the sample proportion (we decided 60% in this research),

- N: is the population size.

With a population size of 383, and replacing in the formula all parameters by their respective values, we found a sample size of 189; say 190 DU.

We collected data by questionnaires and self-observations by proportional random sampling[38]. We divided the population size into smaller groups of equal dwellings units and from each group we randomly[39] selected equal number of respondents. Since we focused at estimating the percentages and the total number of counts of the existence of necessary functions, we asked respondents to provide a simple Yes or No (Poduri, 2000) to each of the survey questions.

[37] The community A is not entirely shown on Figure 3-4, it continues towards the east.

[38] Proportional sampling is a method of sampling whereby a researcher divides a finite population into sub-populations, thereafter applies random sampling techniques to each sub-population.

[39] Random does not mean hazardous. Instead, each respondent has a known non-zero probability to be selected.

The results of surveys data analysis are summarized on Table 7-1 below. They are shown together with the Government's targets by the Ministry of Infrastructures of Rwanda, regarding the highlighted necessary functions, before and after the survey period.

From below data summary, apart from the solid wastes disposal[40], other necessary functions in community B were found to be critical with respect to the country's past and future targets.

In contrast, the community A with the same locational and physical contexts already reached or even overpassed the future targets for most of necessary functions

Table 7-1: Necessary functions in two communities versus the Government's targets

Necessary functions per DU	**Records and targets (percentage)**			
	2018 survey results		Government targets	
	Community B	Community A	2015 target	2035 target
Accessibility by cars	12	96	60	100
Potable water	34	100	85	100
Grid electricity	41	100	50	100
Liquid wastes disposal	17	89	65	100
Solid wastes disposal	100	100	100	100
Restrooms ownership	53	118	100	100

7.2. Existing conditions analysis

Prior to well understand the main cause of existing conditions in the study area "B" and thereby propose suitable recommendations and strategies, we made use of SWOT analysis with a focus on leveraging strengths and opportunities to overcome weaknesses and threats hindering the development of the study area. We referred the internal factors as either strengths or weaknesses, whereas we classified external ones as either opportunities or threats. The outcomes of the analysis are summarized in Table 7-2.

Apart from the land tenure security, the study area is strategically located in terms of its market land value. This is because the characteristics of its surrounding neighborhood create many pulling factors, making it solicited by investors for business opportunities.

According to the data from the Rwanda National Institute of Statistics[41], the population pyramid (by the end of the year 2019) of the administrative district where the study area is located shows following percentages by age categories: zero - 9 years: 27.5%; 10 – 19: 22.6%; 20 – 59: 44.8%; 60

[40] In Rwanda, each city's administration collaborates with private companies to collect and dispose both solid and liquid (where applicable) wastes on regular basis. Each household and/or business entity contributes a monthly reasonable amount of money for the functioning of those companies.

[41] At the beginning of every year, the Rwanda national institute of Statistics compiles the population data of the previous year from all administrative entities.

and above: 5.10%. These statistics reveals a high proportion of economically active residents, which is an empowering engine for any possible socio – economic transformation.

Table 7-2: Analysis of existing conditions by SWOT

Strengths	**Weaknesses**
➢ Financial resources: - land tenure security: each portion of land is legally registered to owner - land value: this area is solicited for both habitat and small scale business ➢ Physical resources: - Location: this area is in strategic location due to its proximity to many institutions - Topography: gentle slopes characterizes the study area ➢ Human resources: - Population: this area is inhabited by residents in active age[42] - Employments: part-time or permanent jobs to many nearby institutions and organizations, small scale business and trades ➢ Social resources: - Proximity nearby a nine years basic education school - Proximity nearby a district hospital	➢ Sanitation: - Lack of drainage and disposal for wastewaters - Insufficient water supply worsening hygienic conditions - Insufficient toilets ➢ Accessibility and openness: - Unsecure and tiny footpaths, mostly eroded by storm water - Highly condensed dwellings leaving no open spaces ➢ Infrastructure and facilities: - Lack of roads for basic services - Lack of storm water drainage - Lack of water and electrical supply mains ➢ Security: At dark nights, the security of people is compromised by lack of lighting on snaky and narrow footpaths ➢ Fire and health risks due to poor top-structures' building materials
Opportunities	**Threats**
➢ Kigali City Master Plan: This area is proposed to be on-site upgraded ➢ Infrastructures and services: - Transport: this area is surrounded by arterial, semi-arterial and service roads - Services: Electricity and water supply mains passing nearby this area ➢ Mortgage loans availed for land owners from local commercial banks ➢ Public Private Partnership initiatives: This partnership intervene in diverse socio-economic deals, including housing and roads, which initially seem to be a burden to the Government alone.	➢ Weather: - Loss of human lives due to undrained storm water in heavy rain season - Buildings' roofs snatched away by strong winds due to lack of wind corridors ➢ Rich investors threatening to transform the area into business center due to its strategic location. ➢ Infectious diseases from outside that can easily spread throughout the study area

[42]According to Kigali city's annual census data, 94 percent of the population in this area was under 65 years by 2018.

In Kigali city, informal settlements share common challenges mostly related to a high dwellings density. In this regards, the study area suffers poor sanitation conditions mostly linked with insufficient water per capita daily quantity, which exposes the residents to high infection risks of poor sanitation related diseases. Apart from that, the disordered physical arrangement of dwellings makes it impossible to open a common wastewater drainage and disposal system; it results to wastewaters ponding spreading bad smells and other related consequences throughout the community.

In addition to the above-mentioned challenges, the study area suffers a severe problem of mobility for both pedestrians and vehicular access resulting to lack of network channels for conveying public infrastructures and services. In this regards, most of residents in the study area are deprived from access to water supply and electricity connectivity not because such services are not available but because there are no ways to convey them through highly condensed dwellings.

Apart from public utilities and services, the community within the study area is also exposed to an imminent danger of destructive storm waters after heavy rains due to lack of drainage. Eroded tiny footpaths without lighting at dark nights present high risks of injuries and security threats for residents.

In addition to internal challenges, the study area prone to external threats mostly linked to weather conditions during rainy and windy seasons. Moreover, its strategic location to business opportunities makes it highly exposed to private investors willing to switch it into a commercial area by displacing the community with insufficient compensation money.

Resulting strategy from SWOT analysis:

Throughout our analysis, we methodically considered different possible alternatives to upgrade the study area. The most convenient strategy that can work to eliminate weaknesses while alleviating the threats is to “open service streets” throughout the study area as the starting point of on-site upgrading on one hand, and the link for integration with the neighborhood and the city’s development plan on the other hand.

7.3. Creation of service streets as a sustainable solution

This simulation analysis proposes the creation of streets as a sustainable solution for the on-site upgrading of the study area. We will show that the feasibility of that approach is possible under the Public Private Partnership (commonly known as PPP) umbrella, whereby each partner (government, private investors and residents) will have a particular role (Table 7-3) to play for overall success of the project.

The PPP approach have proven successfulness on projects initially seeming a heavy burden on government budget alone. The involvement of private investors and the concerned communities makes a particular project having a participatory character, hence more effective to bring a sustainable solution for a particular problem.

Table 7-3: Key roles of partners

Government	**Residents**	**Private investors**
➢ Organize and chair meetings, prior to listen to all partners for a participatory framework ➢ Trace the streets' routes and evaluate each affected plot value ➢ Stand as a facilitator and/or mediator for any possible dispute between residents and private investors ➢ Prepare public tender documents to be relied on during implementation ➢ Set up guidelines and standards to be followed by private investors	➢ Voluntarily accept to contribute their portions of lands ➢ Voluntarily accept to cooperate with banks for lease holding in case of needs. ➢ Actively participate in implementation phases for income generation	➢ Prepare all necessary drawings as guided by the government side ➢ Construct the streets ➢ Construct and avail apartments lots as primarily agreed in consultation meetings ➢ Comply with general standards and guidelines of both housing and environmental authorities organs ➢ Handover of constructed infrastructures to government's officials who acknowledge their reception.

Scope of simulation analysis:

This analysis is limited to suggesting the creation of streets throughout the study area, guided by the existing mobility rhythm and order of the neighboring community and inspired by the Gothic curves (Spiro Kostof, 1991). We will do modeling and simulation of two scenarios, in order to assess the on-site resettlement capacity as well as its implementation feasibility under the PPP. In the first scenario, we will only create a central linear corridor collector street, whereas in the second scenario we will consider a total on-site redevelopment.

7.3.1. Scenario 1: Creation of a central linear street

Street category and guidelines: With respect to the functional classification of urban roads in Rwanda[43], this study suggests the creation of a "collector street" passing through the center of the study area, to serve as central open space, main channel for public utilities mains as well as a common trunk for access streets.

- *Origin and Destination*: this street will originate and end from and to the existing road network in community A.
- *Itinerary:* wherever possible, the street will follow existing footpaths to minimize inhabited plots. The street pathway will be delineated is such a way to link the community B with the adjacent school.
- *Size*: the width of this collector street will be harmonized to the main street size of community A, which is 4 meters. In addition, however, as the only open space in community B, 4 meters side clearance (including covered drainage trenches) from the street edge to the building line, will be provided on both sides of the street.

Figure 3-5 shows the street cross-section elements (Keith, 2015).

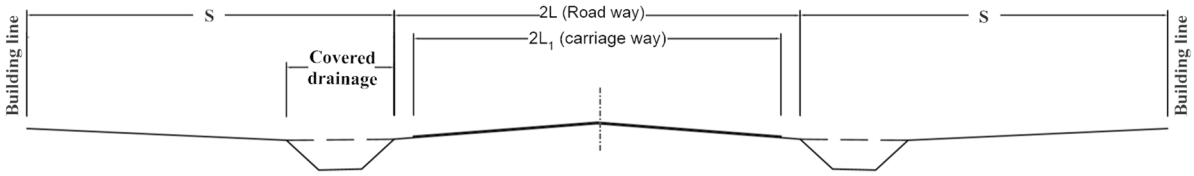


Figure 7-2: Cross-section of the collector street

Whereby: 2L (meters) = 4.5, $2L_1$ = 4.0, S = 4.0, Side drainage to be sized according to the rainfall data for estimation of the peak storm water runoff.

Inventory and feasibility study of scenario 1:

After deciding an optimized pathway (Ebenezer, Emmanuel and Noel, 2011) of the collector street, as shown on Figure 7-3, and its' adjacent building strip, we make an inventory, in Table 7- 4, of affected households[44].

[43] In Rwanda, the Ministry of Infrastructure classifies urban roads into five categories: expressway, arterial streets, sub-arterial streets, collector streets and access or local streets.

[44] In the context of informal settlement, a household consists of the main building and its external annexes like kitchen, washroom and latrine.

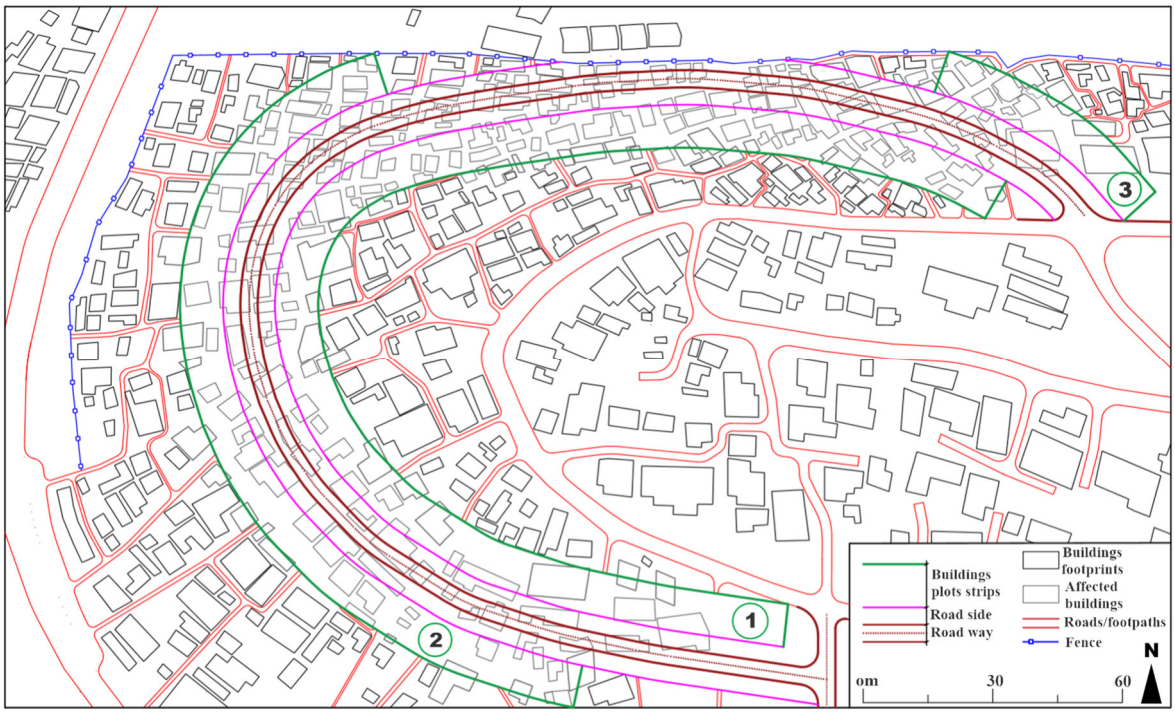


Figure 7-3: Central collector street simulation

Thereafter, we analyze the possibility of resettlement in new apartment lots. From previous resettlement experiences by public private partnership, under the guidance of Rwanda Housing Authority, properties valuation are sorted into three groups with respect to the affected properties values. Consequently, each concerned household receives either one, two and three bedrooms self-contained apartment unit. Therefore, this study recommends the same model to be applied.

Figure 7-3 highlights the new roadway, side walkways and the strips of the new plots. It shows also the footprints of fully and partially affected structures.

Inventory analysis:

a) Affected households: 142 (partially or fully affected by the street and its side clearance)

Table 7- 4: Buildable area measurements

Strips	Width (m)	Length (m)	Perimeter (m)	Area (sq.m)
1	10.0	329.39	687.78	3293.90
2		208.11	436.22	2081.10
3		56.07	132.13	560.70
Total		593.57	1216.13	5935.70

b) Estimation of the resettlement capacity:

Based on previous resettlement experiences from PPP implemented projects for communities with comparable socio-economic conditions as the study area, we approximate the following:

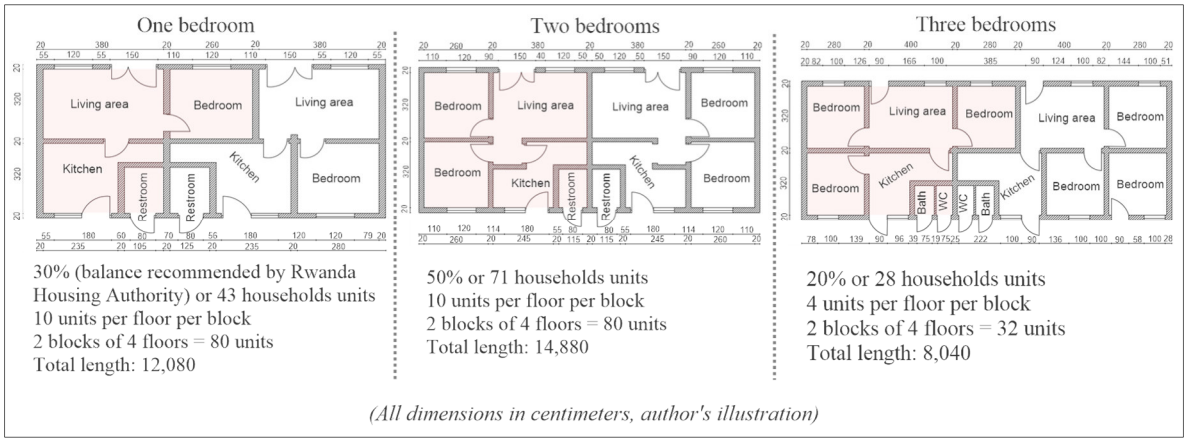


Figure 7- 4: Apartments' typologies[45] and their shares on households units

Rwanda Housing Authority regulates the balance in typologies as well as the layouts plans. This analysis will therefore rely on them in the sake to estimate the resettlement capacity of the study area. Table 7-5 evaluates the capacity of the newly developed land to resettlement all affected households and what would remain in terms of land and apartments units after every concerned resident is served with respect to the PPP agreements.

Table 7-5: Inventory analysis 1

Item	Available	Needed	Remainder
Land length (meters)	All strips (1,2, 3) combined: 593.57	All typologies (1,2,3 bedrooms) combined: 350.0	243.57[46]
One bedroom apartment	80	43	37 (= 80 – 43)
Two bedrooms apartments	80	71	9
Three bedrooms apartments	32	28	4

[45]Rwanda Housing Authority recommends four floors (ground + 3) apartment block as well as household's typologies, dimensions and layout plans.

[46] The remaining land includes separation distances among buildings blocs as well spaces for connecting the collector street to the service streets that will be gradually built after the completion of the pilot project.

7.3.2. Scenario 2: Simulation of total on-site resettlement

In this case, we will consider the feasibility of the on-site street-led total redevelopment of the study area, as shown on Figure 7- 5, keeping unchanged the guidelines and standards of the first scenario.

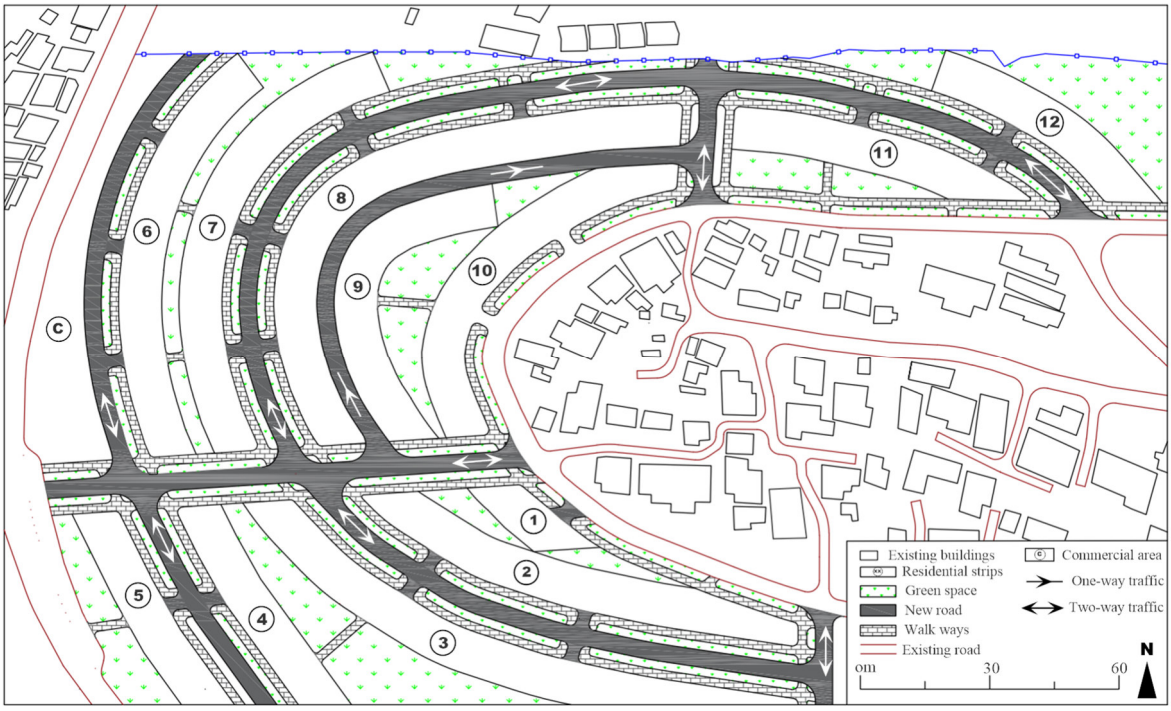


Figure 7-5: On-site street-based total on-site resettlement simulation

Inventory analysis of scenario 2:

a) Affected household: all (383)

b) Resettlement by typologies shares in dwellings units (based on balance recommended by Rwanda housing Authority):

- One bedroom by 30% of the total: 383 X 0.3 = 115

  Three blocks of four floors: 120, on total length of 181.20 meters

- Two bedrooms by 50%: 191

  Five blocks of four floors: 200, on a total length of 372.0 meters

- Three bedrooms by 20%: 77

  Five blocks of four floors: 80, on a total length of 201.0 meters

Table 7-6: Inventory analysis 2

Item	Available	Needed	Remainder
Land length (meters)	All strips (1 to 12) combined: 1020.54	All typologies combined: 754.20	266.34
1 bedroom apartment	120	115	5
2 bedrooms apartments	200	191	9
3 bedrooms apartments	80	77	3

Cost and time estimate:

a) Cost estimate:

Based on previous projects of similar conditions, we estimate the total cost at 12 millions USD allocated as follow:

- Road construction: considering a total road length of 990 meters (say 1 kilometer), and given that the cost per kilometer of road construction in Kigali city is estimated at 500,000 USD for cobbled road and 1,500,000 USD for tarmac road,
- Cost of buildings: 10 millions USD. Unforeseen: ½ millions USD.

We recommend the cobbled road for following reasons:

- Construction cost: three times cheaper than the tarmac road cost
- Maintenance: easy and cheaper compared to tarmac road
- Life span: the cobbled road is estimated to last for 500 years, while the tarmac starts disintegration at about 20 years
- The cobbled roads construction is work force - based, therefore offering more jobs opportunity to the concerned community. Whereas the tarmac is mostly machine – based construction.

b) Implementation time: estimated at 20 months if there are no budget constraints.

Evaluation of project's success among partners:

The main objective of the Public Private Partnership is to solve problems that initially seem to be a burden to the government alone.

The overall success of this partnership rely on the satisfaction of either involved party.

Table 7-7 summarizes gains and/or profits of involved partners.

From this simulation analysis, on one hand, the Government expects the implementation of the master plan for the concerned area for its integration within the city fabric and the overall wellbeing of the involved community at a little budget as explained in the paragraph above. On the other hand, the private investors expect to not only make short – term profits form the implementation of roads

construction by the full government budget, buildings construction by lease holding, but also long – term profits from the management of remained land after readjustments and total resettlement. Concerning the community, it will profit from resettlement in decent houses within a secure physical environment while maintaining their historical social networking.

Table 7-7: Project evaluation summary

Results	Partners		
	Government	**Investors**	**Citizens**
Expected	• Implementation of the Master Plan by on-site upgrading of the study area • Socio-economic integration of the study area within the overall city fabric • Overall wellbeing of citizens	Making short and long term profits through the implementation of the project phases: Roads and apartments construction	• Accessibility to basic services and utilities Security of land tenure Improved sanitation conditions Secure physical environment Maintaining the social networking among residents
Obtained	After the completion of this project: • The Government goals with regards to citizens wellbeing would be achieved • The guidelines of the Kigali City Master Plan towards this area would be respected	• Short term profits: i) From roads construction by full Government budget ii) From selling out remained apartments units (shown on Table 5 above) all concerned citizens are served • Long-term profits: investors will manage the remaining plots by either constructing commercial buildings, health center, elementary school, multipurpose hall, etc. and/or more apartments units for sale.	• During implementation phase: Residents will be employed as workforce in different construction works, thereby generating income. • After the resettlement process: citizens will live in better and secure physical conditions, improved wellbeing due to better sanitation conditions, feel more secure and stable from the urbanization pressure and related threats.

Merits of street–based on-site informal settlement upgrading over total relocation:

As previously mentioned, the Public Private Partnership already implemented some projects for informal settlements eradication in Kigali city by a total relocation and resettlement of communities. As a showcase, Figure 7-6 shows an example of PPP's total relocation project. In this case, the city of Kigali collaborated with a private developer to relocate and resettle three neighboring informal settlement area A, B and C.

Under this agreement, the private company was entitled to invest about ten (10) millions US dollars, on one hand, to construct a modern apartments lots comprising over 1,000 dwelling units on green fields availed by the city of Kigali.

On the other hand, the developer will invest about US dollars fifty six (56) millions to develop the three ex-slum areas into decent residential estates, as per the Kigali City Master Plan.

In Table 7-8, we will crosscheck the merits and demerits of each approach; thereafter suggest the most commendable informal settlement upgrading approach.

(Satellite view of informal settlements to be razed off (Google Earth image 2020)

New site (photos: author's field survey, December 2019)

Figure 7-6: Total relocation and resettlement PPP's project

In this section, we will compare the above-discussed approaches of informal settlements upgrading by crosschecking their merits and demerits on different socio-economic as well as the physical environment viewpoints impact on the concerned communities. We will consider the total community relocation versus the street – based on-site upgrading under its two scenarios (central collector street and total on-site resettlement) as earlier discussed.

From the parallel cross comparison with respect to key points, the outcome summary will enable us to suggest the most optimized informal settlement upgrading approach that stands out not only as sustainable, but also satisfying all involved Public Private Partnerships parties expectations.

Table 7-8: PPP on-site upgrading and total relocation projects, crosscheck analysis

View points		Total relocation and resettlement		Street – based on-site upgrading			
				Scenario 1		Scenario 2	
		Merits	**Demerits**	**Merits**	**Demerits**	**Merits**	**Demerits**
Resettlement capacity		Full	-	Full by multi-floors apartment	-	Full	-
Social environment		-	Social isolation	Keeps safe social networks	-	Undisturbed	-
Community participation		-	Destabilization Total isolation	Participatory approach	-	Partial involvement	-
Socio-economic impacts	Jobs/business Opportunities	-	High risks of jobs/business losses	Jobs/business kept safe	-	Kept safe	-
	Transport Cost	-	High risks to be increased	Remain unchanged	-	Unchanged	-
	Gross family Income	-	Likely to decrease	Likely to increase	-	Likely to increase	-
	Education system	Elementary school on site	Higher education schools far away	New elementary school in addition to existing education system	-	Undisturbed	-
	Health centers and hospitals	Health post on site	Far from referee hospitals	New health post in addition to existing health system	-	Improved	-
	Spiritual life	-	Deeply affected	Not affected	-	Not affected	-
Physical environment	Open spaces	Wide	-	Improved	Not enough	Enough	-
	Entertainment facilities	Well planned	-	Improved	Not enough	Enough	-
	Accessibility	Planned local access network	- Requires commuting for daily needs - Isolated from city systems	- Most daily routine activities by walk - integrated within the city fabric	Some challenges are faced	Excellent	-
	Infrastructures level	Pre-planned and well organized	-	Availed after opening service streets	Limited level of planning	Good	-
	Interior comfort	Modern finishing and installations	Family size might not match available space	- Harmonized for resettled residents - Progressive self-upgrade	Long term process	Modern finishing	Some challenge for big families

Neighborhood	-	Isolated village	Incorporated within the city fabric, ease of outings and entertainment	-	Well connected to the overall city systems	-
Maintenance	-	Some residents might not afford maintenance cost	Participatory approach: Flexibility to choose maintainable typology	-	Flexibility to choose local available materials	Some residents might not afford
Environmental impact	Positive due to change of slums into decent housing	Negative due to transformation of green lands into residential village	Positive due to new open spaces and improved sanitation	Disposal of demolished debris	Positive	Disposal of debris
Project budget (in millions USD)	Estimated to 45 (for buildings infrastructures, services and land) for 1,000 dwellings units		Estimated to 3.5 (buildings, infrastructures and services) for 112 dwellings units		Estimated to 12 (buildings, infrastructures and services) for 383 dwellings units	
Project period, if no budget constraints (months)	Estimated to 40		Estimated to 10		Estimated to 20	
In summary	In consideration of the above-enumerated viewpoints and their merits and demerits across different approaches of informal settlement upgrading, the street – based on-site upgrading approach present more advantages socially as well as economically. Therefore, we recommend the same for a sustainable informal settlement upgrading approach, not only in Kigali city but also in other informal settlements sites with similar conditions in Rwanda. Either scenario choice will depend on the available budget.					

Chapter 8 General Conclusions

8.1. Recall of thesis objectives and concluding discussions

The conclusions and implications of this work are highlighted below, using the initial research objectives as a framework. The main objective of this study was assessing and analyzing the main reasons behind the existing conditions of housing, public infrastructure, facilities and services within the selected upgradable informal settlement areas.

Towards achieving this objective, we checked out the following existing conditions in line with the Sustainable Development Goals: (i) the interrelationships among different indicators in informal settlements. (ii) The existence of hierarchical clusters among the households. (iii) The status of the dwellings based on the indicators and thresholds for defining informal settlements and slums. (iv) The key infrastructure defining the current socio-economic standpoint of the study precincts. (v) The conditions of the housing in terms of durability and overcrowding, as pre-defined by the United Nations Human Settlement Program. (vi) The requirements in space and density as recommended by the World Health Organization for healthy housing. (vii) The current sanitation situation compliance with the minimum standards set by the World Health Organization.

The historical development context of Kigali city resulted in a complex variety of informal housing typologies. Outcomes from exploratory data exercise of this study has shown that hierarchies do exist among the households, whereby they sort into clusters groups with respect to their socio-economic standpoints, expressed by the differences in levels of housing quality as well as the accessibility to public infrastructures and services. From this analysis, the households divide into three major blocks. The first includes easily accessible and structurally stable houses with good sanitation conditions. The second block encompasses the majority of mud blocks houses, on narrow streets or tiny footpaths with survival sanitation services. The last block englobes structurally critical houses and mostly built in high-risk zones subjected to landslides in heavy rains, their hazardous accessibility inflicts them very poor sanitation status.

Nonetheless, the empirical results reported herein should be considered in the light of some limitations. The first was the allocated budget that constrained us to select the minimum acceptable sample sizes statistical data analysis; the results could have been better with larger samples. The second limitation was the heterogeneity in religions, whereby we omitted some social status related questions that appeared to be taboos or not in line of beliefs of some religious groups. Without this constraint, we could have achieved a better understanding of socio-economic standpoint. The third

limitation was the lack of demographic evolution within the study precincts that could have revealed the pressure exerted on available public infrastructure and services.
Further research should consider larger sample size and design the questionnaire keeping in mind of different religious affiliations to meet their respective beliefs.

According to UN-Habitat's indicators and thresholds for defining slums and informal settlements, our findings from data analysis showed that the study precincts have both types of dwellings at proportions of 24% and 76% respectively. The slums' share in the precincts' dwellings is less than rate of overall Kigali city's slums (49%); this makes a strength for the precincts' on-site upgradability, as fewer dwellings will have to be replaced.

In terms of durability of houses according to UN-Habitat guidelines, this study found that 11% and 30% of dwellings of the first and the second study areas respectively, are built on high slopes subjected to landslides during heavy rain seasons. Moreover, 47% and 30% of houses from both study areas respectively, are structurally unstable. Concerning space requirements, 16% and 21% of households from the first and the second study areas respectively are overcrowded with more than three people sharing one room.

Referring to the World Health Organization (WHO) recommended standards for minimum essential levels for health and hygiene per capita per day, 57% and 26% of the two respective study precincts dwellers use below 20 litters. According to the same organization's guidelines, 56% and 29% of dwellers from the two respective case studies lack access to improved sanitation. Concerning the density requirements, while WHO recommends a maximum of 350 habitable rooms to the hectare, the two respective precincts score an average of 520 and 417. This reveals a high housing demand that out-striped the supply and it worsen the sanitation conditions.

In line with Banashree B et al. (2012) publication endorsed by the UN-Habitat, this research's findings have proven that scarce roads traced within the study precincts played a leading role for housing structure, piped water supply and wastewater drainage. Therefore, we conclude that the accessibility conditions is the key factor governing the households clustering character. Well accessible dwellings are the strongest in terms of construction materials and have a good connectivity to piped water, wastewater and storm water drainage systems as well a good connectivity to the grid electricity. As the street size narrows down, the dwellings' quality and water supply and electricity connectivity reduce until becoming critical or worse. From the simulation analysis, this study has shown that it is possible to transform an informal settlement area into a decent sustainable community through a participatory approach involving the concerned residents, public investors and the government. Hence, we recommend these research findings to the administrators and implementers

of the onsite informal settlements and slums in the developing world's cities as a guidance towards achieving the Sustainable Development Goals for the urban poor.

8.2. Areas for further research

This study has found a street as a tool for onsite informal settlements and slums upgrading. However, the study has also raised various issues that need to be considered for further research as follow:

8.2.1. Functions of the street as a tool for informal settlements transformation

The necessity and importance of tracing streets for on-site informal settlements upgrading goes far beyond the mobility function. This is because they will be the only public spaces available. Therefore, playing a multipurpose role that needs to be studied in details for a successful street-led onsite informal settlements and slums upgrading approach.

(i) Serving and providing the pathway for water pipes, power lines, street lighting and drainage systems.

(ii) Streets will be the setting for informal commerce such as hawking and vending, small manufacturing, repairs, garbage recycling, to mention but a few.

(iii) Hosting the cultural activities processions and celebration performances, serve as children play fields and act as a common space for residents' interactions.

(iv) Serving as outdoor extensions of living space for small houses by hosting daily routine activities such as washing, cooking and socializing.

(v) Increasing the land value, hence motivating residents to invest in upgrading their households.

(vi) Disasters mitigation such as speedy runoff storms damages after heavy rains, fire hazards, wind hazards to mention but a few.

In consideration of the above listed points, a detailed study is needed for the full functionality of the street as a common denominator to necessary socio-economic functions and the overall integration of informal settlements within the city fabric.

8.2.2. Land readjustment model

In order to meet a full functionality of streets in the context of informal settlements, an appropriate land readjustment model needs to be a separate detailed study to solve the current challenges while keeping the community's strong ties and social networks.

8.2.3. Land tenure revision

The current land tenure status will not work for an appropriate land readjustment that solves a complex existing situation. Therefore, a detailed separate study on a convenient land tenure is necessary.

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Annexes

Annexes

Annex 1: Indicators of 50 countries with slums, having only one city with a population from one million people (World Bank, open source data).

3 digit country code	urban pop (% of tot pop) 2017	urban pop (% of tot pop) 2000	Urban pop growth (an. %) 2017	Urban pop growth (an. %) 2000	Pop living in slums (% urban pop) 2017	Pop living in slums (% urban pop) 2000	Fertility rate (births/woman) 2017	Fertility rate (births/woman) 2000	People using at least basic sanit services (% urban pop) 2017	People using at least basic sanit services (% urban pop) 2000	Nurses and midwives (per 1,000 people) 2017	Nurses and midwives (per 1,000 people) 2000	Hospital beds (per 1,000 people) 2017	Hospital beds (per 1,000 people) 2000	Access to electricity (% of pop) 2017	Access to electricity (% of pop) 2000	People using at least basic drinking water services (% pop) 2017	People using at least basic drinking water services (% pop) 2000
AFG	25.25	22.08	3.46	3.39	70.70	62.70	4.63	7.49	43.42	23.52	0.18	0.58	0.39	0.30	97.70	23.00	67.06	27.77
AGO	64.15	50.09	4.39	5.68	55.50	65.80	5.60	6.64	49.88	27.56	0.41	0.99	0.80	0.80	41.96	20.00	55.84	41.14
ARM	63.10	64.67	0.33	-0.63	9.30	14.40	1.75	1.65	93.64	86.90	6.11	4.86	4.20	6.44	100.00	98.90	99.91	95.13
BDI	12.71	8.25	5.72	4.35	57.90	64.30	5.50	6.92	45.82	45.21	0.85	0.19	0.79	0.26	9.30	2.98	60.83	50.66
BEN	46.77	38.33	3.91	3.82	61.50	74.30	4.91	5.96	16.45	8.60	0.76	0.75	0.50	0.23	34.50	21.40	47.89	54.92
BFA	28.74	17.84	5.03	6.72	57.10	65.90	5.27	6.59	19.40	11.29	0.88	0.50	0.40	0.11	17.51	9.14	47.89	54.92
CAF	40.98	37.64	2.16	2.51	93.30	91.90	4.80	5.50	25.32	15.02	0.21	0.41	1.00	0.37	29.83	6.00	46.33	58.26
CIV	50.33	43.16	3.44	3.56	57.00	55.30	4.70	5.87	32.13	21.00	0.56	0.57	0.40	0.17	65.60	47.62	72.87	70.76
COG	66.46	58.70	3.26	3.68	46.90	53.40	4.48	4.87	20.17	11.92	0.63	1.05	1.60	1.60	64.71	33.89	73.22	57.16
DJI	77.65	76.53	1.75	2.55	68.70	65.60	2.79	4.48	63.61	47.24	0.73	0.38	1.40	1.75	60.20	56.40	75.63	75.56
DZA	72.05	59.92	2.87	2.70	11.80	9.96	3.04	2.51	87.59	83.73	2.22	2.19	1.90	2.10	100.00	98.75	93.56	89.84
ETH	20.31	14.74	4.87	4.16	73.90	88.60	4.35	6.54	7.32	3.40	0.83	0.22	0.33	0.20	44.30	12.70	41.06	18.70
GAB	88.98	78.88	3.27	3.40	37.00	38.70	4.01	4.53	47.41	34.46	2.95	0.49	1.30	0.40	91.90	73.60	85.77	79.54
GIN	35.79	30.87	3.70	3.17	82.30	57.30	4.78	6.08	22.72	9.43	0.12	0.46	0.30	0.30	35.40	15.54	61.90	62.73
GMB	60.60	47.87	4.10	5.04	34.80	45.40	5.28	5.88	39.23	57.65	1.54	0.87	1.10	0.80	56.20	34.30	77.99	75.00
GTM	50.68	45.33	2.34	3.18	34.50	48.10	2.92	4.60	65.06	63.30	0.07	1.05	0.44	0.70	93.30	73.32	94.19	85.75
HND	56.46	45.46	2.84	3.85	27.50	34.90	2.50	4.24	81.25	62.64	0.74	0.10	0.64	1.06	86.50	67.41	94.83	84.80
HTI	54.35	35.60	3.07	3.45	74.40	93.40	2.99	4.34	34.70	16.75	0.68	3.26	0.71	0.70	43.80	33.70	65.47	56.24
JOR	90.75	78.27	2.62	1.80	23.40	15.80	2.85	4.11	97.34	98.46	3.36	0.45	1.47	1.70	100.00	98.68	98.94	99.40
KEN	26.56	19.89	4.09	4.48	56.00	54.80	3.57	5.18	29.05	33.59	1.06	0.92	1.40	1.90	63.59	15.36	58.92	47.32
KHM	22.98	18.59	3.28	2.86	55.10	78.90	2.53	3.81	59.23	9.96	0.70	0.99	0.90	0.60	89.07	16.60	78.51	52.35
LAO	34.37	21.98	0.63	6.26	20.80	79.30	2.71	4.31	74.46	28.29	1.26	0.33	1.50	0.90	93.60	43.09	82.06	46.52
LBR	50.70	44.33	3.36	6.14	70.30	68.30	4.39	5.87	16.97	13.52	0.53	0.29	0.80	0.34	24.20	3.00	72.95	62.17
MDG	36.52	27.12	4.52	4.11	77.00	84.10	4.13	5.55	10.51	4.55	0.15	0.67	0.20	0.42	24.10	13.59	54.40	35.77
MLI	41.57	28.36	4.92	5.35	56.30	75.40	5.97	6.90	39.34	16.19	0.36	0.75	0.10	0.24	43.10	9.38	78.26	48.75
MMR	30.32	27.03	1.43	1.84	41.00	45.60	2.17	2.88	64.33	70.89	1.01	3.61	1.04	0.70	69.81	47.00	81.77	46.27
MNG	68.36	57.13	1.96	1.78	42.70	64.90	2.91	2.14	58.48	47.96	3.83	0.33	8.00	7.50	93.84	67.30	83.31	61.82
MOZ	35.45	29.10	4.40	3.29	80.30	78.20	4.92	5.83	29.36	10.46	0.68	0.64	0.70	0.28	29.27	5.98	55.69	19.90
MRT	52.82	38.09	4.46	2.32	73.20	79.90	4.62	5.41	48.44	17.44	1.067	0.591	0.40	0.17	42.90	22.20	70.70	41.00
MWI	16.71	14.61	3.92	3.28	65.10	66.40	4.30	6.10	26.23	20.80	0.44	0.21	3.40	1.34	12.70	4.80	68.83	52.94
NER	16.35	16.19	4.21	4.12	70.10	82.60	7.00	7.68	13.57	5.07	0.27	0.21	0.39	0.12	18.18	6.48	50.27	35.66
NIC	58.30	55.19	1.63	1.83	45.50	60.00	2.43	3.11	74.43	58.37	1.55	0.47	3.80	1.48	86.80	72.83	81.52	81.22
NPL	19.34	13.40	3.39	5.93	54.30	64.00	1.97	3.96	62.05	15.12	2.85	0.66	0.30	0.20	92.41	27.70	88.81	79.99
PAN	67.36	62.20	2.21	3.18	25.80	23.00	2.49	2.74	83.32	61.07	3.09	2.77	2.25	2.21	100.00	81.92	96.38	88.23
PER	77.72	73.04	1.90	2.02	34.20	46.20	2.28	2.85	74.34	64.20	2.21	0.66	1.59	1.47	94.80	72.50	91.13	80.67
PRY	61.30	55.33	1.76	3.19	17.10	17.60	2.45	3.55	89.78	70.34	0.74	1.85	0.83	1.34	99.30	89.15	99.61	75.36
RWA	17.13	14.93	3.04	11.55	53.20	79.70	4.09	5.64	66.57	45.44	1.12	0.41	0.87	1.60	34.10	6.20	57.71	45.44
SDN	34.37	32.50	3.12	2.57	88.40	91.60	4.47	5.47	36.58	20.59	0.70	1.04	0.74	0.81	56.50	23.00	60.27	43.43
SEN	46.74	40.32	3.76	2.72	39.40	48.90	4.70	5.45	51.47	38.89	0.31	0.30	0.30	0.40	61.70	37.74	80.68	59.92
SLE	41.64	35.63	3.14	3.38	75.60	97.00	4.36	6.32	15.65	10.18	0.22	0.46	0.40	0.18	23.40	16.80	60.81	39.88
SOM	44.39	33.25	4.11	4.77	72.10	73.50	6.17	7.63	38.34	19.67	0.11	0.19	0.87	0.42	33.41	7.40	52.44	19.60
TCD	22.86	21.64	3.87	3.84	88.20	93.90	5.85	7.35	8.34	11.55	0.23	0.26	0.40	0.30	10.90	2.70	38.70	41.41
TGO	41.16	32.91	3.79	4.33	51.20	62.10	4.38	5.42	16.13	9.99	0.42	0.35	0.70	0.90	48.00	16.96	65.13	45.88
THA	49.20	31.39	1.89	2.38	25.00	26.00	1.53	1.67	98.75	92.02	2.96	1.49	2.10	2.20	99.90	82.10	99.93	93.63
TUN	68.64	63.43	1.57	1.60	8.20	8.00	2.22	2.14	90.92	77.08	2.51	2.85	2.18	1.73	100.00	94.80	96.25	87.90
TZA	33.05	22.31	5.20	4.10	50.70	70.10	4.95	5.69	29.91	4.32	0.58	0.38	0.70	1.70	32.73	9.59	56.73	27.25
UGA	23.20	14.79	6.25	5.79	53.60	75.00	5.10	6.87	18.47	17.39	1.47	0.71	0.50	0.70	31.82	7.74	49.10	26.75
YEM	36.02	26.27	4.17	4.82	60.80	67.20	3.89	6.31	59.05	42.10	0.77	0.70	2.30	0.59	79.20	49.98	63.47	37.85
ZMB	42.98	34.80	4.21	1.38	54.00	57.20	4.72	6.04	26.37	23.66	1.30	0.71	2.00	1.46	40.30	16.70	59.96	49.49
ZWE	32.24	33.76	1.28	1.72	25.10	3.30	3.71	3.75	36.22	45.93	2.60	0.74	1.70	2.10	40.48	33.88	64.05	71.73

3 digit country code	GDP per capita (USD) 2017	GDP per capita (USD) 2000	Unemployment rate (% of total labor force) 2017	Unemployment rate (% of total labor force) 2000	Age dependency ratio (% of working-age pop) 2017	Age dependency ratio (% of working-age pop) 2000	Children out of school (% primary school age) 2017	Children out of school (% primary school age) 2000	Lower secondary completion rate(% of relevant age group) 2017	Lower secondary completion rate(% of relevant age group) 2000	Primary completion rate (% relevant age group) 2017	Primary completion rate (% relevant age group) 2000	Pupil-teacher ratio, primary 2017	Pupil-teacher ratio, primary 2017
AFG	556.30	179.43	11.06	11.52	86.00	104.86	43.70	73.23	53.08	16.03	84.41	27.58	47.98	33.19
AGO	4095.81	556.84	7.12	3.84	96.82	99.07	18.40	54.65	25.00	17.37	54.00	29.20	50.03	41.75
ARM	3914.50	622.74	17.70	11.05	46.09	55.83	7.69	12.87	89.04	86.46	91.99	93.90	15.42	16.07
BDI	293.00	136.46	1.49	1.88	91.36	110.84	4.33	58.56	39.72	7.88	67.67	24.35	49.61	55.36
BEN	1136.59	511.40	2.46	0.83	84.89	93.78	2.97	37.52	45.85	15.20	64.44	37.80	43.57	52.65
BFA	738.27	254.72	6.22	2.57	90.80	98.16	22.99	63.25	37.01	6.54	63.52	25.42	40.68	48.88
CAF	450.90	251.21	3.74	3.95	90.40	87.99	33.44	52.38	9.81	8.53	40.87	23.84	83.41	88.63
CIV	2111.03	651.31	3.27	4.51	81.84	86.77	11.23	43.49	45.81	23.66	71.60	43.29	42.43	44.97
COG	2223.85	1029.58	9.76	19.92	80.46	81.42	10.71	48.18	50.10	27.23	71.61	31.44	44.44	60.48
DJI	2914.38	768.18	10.38	10.72	52.53	78.52	40.03	72.96	47.12	14.46	62.98	26.69	30.42	39.54
DZA	4044.28	1765.02	11.80	29.77	55.80	63.05	0.51	9.25	80.05	51.83	105.64	80.17	24.23	28.40
ETH	768.52	124.46	2.12	3.49	80.96	98.27	14.38	59.73	44.00	8.31	54.11	22.32	55.07	67.34
GAB	7230.40	4125.72	19.98	17.36	67.80	85.97	9.09	17.00	37.00	21.60	71.90	68.94	24.53	51.94
GIN	856.57	363.48	4.32	4.50	89.23	99.45	21.91	54.24	49.71	11.31	59.67	31.67	47.15	45.59
GMB	676.66	594.15	9.14	9.42	88.65	98.56	19.85	35.48	56.01	40.20	69.27	66.13	38.68	37.44
GTM	4451.45	1664.30	2.46	2.77	65.97	91.26	11.69	14.32	56.94	29.60	79.94	55.51	20.18	32.56
HND	2453.73	1080.46	5.53	3.92	58.49	86.93	17.46	14.25	45.76	24.66	81.62	69.38	25.60	34.06
HTI	765.73	811.53	13.73	8.23	62.50	79.74	41.89	57.45	48.20	24.85	50.15	48.52	33.41	33.41
JOR	4162.82	1651.62	15.11	13.70	63.12	74.43	19.79	8.70	58.74	83.97	71.34	94.47	21.04	23.69
KEN	1572.34	397.48	2.69	2.86	74.23	90.56	18.77	35.69	79.20	76.24	99.68	86.32	30.65	34.44
KHM	1385.26	302.58	0.68	1.07	55.48	80.74	9.20	6.83	54.24	22.39	89.55	41.16	41.66	50.12
LAO	2423.85	325.19	0.66	1.95	75.40	85.75	5.28	24.14	65.48	35.25	91.17	67.39	22.34	30.14
LBR	698.70	306.83	3.00	2.28	80.84	92.75	21.36	48.38	44.21	38.98	60.60	66.63	22.32	38.27
MDG	515.29	293.61	1.73	5.80	78.26	99.47	1.96	33.23	36.56	13.31	67.58	36.71	39.81	47.95
MLI	830.56	269.87	7.33	5.32	100.96	58.75	32.59	55.96	29.70	15.92	49.61	31.07	38.22	65.30
MMR	1291.54	190.61	1.55	0.79	47.95	62.50	2.34	10.27	61.07	33.19	95.40	76.46	23.05	32.77
MNG	3669.42	474.22	6.36	6.14	51.39	91.71	0.59	7.14	105.17	62.72	91.51	86.95	30.38	32.58
MOZ	461.42	319.36	3.31	2.84	91.78	87.87	10.13	42.98	22.82	3.87	51.99	16.58	52.44	63.99
MRT	1600.88	676.57	9.58	9.87	76.66	96.86	21.68	39.93	36.33	13.75	69.71	44.28	36.35	44.99
MWI	356.72	156.39	5.71	5.93	88.49	102.90	1.77	1.94	21.56	33.05	80.35	63.48	58.68	63.22
NER	516.89	197.34	0.49	1.47	111.34	76.83	33.51	73.10	17.79	4.78	62.26	18.38	36.34	40.67
NIC	2159.16	1007.50	3.30	7.52	55.28	80.93	3.68	14.85	72.70	44.50	84.88	65.77	30.22	35.66
NPL	911.44	229.49	1.40	1.80	58.73	64.75	3.52	27.89	94.60	42.38	121.72	66.75	22.42	38.04
PAN	15150.35	4060.32	3.90	3.73	54.44	60.01	13.22	4.70	76.80	45.47	89.80	92.05	21.96	24.74
PER	6710.51	1955.59	3.46	5.74	51.91	64.75	3.40	0.86	93.57	75.33	97.45	96.84	17.94	28.74
PRY	5680.58	1663.61	4.61	9.30	56.12	74.92	10.72	0.89	73.23	70.18	88.82	91.03	24.16	26.96
RWA	772.32	260.78	1.06	0.76	75.40	92.36	2.32	14.31	37.66	1.74	78.20	25.08	57.86	54.03
SDN	1111.87	366.17	17.06	15.44	78.86	88.19	38.30	41.25	57.54	52.13	61.69	57.55	25.30	32.00
SEN	1361.70	604.65	6.61	5.61	86.26	91.99	24.22	41.16	37.38	13.44	61.20	39.03	32.81	50.92
SLE	499.38	138.70	4.50	3.41	79.66	90.34	0.51	55.45	50.91	20.38	70.19	67.86	39.44	37.26
SOM	309.06	126.92	11.41	11.76	98.44	99.32	85.55	80.19	49.00	28.40	42.00	57.00	35.52	35.52
TCD	665.95	165.76	1.85	1.03	99.47	107.17	32.04	48.63	15.23	8.81	37.92	22.15	56.89	68.62
TGO	626.09	302.21	2.13	4.46	80.14	85.57	7.39	12.64	46.58	22.45	91.61	66.63	40.13	37.46
THA	6592.91	2007.74	2.03	2.39	40.43	43.91	1.73	1.08	78.59	27.15	93.45	84.89	16.89	20.79
TUN	3481.23	2211.83	15.38	14.94	47.41	56.94	1.16	4.77	73.33	70.66	95.05	86.63	16.57	23.21
TZA	1004.84	410.95	8.36	3.07	88.32	89.96	15.44	46.43	30.80	6.42	68.70	50.54	47.15	40.28
UGA	747.20	261.87	1.79	2.83	97.01	108.10	4.36	42.57	26.43	14.92	52.67	60.41	42.66	59.43
YEM	882.40	554.45	13.15	11.57	74.99	107.11	7.55	42.85	53.10	47.08	72.30	58.85	26.93	22.37
ZMB	1534.87	345.69	11.63	12.93	90.46	95.32	14.90	33.06	54.77	24.03	79.97	59.03	43.32	49.88
ZWE	1548.17	563.06	5.17	5.64	83.47	82.00	10.31	10.50	71.13	51.19	98.12	93.23	36.41	37.04

Annex 2: Indicators of 50 cities with slums (World Bank, open source data)

Country	City	City code	X	Y	X	Y
			2017		2000	
Afghanistan	Kabul	KAB	70.7	62.3	62.7	29.6
Algeria	Alger	ALG	11.8	89.7	10.0	91.4
Angola	Luanda	LAD	48.6	64.3	65.8	47.5
Armenia	Yerevan	EVN	9.3	99.7	14.4	92.3
Benin	Cotonou	COO	58.8	26.5	74.3	19.0
Burkina Faso	Ouagadougou	OUA	57.1	39.4	65.9	50.3
Burundi	Bujumbura	BJM	47.7	41.7	64.3	40.6
Cambodia	Phnom Penh	PNH	45.1	95.8	78.9	46.4
Central Afr. Rep.	Bangui	BGF	95.4	49.1	91.9	26.1
Chad	N'Djamena	NDJ	86.9	30.1	93.9	25.5
Congo	Brazzaville	BVZ	47.8	27.2	53.4	16.3
Cote d'Ivoire	Yamoussoukro	YAM	60.1	46.1	55.3	39.0
Djibouti	Djibouti	JIB	64.5	76.3	65.6	58.1
Ethiopia	Addis Ababa	ADD	64.3	19.6	88.6	16.0
Gabon	Libreville	LBV	36.6	48.7	38.7	35.5
Gambia	Banjul	BJL	27.1	45.5	45.4	50.5
Guatemala	Nueva	NUE	31.0	79.2	48.1	81.5
Guinea	Conakry	CKY	50.1	33.8	57.3	23.6
Haiti	Port-au-Prince	PAP	65.9	43.8	93.4	27.8
Honduras	Tegucigalpa	TGU	38.6	85.3	34.9	75.8
Jordan	Amman	AMM	23.4	97.4	15.8	98.6
Kenya	Nairobi	NBO	46.5	34.7	54.8	35.7
Laos	Vientiane	VTE	21.1	95.4	31.4	67.1
Liberia	Monrovia	ROB	70.3	27.7	68.3	25.3
Madagascar	Antananarivo	TNR	61.2	17.8	84.1	9.4
Malawi	Lilongwe	LLW	65.1	34.1	66.4	32.0
Mali	Bamako	BKO	47.2	53.3	75.4	33.9
Mauritania	Nouakchott	NKO	73.2	74.8	79.9	34.5
Mongolia	Ulaanbaatar	ULN	38.3	66.3	64.9	64.2
Mozambique	Maputo	MPM	77.2	52.3	78.2	31.7
Myanmar	Nay Pyi Taw	NPT	56.1	76.0	45.6	82.5
Nepal	Kathmandu	KTM	49.3	67.3	64.0	32.6
Nicaragua	Managua	MGA	42.2	83.7	60.0	70.5
Niger	Niamey	NIM	58.8	43.8	82.6	25.2
Panama	Panama City	PTY	22.1	92.3	23.0	71.5
Paraguay	Asunción	ASU	17.1	94.2	17.6	85.1
Peru	Lima	LIM	33.1	79.6	46.2	77.2
Rwanda	Kigali	KGL	42.1	51.9	79.7	63.3
Senegal	Dakar	DKR	29.5	65.0	48.9	63.1
Sierra Leone	Freetown	FRE	59.7	25.7	97.0	20.4
Somalia	Mogadishu	MGQ	72.1	61.1	73.5	44.7
Sudan	Khartoum	KRT	88.4	60.1	91.6	40.5
Tanzania	Dar es Salaam	DSM	40.1	42.6	70.1	10.6
Thailand	Bangkok	BKK	23.7	99.2	26.0	89.2
Togo	Lomé	LOM	54.3	28.6	62.1	24.4
Tunisia	Tūnis	TUN	8.1	95.3	8.0	93.6
Uganda	Kampala	KAM	48.3	26.1	75.0	30.6
Yemen	Sana'a	SAH	66.2	87.9	67.2	85.8
Zambia	Lusaka	LUN	54.6	36.2	57.2	45.9
Zimbabwe	Harare	HRE	33.5	46.2	3.3	65.0

X: population living in slums (% of urban population)

Y: people with access to basic sanitation services (% of urban population)

Annex 3: First case study area raw data

Respondents	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
	House scape		Houses characteristics								Accessibility		Sanitation		
	Open space (%)	Number of trees	Main building area (m2)	Number bed rooms	Family size	House age (years)	Exterior opening (m2)	Foundation depth (cm)	Structuralcracks (No)	Wall width (cm)	Distance to nearest access (m)	Access width (m)	Daily water use (l)	Wastewater/ day (l)	Distance to sewer (m)
1	18	2	56	2	6	10	3	50	2	26	41	1.4	40	35	49
2	27	4	64	3	5	13	2	55	1	25	38	1.6	40	30	50
3	21	1	48	2	3	12	2	40	2	25	20	2.2	50	40	18
4	32	0	61	3	7	15	3	60	0	22	5	6	200	150	8
5	10	1	72	4	8	8	4	60	1	22	4	6	180	150	9
6	31	0	60	3	4	16	3	55	0	22	3	6	200	120	7
7	24	3	59	3	7	13	2	50	1	25	29	1.8	60	50	33
8	38	1	62	2	5	17	3	60	0	22	6	4	160	120	5
9	23	2	74	4	3	13	3	65	0	22	3	4	180	150	10
10	19	4	71	3	5	11	4	65	0	25	5	4	200	150	8
11	8	0	72	4	7	8	3	60	1	22	3	6	220	180	11
12	37	5	68	3	6	16	5	60	0	22	6	3.2	160	130	9
13	49	2	53	3	4	21	3	0	4	29	47	1.4	60	30	54
14	24	2	69	3	6	15	3	50	2	25	6	6	150	100	5
15	38	1	58	2	3	16	4	50	1	25	26	2.2	100	80	19
16	12	3	83	4	5	9	4	60	0	22	7	4	120	80	10
17	16	1	78	3	2	10	5	55	0	22	4	6	160	120	10
18	31	0	62	3	7	14	3	50	2	25	31	1.4	60	50	25
19	29	4	66	3	6	12	4	50	3	26	25	1.8	80	60	28
20	41	2	59	2	4	19	2	50	2	26	19	1.8	120	100	17
21	24	3	69	3	3	13	4	55	1	22	6	4	160	100	4
22	8	1	58	2	5	8	3	50	4	25	26	1.4	80	50	31
23	2	0	62	3	6	4	2	50	2	25	30	1.8	80	60	24
24	25	3	71	4	7	13	4	60	1	22	5	6	180	140	8
25	39	4	84	4	7	16	3	65	1	22	8	4	160	120	6
26	42	5	75	4	8	19	4	60	0	22	3	6	200	150	9
27	37	2	98	5	6	15	5	65	0	25	11	4	120	80	13
28	36	3	69	3	8	17	3	55	2	25	18	2.2	160	120	13
29	15	1	81	4	7	8	4	60	1	22	7	4	120	80	13
30	6	0	47	1	3	3	2	0	4	30	55	0.9	60	40	41
31	37	3	83	4	7	16	3	55	2	22	9	1.8	180	120	13
32	16	5	68	3	6	7	4	60	1	22	4	4	220	180	9
33	48	1	95	4	5	20	2	65	0	25	5	4	180	140	12
34	36	0	76	3	8	17	3	60	0	22	7	6	160	120	8
35	21	4	72	3	9	11	3	55	0	26	23	2.2	80	50	29
36	53	1	67	3	5	33	4	55	1	25	42	1.2	80	60	32
37	32	1	91	4	8	15	3	60	1	22	4	6	150	100	7
38	4	5	52	2	5	2	2	40	3	26	29	1.6	60	50	38
39	51	2	79	3	2	30	4	50	0	25	8	4	200	140	7
40	21	1	63	3	5	11	3	55	0	26	24	2.2	100	80	18
41	19	1	52	2	4	9	2	40	2	26	32	1.8	50	40	37
42	26	0	78	3	6	12	3	60	1	22	12	2.2	120	80	19
43	20	6	64	3	7	8	4	50	1	25	6	4	80	60	10
44	27	2	75	3	8	14	2	50	2	25	24	2.2	80	50	19
45	22	1	104	5	4	10	4	70	0	22	6	6	180	160	4
46	38	3	68	3	6	17	2	50	3	26	27	1.8	60	40	31
47	59	3	74	3	7	38	3	55	1	26	19	2.2	120	100	25
48	4	1	51	2	4	2	4	40	2	26	38	1.4	60	50	44
49	0	2	43	1	5	2	2	0	5	29	36	1.8	60	30	30
50	33	5	66	3	4	15	2	50	2	26	27	1.8	100	80	25
51	15	1	76	3	7	5	4	50	1	25	21	1.8	80	40	24
52	21	3	81	4	3	9	3	60	0	22	6	4	160	100	4
53	46	2	110	5	8	21	5	65	0	22	3	6	250	180	7
54	33	0	52	2	6	18	3	40	3	26	23	1.6	80	50	30
55	7	2	45	2	3	3	3	0	4	30	56	0.9	40	20	43

56	39	4	78	3	8	13	3	50	2	25	18	2.2	80	60	23
57	17	1	93	4	7	7	4	60	1	26	24	2.2	80	50	27
58	6	1	84	4	5	3	4	60	0	22	5	6	200	140	6
59	3	0	35	1	3	3	3	0	4	30	41	0.9	40	30	40
60	18	1	48	1	6	7	2	0	5	29	36	1.6	40	20	41
61	25	4	81	4	5	9	2	55	0	22	6	4	200	150	9
62	20	2	65	3	8	8	3	50	2	26	25	2.2	120	100	20
63	9	1	54	2	6	3	2	40	2	26	36	2.2	80	50	37
64	45	2	71	3	5	22	3	50	0	25	12	2.2	100	60	8
65	0	0	32	1	4	1	1	0	3	30	34	1.8	100	80	39
66	31	2	68	3	7	13	2	40	2	26	17	1.2	60	50	21
67	13	0	54	2	4	6	2	30	3	26	24	1.6	80	40	27
68	38	3	77	3	6	17	3	55	0	25	31	1.4	100	60	25
69	16	2	64	3	5	9	2	55	1	26	25	1.4	80	60	20
70	34	2	82	4	3	14	3	60	0	22	5	4	180	140	7
71	51	4	74	4	6	31	2	55	1	22	3	6	160	140	9
72	21	2	57	2	4	9	2	40	2	25	9	6	180	120	6
73	36	1	81	4	5	17	3	55	2	25	17	6	120	80	23
74	58	0	79	4	7	37	4	50	1	26	24	2.2	80	60	14
75	13	1	80	3	3	3	2	50	3	22	4	6	200	150	7
76	9	1	61	3	6	2	3	40	2	26	23	1.8	60	40	25
77	57	4	82	3	7	35	3	55	0	25	19	1.8	80	50	26
78	13	2	59	2	3	3	2	40	3	26	20	1.6	60	50	15
79	9	0	65	3	2	4	3	50	2	25	16	2.2	140	100	19
80	0	0	29	1	4	1	3	0	6	29	52	0.9	60	50	57
81	63	4	72	3	5	41	4	55	0	22	7	4	200	150	5
82	5	1	62	3	6	2	4	50	2	25	18	2.2	100	85	25
83	22	3	69	3	6	9	2	55	0	25	25	1.8	80	60	21
84	43	2	81	3	4	18	3	60	0	22	5	6	180	120	3
85	27	0	63	2	3	12	3	40	2	26	31	1.8	60	50	28
86	31	2	60	2	6	14	4	40	3	26	23	1.6	100	80	27
87	26	4	75	3	5	11	4	55	0	25	25	1.2	90	50	21
88	72	1	67	3	8	53	2	50	0	25	19	1.8	120	80	22
89	36	1	75	3	6	17	3	55	1	22	10	2.2	180	140	8
90	24	1	78	4	4	11	3	55	0	22	11	2.2	160	140	12
91	49	3	53	2	2	23	3	40	3	26	32	1.4	60	50	28
92	38	2	86	4	5	17	4	60	0	22	5	6	240	180	7
93	29	1	77	3	7	14	3	50	2	26	24	1.8	60	40	18
94	6	3	50	2	5	4	2	0	4	30	46	0.9	40	30	40
95	41	4	73	3	4	23	3	55	1	22	5	6	240	200	10
96	53	3	59	2	5	33	3	40	2	25	23	2.2	80	50	31
97	22	1	85	4	6	9	4	55	1	25	29	1.8	80	60	21
98	48	2	75	3	3	27	3	50	0	25	31	1.2	80	50	25
99	51	5	93	4	7	29	3	60	0	22	6	4	240	180	9
100	15	2	87	4	5	5	4	60	1	25	26	1.8	60	40	22
101	30	1	112	5	4	13	4	70	0	22	6	6	180	130	11
102	17	0	81	3	2	7	4	60	0	22	3	6	200	150	5
103	5	0	52	2	6	2	2	40	3	25	31	1.4	60	40	36
104	32	3	80	3	8	13	3	60	1	22	5	4	220	150	2
105	19	1	51	2	5	8	2	0	5	30	41	1.2	40	20	31
106	60	1	79	3	4	38	3	60	1	22	4	6	160	120	7
107	14	2	62	3	5	4	3	50	2	25	26	1.6	80	60	29
108	32	4	83	3	4	17	3	55	1	26	29	1.4	100	50	33
109	7	1	61	2	3	3	4	40	3	26	32	1.4	60	40	26
110	0	0	31	1	4	2	2	0	3	28	24	1.8	60	50	22
111	43	2	82	4	6	24	3	60	0	22	11	2.2	160	100	15
112	12	1	72	3	4	5	3	55	1	25	20	2.2	80	60	19
113	69	4	95	4	7	43	4	65	0	22	6	4	180	120	4
114	6	3	62	3	8	3	3	40	3	26	28	1.2	80	60	25
115	40	0	86	4	2	17	3	55	1	22	3	6	220	180	5
116	28	4	59	3	4	11	3	30	4	26	27	1.4	100	70	31
117	70	2	74	3	6	48	2	50	2	26	32	0.9	80	50	33
118	22	1	57	2	7	14	3	40	2	26	24	1.6	60	40	27
119	38	1	86	4	4	23	3	50	2	25	8	2.2	200	150	11
120	48	4	76	3	3	31	4	50	3	26	11	2.2	180	150	7
121	31	2	105	4	7	19	5	80	0	22	5	6	220	180	9
122	3	3	41	1	8	2	2	0	6	31	46	1.2	40	30	40
123	12	0	51	1	4	3	3	30	3	26	28	1.8	60	50	32
124	53	2	82	3	5	33	4	55	1	22	6	4	140	100	9
125	10	1	77	3	2	3	3	50	1	26	32	1.6	60	40	28
126	36	4	53	2	1	19	3	40	2	26	19	1.6	120	90	16
127	61	2	68	3	4	42	2	55	2	25	28	1.2	80	60	25
128	28	3	72	3	5	13	3	55	1	26	31	0.9	60	50	36
129	30	1	84	4	6	17	4	60	0	22	4	6	240	200	7
130	44	1	72	3	3	21	3	50	0	25	27	1.4	40	20	20

131	19	0	61	3	7	9	2	40	2	25	10	4	180	150	7
132	61	3	63	2	2	36	3	40	0	26	23	1.8	100	90	26
133	40	1	92	4	8	19	3	65	0	22	9	2.2	220	150	12
134	29	3	60	3	1	13	2	40	2	26	33	1.2	60	30	37
135	36	5	81	3	4	23	3	55	1	22	8	2.2	160	120	11
136	15	2	50	2	6	8	3	40	3	25	27	1.8	80	50	22
137	64	1	89	4	2	31	3	60	1	22	7	4	140	80	11
138	31	2	64	3	7	16	2	50	1	25	18	1.8	120	100	14
139	27	3	59	2	5	11	2	40	2	26	32	1.4	40	30	26
140	42	2	98	4	8	28	3	65	0	22	5	6	240	200	10
141	6	1	51	2	5	4	3	30	3	26	33	1.2	40	30	36
142	45	0	78	3	6	30	4	55	1	22	7	4	220	150	12
143	14	1	54	2	5	5	3	0	2	31	38	1.2	50	40	34
144	8	1	61	3	3	3	3	50	2	26	24	1.8	80	50	20
145	0	0	32	1	7	3	1	0	3	29	36	1.2	60	40	32
146	67	2	79	3	8	45	2	55	0	26	25	2.2	80	60	31
147	25	2	57	1	4	16	3	40	0	26	22	1.8	80	50	18
148	18	1	46	2	6	11	2	0	4	30	34	1.6	70	50	31
149	23	4	83	3	5	10	3	60	0	22	6	4	200	150	10
150	20	2	91	4	8	9	3	60	0	22	7	6	160	100	12
151	37	6	66	3	4	22	2	50	1	26	32	1.4	60	50	34
152	9	2	51	2	5	4	2	40	2	26	26	2.2	60	50	22
153	34	1	83	3	6	20	2	60	0	22	4	6	180	130	7
154	41	3	79	3	8	23	3	60	0	25	27	1.4	70	60	30
155	28	1	54	2	3	17	3	30	3	26	23	1.6	60	40	20
156	1	1	31	1	4	3	2	0	3	29	41	1.2	40	30	46
157	27	2	81	4	5	11	3	55	2	25	31	0.9	50	30	40
158	18	3	53	2	6	12	3	40	2	26	28	1.4	60	40	24
159	47	1	92	4	2	25	4	60	0	22	7	6	200	150	11
160	70	1	52	2	5	44	3	0	3	29	37	1.2	60	50	33
161	76	2	43	1	6	43	2	0	4	30	34	1.2	60	50	39
162	22	4	85	3	4	9	4	55	0	22	5	4	240	200	8
163	8	1	67	3	8	3	3	50	0	26	25	2.2	80	40	22
164	63	0	72	3	4	29	4	50	2	26	31	1.6	60	40	34
165	36	2	85	4	6	17	3	60	0	22	7	6	120	90	3
166	39	1	63	3	3	21	2	40	3	25	27	1.6	100	60	31
167	52	4	56	2	5	32	3	30	3	25	30	1.4	60	50	27
168	3	1	30	1	4	2	2	0	6	29	33	1.2	80	60	37
169	42	1	74	3	3	19	3	50	2	26	20	1.8	80	50	16
170	29	0	67	3	3	13	2	50	1	26	29	1.8	40	30	23
171	32	2	65	2	6	12	4	50	2	25	28	1.8	60	40	25
172	53	1	82	3	7	31	3	60	0	22	6	6	140	120	3
173	9	1	70	3	3	3	4	50	2	26	28	2.2	50	40	32
174	41	2	92	4	8	23	3	60	0	22	10	4	220	180	7
175	56	2	74	3	2	32	3	50	0	25	32	2.2	40	20	28
176	8	0	42	1	5	3	2	0	3	30	36	1.6	40	30	39
177	31	1	78	3	7	18	3	55	0	22	7	6	180	150	4
178	14	2	62	2	5	10	2	40	2	26	29	1.2	60	30	32

Annex 4: **Door-to-door questionnaire (second study area)**

QUESTIONNAIRE ON UPGRADING INFORMAL SETTLEMENTS

Respondent personal details (for statistics purpose)

1. Age: ☐ years
2. Sex: ☐ M ☐ F
3. Occupation: ☐ employed

   ☐ unemployed
4. Household status: ☐ our house ☐ rented house
5. Land registration: ☐ registered ☐ not yet registered

Please write here any comment, idea or advice about this survey

SECTION I: HOUSING

Questions in this section aim to have general information of the states and conditions of existing building in order to have the basis of upgrading possibilities propositions.

1. **House usage**
    1. ☐ Residential
    2. ☐ Commercial
2. **House foundation**
    a. Does this house have foundation?
        1. ☐ Yes
        2. ☐ No

If yes, please answer the following:

b. Construction materials of foundation
    1. ☐ Stones with cement mortar
    2. ☐ Stones with mud mortar
    3. ☐ N/A

c. Depth of foundation
    1. ☐ 50 cm – 1m
    2. ☐ Less than 50cm
    3. ☐ N/A

3. **Elevation**

a. Existence of water proof course
    1. ☐ Yes
    2. ☐ No

b. What are the building materials for elevation?
    1. ☐ Burnt bricks with cement mortar
    2. ☐ Burnt bricks with mud mortar
    3. ☐ Earth blocks with mud mortar
    4. ☐ Wood and mud

c. Existence of a lintel.

Does the house have a lintel?

1. ☐ Yes
2. ☐ No

d. plastering materials

1. ☐ Cement plaster
2. ☐ Mud plaster covered by cement plaster
3. ☐ Mud plaster

4. Roofing materials

a. Roof members

1. ☐ Steel members
2. ☐ Wood members
3. ☐ Combination of wood and steel members

b. Roof covering

1. ☐ Galvanized iron sheets
2. ☐ Local handmade tiles
3. ☐ Industrials tiles

5. House units

Existence of:

1. Living room: 1. ☐ Yes 2. ☐ No
2. Kitchen: 1. ☐ Yes 2. ☐ No
3. Bathroom: 1. ☐ Yes 2. ☐ No
4. Storeroom: 1. ☐ Yes 2. ☐ No
5. Number of bed rooms: ☐ 1 ☐ 2 ☐ 3 ☐ 4
6. ☐ N/A

6. Family size

Permanent family members:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ N/A

7. Age of the house

In years:

☐ 0-5 2. ☐ 5-10 3. ☐ 10-20 4. ☐ 20-30

8. Structural state of the house

a. Presence of:

1. ☐ Horizontal cracks
2. ☐ Vertical cracks
3. ☐ Both vertical and horizontal cracks
4. ☐ no cracks

b. Presence of moisture in walls

1. ☐ Yes
2. ☐ No

c. Excessive settlement

Is there any visible unequal settlement throughout the house contour? 1.☐ Yes 2.☐ N0

SECTION II: SANITATION

These questions aim at collecting information about the current hygienic conditions as a basis for their improvement towards reduction and/or eradication of poor hygiene related diseases.

A. Daily water use

How many jericans do you use daily for?

1. Kitchen (food preparation, cooking , dish washing)

1.☐ 1 2.☐ 2 3.☐ 3 4.☐ 4 5.☐ N/A

2. Laundry (cloths washing, house cleaning)

1.☐ 1 2.☐ 2 3.☐ 3 4.☐ 4 5.☐ N/A

3. Bathing

1.☐ 1 2.☐ 2 3.☐ 3 4.☐ 4 5.☐ 5 6.☐ N/A

4. Other uses (car washing, gardens watering, domestic animals, etc.)

1.☐ 1-5 2.☐ 5-10 3.☐ N/A

In case you have water system toilet type:

5. How many toilet seats?

1.☐ 1 2.☐ 2 3.☐ N/A

6. Approximate the daily times of toilet flushing

1. ☐ 5-10 2.☐ 10-15 3. ☐ 15-20 4. ☐ N/A

B. Solid wastes generation

1. **Organic (biodegradable) wastes**

Approximate number of baskets of wastes per week of:

a. Food related organic wastes (food preparation wastes and food leftovers)

1. ☐ 1 2.☐ 2 3.☐ 3 4.☐ 4 5.☐ 5 6.☐ N/A

b. Other organic wastes (waste papers, paper shopping bags, etc.)

1.☐ 1 2.☐ 2 3. ☐3

2. **Plastic related wastes**

(Old or broken domestic appliances, plastic bags, etc.)

Number of baskets per month

1.☐ 1 2. ☐ 2 3. ☐3

3. **Metals related wastes**

(Old metallic domestic equipment and appliances)

1.☐ 1 basket; 2.☐N/A

SECTION III: PUBLIC NETWORKS

3.1. TRANSPORTATION

Transport accessibility

1. What kind of vehicle can access your house?

Check all that apply:

1. ☐No access at all
2. ☐ Two wheels vehicle
3. ☐Small size cars
4. ☐All passenger car sizes
5. ☐Trucks and buses

2. What time do you spend to access the nearest road for public transport?

1. ☐ 0 to 10 minutes
2. ☐ 10 to 20 minutes
3. ☐ 20 to 30 minutes

3. Estimate waiting time for buses in peak hours (6 – 8 am , 5 -7 pm)

1. ☐ 5 – 15 minutes
2. ☐ 15 -30 minutes
3. ☐ 30 -60 minutes
4. ☐ N/A

4. What is your average waiting time at the bus stop?

1. ☐ Less than 5 minutes
2. ☐ Less than 15 minutes
3. ☐ Less than 30 minutes
4. ☐ N/A

5. What is your average journey time to town

Please specify ☐

6. How often per week, do you miss the bus to commute to work?

1. ☐ 1 time 2. ☐ 2 times 3. ☐ 3 times 4. ☐ N/A

7. In case you miss a bus, which alternative do you dispose to get to work?

1. ☐ On foot
2. ☐ car taxi
3. ☐ Motor cycle taxi
4. ☐ N/A

8. Would you like more off peak services?

1. ☐ Yes
2. ☐ N/A

9. If yes, would you use more off peak services in the:

1. ☐ Early morning
2. ☐ evenings
3. ☐ N/A

10. Do you find the bus journey

1. ☐ Comfortable
2. ☐ Crowded but acceptable
3. ☐ N/A

11. How would you rate the following on public transport (buses)?

(Please circle your choice, 1 is the lowest and 10 is the highest).

1. Reliability: 1 2 3 4 5 6 7 8 9 10
2. Safety: 1 2 3 4 5 6 7 8 9 10
3. Frequency: 1 2 3 4 5 6 7 8 9 10
4. Cost: 1 2 3 4 5 6 7 8 9 10

In case, you access local road:

12. Can two vehicles cross? 1. ☐ Yes 2. ☐ No 3. ☐ N/A

13. Construction materials for bridges

1. ☐ Wood without foundation
2. ☐ Wood with stone foundation
3. ☐ Reinforced concrete bridge
4. ☐ culvert
5. ☐ N/A

14. Road surface conditions

Check all that apply

1. ☐ Muddy and slippery in rain periods
2. ☐ Dusty in dry periods
3. ☐ Stones paved roads
4. ☐ All type of passenger cars can circulate
5. ☐ Highly rough surface, circulation possible for jeeps only
6. ☐ N/A

3.2. WATER SUPPLY

1. Estimate the quantity of water used per day in unit that is most convenient to you, (Fill the number in the box below)…… (Converted into litters)

☐ Litters/day

2. Main water source:

Where do you most often get water?

1. ☐ Tap
2. ☐ Spring, is this spring protected? ☐ yes ☐ no

3. Why do you choose to get water from this place?

Tick all that apply:

1. ☐ Distance
2. ☐ Cost

3. ☐ Quality
4. ☐ Reliability
5. ☐ Availability

4. What do you use this water for?

Tick all that apply:

1. ☐ Bathing
2. ☐ Cooking
3. ☐ Drinking
4. ☐ Cleaning
5. ☐ animals
6. ☐ gardening
7. ☐ laundry

5. How much do you pay for this water?

☐ FRW/Jerican

6. Are there times when you find no water at this source? (all say YES)

How often there is no water at this place?

1. ☐ At least every day 2. ☐ At least once a week

7. Do you ever collect rainwater?

1. ☐ Yes 2. ☐ No

(**Observation**: is there guttering and tank/drum for rainwater collection: 3. ☐ yes 4. ☐ no)

8. Do you ever buy water from vendors

1. ☐ Yes 2. ☐ no

If yes, how often do you buy water from a vender?

1. ☐ Every day 2. ☐ At least once a week

3. ☐ At least once a month 4. ☐ N/A

9. How much water do you buy on each occasion?

☐ Jericans

10. Water collection and storage

In case you collect water away from your house:

a. Which people collect water in your family?

1. ☐ Children 2. ☐ Women 3. ☐ Men

4. ☐ Anybody who is available 5. ☐ N/A

b. Where do you keep or store your water?

Type of container and place: ____

11. Do you do anything to your water before you drink it?

1. ☐ Yes 2. ☐ No

3. If yes, what do you do to it? ____

2.3. ELECTRICITY SUPPLY.

1. Is this house connected to public electricity?

1. ☐ Yes 2. ☐ no

If no,

2. What is the main reason?

1. ☐ Financial reasons 2. ☐ No power lines around my place 3. ☐ N/A

If yes,

3. What are the electrical appliances do you use? Please fill the number of items in the box where it applies.

1. ☐ Lights	6. ☐ Printer	11. ☐ Coffee maker
2. ☐ Television(s)	7. ☐ Radio	12. ☐ Microwave oven
3. ☐ DVD(s)	8. ☐ Fridges	13. ☐ Cloves washer
4. ☐ Video(s)	9. ☐ Freezers	14. ☐ Iron
5. ☐ Computer(s)	10. ☐ Cooker	15. ☐ All above

4. Do you find electric power enough for your house demand?

1. ☐ Yes 2. ☐ no ☐ N/A

If no,

5. What time of the day do you often have shortage of power?

1. ☐ 6 am – 6pm
2. ☐ 6pm – 11pm
3. ☐ N/A

6. **What electrical items do not work during power reduction periods? (Please fill in the table below).**

Electrical items list	
1	
2	
3	
4 . . .	

7. **How often power cut offs occur?**
   1. ☐ Almost every day
   2. ☐ At least once a week
   3. ☐ N/A

Annex 5: Second case study raw data from questionnaires

Respondents ID						Housing																				
						1	2			3				4		5					6	7	8			
SN	Sex	Age	Emp.	H. ow	L. reg		a	b	c	a	b	c	d	a	b	a	b	c	d	e			a	b	c	d
1	1	28	1	1	1	1	1	2	2	2	3	2	2	2	1	1	1	2	2	3	6	3	2	1	2	1
2	1	33	1	2	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	4	7	3	4	2	2	1
3	2	41	2	1	2	1	1	2	2	2	3	2	3	2	2	2	2	2	1	2	8	1	2	1	1	1
4	2	45	1	2	1	1	2	3	3	2	4	2	2	2	1	1	2	2	1	3	9	3	2	1	1	1
5	2	24	1	2	1	1	1	1	1	1	2	1	1	2	2	1	1	1	1	3	6	2	4	2	2	2
6	1	30	2	1	1	1	1	2	1	1	2	1	2	2	2	1	1	1	1	3	6	4	4	2	2	1
7	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	8	4	4	2	2	2
8	1	33	1	2	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	3	5	4	4	2	2	2
9	1	40	2	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	4	9	3	4	2	2	2
10	2	35	1	1	1	2	1	2	1	1	1	1	1	2	2	1	1	1	1	5	1	3	4	1	2	2
11	1	28	1	2	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	1	3	4	2	2	2
12	1	35	2	1	1	1	1	2	1	1	3	1	2	2	2	1	1	1	1	3	7	3	4	2	2	2
13	2	40	2	1	1	1	1	1	1	1	2	1	1	2	2	1	1	1	1	3	6	4	4	2	2	2
14	1	52	1	2	1	1	2	3	3	2	4	2	2	2	1	1	1	2	1	2	5	3	1	1	1	2
15	1	39	1	1	1	2	2	3	3	1	2	1	1	2	1	3	3	3	3	5	2	4	4	2	2	2
16	2	30	2	1	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	10	4	4	2	2	2
17	2	38	1	2	2	1	2	3	3	2	4	2	2	2	1	1	2	2	1	2	8	2	1	1	1	1
18	2	51	1	1	1	1	2	3	3	2	4	2	2	2	1	1	1	1	1	3	7	3	1	1	1	1
19	1	48	1	2	1	1	1	2	2	1	3	1	2	2	2	1	1	1	1	3	6	3	2	1	1	2
20	2	62	2	1	1	1	1	1	1	1	1	1	1	2	3	1	1	1	1	4	7	4	4	2	2	2
21	1	28	1	1	1	1	1	2	2	2	3	1	3	2	2	1	2	1	1	2	6	2	3	1	2	2
22	2	48	2	2	1	1	1	2	1	1	3	1	2	2	1	1	1	1	1	3	9	3	4	2	2	2
23	2	35	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	1	1	3	8	2	4	2	2	2
24	2	45	1	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	6	2	3	1	1	1
25	1	28	2	1	1	1	2	3	3	2	4	2	2	2	1	2	2	2	1	2	5	2	3	1	2	1
26	1	40	1	2	2	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	2	4	4	2	2	2
27	2	52	1	1	1	1	1	2	2	1	2	1	1	2	1	1	1	1	1	4	7	4	4	2	2	2
28	2	23	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
29	2	26	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
30	1	33	1	2	1	2	1	1	1	1	1	1	1	2	3	3	3	3	1	5	2	4	4	2	2	2
31	1	34	2	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	7	3	4	2	2	2
32	1	41	1	2	1	1	1	2	2	1	2	1	1	2	1	1	2	1	1	3	6	3	4	2	2	2
33	1	33	1	2	1	1	2	3	3	2	4	2	2	2	1	1	1	1	1	3	8	3	2	1	1	1
34	1	33	1	2	2	1	1	2	1	1	3	1	2	2	1	1	1	1	1	3	7	3	4	2	2	2
35	1	33	2	1	1	1	1	2	2	1	3	1	2	2	2	1	1	1	1	3	8	3	2	1	1	2
36	2	56	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	6	2	4	2	2	2
37	2	30	2	2	1	1	1	2	1	1	2	1	2	2	2	1	1	1	1	1	1	3	4	2	2	2
38	2	33	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	3	6	3	4	2	2	2
39	1	33	1	2	1	1	1	2	2	2	3	2	2	2	1	1	1	2	2	3	7	3	2	1	2	2
40	2	43	2	1	1	1	2	3	3	2	4	2	2	2	1	1	1	2	1	4	8	3	1	1	1	1
41	1	46	1	1	1	1	1	2	2	1	3	1	2	2	2	1	1	2	1	3	5	3	2	1	1	2
42	2	33	1	1	1	2	1	1	1	1	1	1	1	2	5	3	3	3	1	5	1	4	4	2	2	2
43	1	34	2	1	1	1	1	2	1	1	3	1	2	2	2	3	3	3	3	3	6	3	4	2	2	2
44	1	45	1	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	5	2	3	2	1	2
45	1	38	1	1	1	2	2	3	3	1	2	1	1	2	1	3	3	3	3	5	10	4	4	2	2	2
46	1	43	1	1	1	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	1	4	4	2	2	2
47	2	37	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	6	4	4	2	2	2
48	2	25	1	1	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
49	1	45	2	1	1	1	1	2	2	1	3	1	2	2	2	1	1	1	1	3	7	3	2	1	1	2
50	2	27	1	2	1	1	1	1	1	1	2	1	1	2	2	1	1	1	1	3	6	2	4	2	2	2
51	1	34	1	1	1	1	1	2	1	1	3	1	2	2	1	1	1	1	1	4	8	3	4	2	2	2
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56	2	30	1	1	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	1	4	4	2	2	2
57	2	52	2	1	1	1	1	2	2	1	3	1	2	2	1	1	1	1	2	3	6	4	4	2	2	2
58	1	53	1	1	1	1	2	3	3	2	4	2	2	2	1	1	1	2	1	3	7	3	1	1	1	1
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66	1	42	1	2	1	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	1	4	4	2	2	2
67	2	38	1	2	1	1	2	3	3	2	4	2	2	2	1	1	2	2	1	2	5	2	1	1	1	1
68	2	25	2	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
69	1	50	1	1	1	1	1	2	2	1	2	1	1	2	1	3	3	3	3	4	4	4	4	2	2	2
70	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	6	4	4	2	2	2
71	2	27	1	2	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	1	3	4	2	2	2
72	2	48	1	2	1	1	1	2	1	1	3	1	2	2	1	1	1	1	1	3	8	3	4	2	2	2
73	2	38	2	2	1	1	2	3	3	2	4	2	2	2	1	1	2	2	1	2	5	2	1	1	1	1
74	1	33	1	2	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	3	7	4	4	2	2	2
75	1	35	1	2	1	2	1	2	1	1	1	1	1	2	2	1	1	1	1	5	10	3	4	1	2	2
76	1	42	1	2	1	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	1	4	4	2	2	2
77	2	53	2	1	1	1	2	3	3	2	4	2	2	2	1	1	2	2	1	2	4	2	1	1	1	1
78	2	35	1	2	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	3	3	3	4	2	2	2
79	1	38	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	9	3	4	2	2	2
80	2	27	2	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
81	1	29	1	2	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	10	3	4	2	2	2
82	2	45	1	1	2	1	1	2	2	1	2	1	1	2	1	1	2	1	1	3	3	3	4	2	2	2
83	2	55	2	1	1	1	1	2	1	1	3	1	2	2	2	1	1	1	1	3	6	2	4	2	2	2
84	1	58	1	2	1	1	2	3	3	2	4	2	2	2	1	1	1	2	1	2	6	3	1	1	1	2
85	1	28	1	1	1	1	2	3	3	2	4	2	2	2	1	2	2	2	1	2	4	2	3	1	2	1
86	1	40	1	2	1	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	2	4	4	2	2	2
87	2	30	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	1	1	3	6	2	4	2	2	2
88	2	45	2	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	5	2	3	2	1	2
89	1	29	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2
90	1	44	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	4	7	3	4	2	2	2
91	1	37	1	1	1	2	1	2	1	1	3	1	2	2	2	1	1	2	1	3	7	3	4	2	2	2
92	1	47	1	2	1	1	1	2	2	1	2	1	1	2	1	1	2	1	1	3	6	3	4	2	2	2
93	1	33	1	2	1	1	1	2	1	1	3	1	2	2	2	1	2	1	1	3	6	4	4	2	2	1
94	1	51	1	1	1	1	1	2	2	2	3	2	2	2	1	1	1	2	1	3	8	3	2	1	2	2
95	1	26	2	1	1	1	2	3	3	2	4	2	2	2	1	2	2	2	1	2	4	2	3	1	2	2
96	2	50	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	7	2	4	2	2	2
97	2	38	1	2	1	1	2	3	3	2	4	2	2	2	1	1	2	2	1	2	5	2	1	1	1	2
98	1	27	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	1	2	2
99	2	64	2	1	1	1	1	1	1	1	1	1	1	2	3	1	1	1	1	4	6	4	4	2	2	2
100	1	54	1	1	1	1	1	1	1	1	2	1	1	2	2	1	1	1	1	3	7	2	4	2	2	2
101	1	29	1	2	1	2	1	1	1	1	2	1	1	2	1	3	3	3	3	5	10	3	4	2	2	2
102	2	44	2	2	1	1	1	2	1	1	3	1	2	2	1	1	1	1	1	3	5	3	4	2	2	2
103	1	35	1	2	1	1	1	2	1	1	3	1	2	2	2	1	2	1	1	3	6	4	4	2	2	1
104	1	36	1	1	1	1	1	2	1	1	3	1	2	2	1	1	1	1	1	3	8	3	4	2	2	2
105	1	41	1	1	2	2	2	2	1	1	2	1	1	2	1	3	3	3	3	5	1	4	4	2	2	2
106	1	37	1	2	1	2	1	1	1	1	1	1	1	1	3	3	3	3	3	5	1	4	4	2	2	2
107	2	35	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	4	4	2	2	2
108	2	38	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	7	4	4	2	2	2
109	2	26	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	2	3	4	2	2	2
110	1	37	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	2	3	4	2	2	2
111	1	45	2	1	1	1	1	2	2	1	3	1	2	2	2	1	1	1	1	3	7	3	2	1	1	2
112	1	35	1	2	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	4	2	3	4	2	2	2
113	2	47	1	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	6	2	3	1	1	1
114	1	47	1	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	7	2	3	1	1	1
115	2	32	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	1	1	3	2	2	4	2	2	2
116	1	38	1	2	1	1	1	2	1	1	3	1	2	2	2	1	2	1	1	3	6	4	4	2	2	1
117	2	37	2	2	1	2	1	2	1	1	1	1	1	2	2	1	1	1	1	5	1	3	4	1	2	2
118	1	41	1	2	1	1	1	2	2	1	3	1	2	2	2	1	1	1	1	3	5	3	2	1	1	2
119	1	36	1	1	1	1	1	2	1	1	3	1	2	2	2	1	1	2	1	3	5	3	4	2	2	2
120	1	36	1	2	1	1	1	2	2	2	3	2	2	2	1	1	1	2	2	3	8	3	2	1	2	2
121	2	38	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	3	4	3	4	2	2	2
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169	1	43	1	1	1	1	2	3	3	2	4	2	3	2	1	1	2	2	1	2	8	2	3	2	1	1
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182	2	55	2	2	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	3	4	3	4	2	2	2
183	1	27	1	2	1	1	1	2	1	1	2	1	2	2	1	1	1	1	1	1	1	3	4	2	2	2

Respondents ID						Sanitation (A)						Sanitation(B)				
						1	2	3	4	5	6	1		2	3	4
SN	Sex	Age	Emp.	H. ow	L. reg							a	b			
1	1	28	1	1	1	2	3	3	1	3	4	3	1	2	1	2
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4	2	45	1	2	1	3	2	2	3	3	4	2	1	1	1	2
5	2	24	1	2	1	4	4	4	1	2	2	5	2	2	1	1
6	1	30	2	1	1	3	2	2	1	3	4	2	1	1	2	2
7	2	46	1	1	1	4	3	4	1	2	1	3	2	2	1	2
8	1	33	1	2	1	4	3	4	1	2	2	4	2	1	2	2
9	1	40	2	1	1	4	3	4	1	2	3	3	2	1	1	2
10	2	35	1	1	1	5	1	6	1	1	1	6	2	2	1	2
11	1	28	1	2	1	5	1	6	3	1	1	6	2	2	1	2
12	1	35	2	1	1	3	3	4	1	2	3	3	1	1	2	1
13	2	40	2	1	1	3	3	4	2	3	4	2	1	1	1	2
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15	1	39	1	1	1	5	5	6	2	1	1	6	1	2	1	2
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17	2	38	1	2	2	2	2	2	1	3	4	2	1	1	2	2
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19	1	48	1	2	1	3	2	3	2	3	4	3	1	1	2	1
20	2	62	2	1	1	4	4	4	1	2	3	3	2	1	1	2
21	1	28	1	1	1	2	2	2	3	3	4	2	1	1	2	2
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23	2	35	1	1	1	3	3	4	1	3	4	2	2	1	2	2
24	2	45	1	1	1	2	2	2	3	3	4	2	1	1	2	2
25	1	28	2	1	1	2	2	6	3	3	4	2	1	1	2	2
26	1	40	1	2	2	5	1	6	1	1	1	6	2	1	1	1
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28	2	23	1	2	1	2	2	1	1	1	1	1	1	1	2	2
29	2	26	1	2	1	2	2	1	1	1	1	1	1	1	2	2
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Respondents ID						Tranportation																
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SN	Sex	Age	Emp.	H. ow	L. reg											a	b	c	d			
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131	1	29	1	2	1	3	1	1	2	25	1	3	1	1	1	6	7	5	6	1	4	1
132	2	55	1	1	1	3	1	5	4	10	4	4	2	3	3	6	5	6	5	1	3	2
133	1	35	1	2	1	3	1	1	2	30	1	3	1	1	1	6	6	5	5	1	4	1
134	1	55	1	2	1	2	3	3	3	30	1	1	1	1	2	6	7	6	5	2	1	1
135	2	41	1	1	1	3	2	5	4	10	4	4	2	3	3	6	5	5	7	2	2	3
136	1	47	1	2	1	5	1	5	4	20	4	4	2	3	3	7	6	5	6	1	3	6
137	2	55	1	1	1	1	3	2	3	20	2	1	1	1	2	7	5	6	5	3	5	5
138	1	38	2	2	1	1	3	2	3	35	2	1	1	1	2	6	7	5	5	3	5	5
139	1	39	1	1	1	3	1	1	2	30	1	3	1	1	1	6	7	5	6	1	4	1
140	2	27	1	1	1	3	1	5	4	10	4	4	2	3	3	5	6	6	6	1	4	1
141	2	47	1	1	1	2	3	2	3	25	2	1	1	1	2	6	5	7	5	3	5	5
142	1	27	1	2	1	4	1	5	4	10	4	4	2	3	3	7	5	5	6	1	4	3
143	2	38	2	1	2	4	1	5	4	15	4	4	2	3	3	7	6	7	5	1	2	1
144	1	51	1	1	1	2	3	3	3	30	1	1	1	1	2	6	5	4	5	2	1	1
145	1	53	1	1	1	2	2	3	3	35	2	3	1	1	2	5	6	6	7	3	5	5
146	1	36	1	2	1	3	2	5	4	10	4	4	2	3	3	6	7	5	6	2	2	3
147	2	37	1	1	1	1	3	2	3	35	2	1	1	1	2	7	4	5	7	3	5	5
148	1	37	2	1	1	3	2	2	3	20	2	3	1	1	2	7	5	4	7	2	2	1
149	1	61	1	1	1	2	3	3	3	35	1	1	1	1	2	7	5	6	7	2	1	1
150	1	46	1	1	1	5	1	5	4	20	4	4	2	3	3	6	5	5	7	1	3	6
151	1	66	2	1	1	4	1	5	4	10	4	4	2	3	3	7	6	5	6	2	1	1
152	2	59	1	1	1	3	2	3	3	35	1	3	1	1	2	7	4	5	5	2	1	1
153	1	58	1	2	1	2	3	3	3	35	1	1	1	1	2	7	6	5	6	2	1	1
154	1	29	2	2	1	5	1	5	4	10	4	4	2	3	3	6	5	5	7	1	5	3
155	1	42	1	2	1	3	3	3	3	30	2	3	1	1	2	6	7	5	6	2	1	1
156	2	27	1	2	1	4	1	5	4	10	4	4	2	3	3	7	6	6	7	1	2	2
157	2	43	2	1	1	4	2	2	3	20	1	2	1	2	2	6	7	5	5	1	3	3
158	2	44	1	1	1	5	1	5	4	15	4	4	2	3	3	6	5	5	7	1	3	6
159	1	28	1	2	1	4	1	5	4	10	4	4	2	3	3	4	5	4	5	2	4	3
160	2	39	1	1	1	2	3	2	3	30	2	1	1	1	2	7	6	4	5	3	5	5
161	2	36	1	1	1	3	2	5	4	10	4	4	2	3	3	6	7	5	5	2	2	3
162	2	29	1	2	1	3	1	1	2	20	1	3	1	1	1	7	5	6	6	1	4	1
163	2	32	1	1	1	3	2	3	3	25	1	3	1	1	2	7	5	4	6	2	1	1
164	1	41	1	2	1	5	1	5	4	20	4	4	2	3	3	6	6	7	6	1	3	6
165	1	47	2	1	1	1	3	2	3	30	1	1	1	1	2	6	7	5	7	3	5	5
166	1	28	1	2	1	4	1	5	4	15	4	4	2	3	3	6	5	5	6	2	4	3
167	2	41	1	2	1	3	3	3	3	25	2	3	1	1	2	7	6	7	5	2	1	1
168	1	39	1	2	1	2	3	2	3	30	4	4	2	3	2	6	6	5	5	3	5	5
169	1	43	1	1	1	1	3	2	3	35	1	1	1	1	2	6	5	5	7	3	5	5
170	2	57	2	1	1	1	3	2	3	35	2	1	1	1	2	7	4	5	5	3	5	5
171	2	41	1	1	1	1	3	2	3	30	1	1	1	1	2	7	5	6	7	3	5	5
172	2	61	2	1	1	4	1	5	4	10	4	4	2	3	3	7	5	5	5	2	1	1
173	1	43	1	1	1	3	2	5	4	20	4	4	2	3	3	5	7	5	6	2	2	3
174	1	67	2	1	1	4	1	5	4	15	4	4	2	3	3	6	6	7	5	2	1	1
175	1	38	1	1	1	3	2	3	3	25	1	3	1	1	2	6	5	6	5	2	1	1
176	1	48	1	2	1	5	1	5	4	15	4	4	2	3	3	6	7	7	6	1	3	6
177	2	39	2	1	1	3	2	3	3	25	1	3	1	1	2	7	5	6	5	2	1	1
178	1	38	1	2	2	1	3	2	3	30	3	1	1	2	2	6	5	5	6	2	2	2
179	1	29	1	1	1	4	1	5	4	10	4	4	2	3	3	6	5	6	6	1	3	3
180	2	42	1	1	1	4	1	5	4	15	4	4	2	3	3	7	5	6	5	1	4	3
181	2	51	1	2	1	1	3	2	3	30	2	1	1	1	2	7	6	4	5	3	5	5
182	2	55	2	2	1	3	2	5	4	15	4	4	2	3	3	6	6	6	7	2	2	3
183	1	27	1	2	1	3	1	1	2	30	1	3	1	1	1	6	7	5	6	1	4	1

Respondents ID						Water supply												Electricity supply						
						1	2	3	4	5	6	7	8		9	10		11	1	2	3	4	5	6	7
SN	Sex	Age	Emp.	H. ow	L. reg								a	b		a	b								
1	1	28	1	1	1	200	1	3	1,2,3,4	20	2	1,3	1	2	80	4		1	1	3	1,2,3,4,7,8,11	2	2		1
2	1	33	1	2	1	100	1	1	1,2,3,4,7	20	2	1,3	1	2	80	4		1	1	3	1,2,3,4,7,8,11	2	2		2
3	2	41	2	1	2	80	1	3	1,2,3,4	25	1	1,4	1	3	20	2		2	2	1	0	3	3		3
4	2	45	1	2	1	140	1	3	1,2,3,4,7	25	2	1,4	1	2	80	2		1	1	3	1,5,6,7,9	2	2		2
5	2	24	1	2	1	300	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	1,7,9,13	2	2		2
6	1	30	2	1	1	100	1	1,3	1,2,3,4,7	25	1	1,4	1	3	80	2		2	2	1	0	2	2		3
7	2	46	1	1	1	240	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	1,5,9,10	2	2		2
8	1	33	1	2	1	300	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	1,2,10,11	2	2		2
9	1	40	2	1	1	400	2	5	4,5	10	1	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
10	2	35	1	1	1	40	2	5	4	10	2	2	1	2	80	5		1	1	3	1,5,6,7,9	1	3		2
11	1	28	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
12	1	35	2	1	1	300	2	5	4,5	10	2	1,3	1	2	80	2		1	1	3	1,2,3,8,11	2	2		2
13	2	40	2	1	1	240	1	1,3	4,5	25	1	1	1	2	60	4		1	1	3	1,2,3,5,8,11	1	3		2
14	1	52	1	2	1	120	1	1,3	1,2,3,4	25	2	1,4	1	3	20	1		1	2	1	0	3	3		3
15	1	39	1	1	1	60	2	5	4	10	1	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
16	2	30	2	1	1	60	2	5	4	10	2	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
17	2	38	1	2	2	60	1	1,4	1,2,3,4	30	1	1,4	1	2	80	1		2	2	1	0	3	3		3
18	2	51	1	1	1	120	1	1,4	1,2,3,4	30	2	1,3	1	2	80	1		1	2	1	0	3	3		3
19	1	48	1	2	1	200	1	3	1,2,3,4	30	2	1,3	1	2	80	1		1	1	3	1,2,3,4,7,8,11	1	3		2
20	2	62	2	1	1	350	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	1,5,6,7,9	2	3		2
21	1	28	1	1	1	120	1	1,4	1,2,3,4	30	2	1,4	1	2	80	1		1	2	2	0	3	3		3
22	2	48	2	2	1	160	1	3	1,2,3,4	25	2	1,3	1	2	80	1		1	1	3	1,7,9,13	1	3		2
23	2	35	1	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	60	2		1	1	3	1,2,7,8,9,11	1	3		2
24	2	45	1	1	1	120	1	3	1,2,3,4	30	2	1,4	1	2	80	2		1	2	2	0	3	3		3
25	1	28	2	1	1	100	1	4	1,2,3,4	25	2	1,4	1	2	80	2		1	2	2	0	3	3		3
26	1	40	1	2	2	80	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
27	2	52	1	1	1	350	2	5	1,2,3,4	10	2	2	1	2	80	5		1	2	2	0	3	3		3
28	2	23	1	2	1	150	2	5	4,5	10	2	1,3	2	4	100	5		1	2	1	0	3	3		3
29	2	26	1	2	1	120	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,2,3,4,5,8,11,12	2	2		1
30	1	33	1	2	1	120	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
31	1	34	2	1	1	300	2	1	4,5	10	2	1,3	1	2	80	2		1	1	3	1,2,3,8,11	2	2		2
32	1	41	1	2	1	350	2	5	1,2,3,4	10	2	2	1	2	80	1		1	2	2	0	3	3		3
33	1	33	1	2	1	140	1	3	1,2,3,4,7	25	2	1,3	1	2	80	2		1	1	3	1,5,6,7,9	2	2		2
34	1	33	1	2	2	160	1	3	1,2,3,4	25	2	1,3	1	2	80	1		1	1	3	1,5,6,7,9	1	3		2
35	1	33	2	1	1	200	1	3	1,2,3,4	30	2	1,3	1	2	80	1		1	1	3	1,2,7,8,9,11	1	3		2
36	2	56	1	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	60	2		1	1	3	1,2,7,8,9,11	1	3		2
37	2	30	2	2	1	120	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,5,6,7,9	1	3		2
38	2	33	1	1	1	400	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	0	3	3		3
39	1	33	1	2	1	80	1	3	1,2,3,4	20	2	1,3	1	2	80	4		1	1	3	1,2,3,4,7,8,11	2	2		1
40	2	43	2	1	1	120	1	1	1,2,3,4	25	2	1,3	1	2	80	1		1	2	2	0	3	3		3
41	1	46	1	1	1	200	1	3	1,2,34,	30	2	1,3	1	2	80	1		1	1	3	1,2,3,4,7,8,11	2	2		2
42	2	33	1	1	1	100	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
43	1	34	2	1	1	300	2	5	4,5	20	2	1,3	1	2	80	2		1	1	3	1,2,7,8,9,11	2	2		2
44	1	45	1	1	1	120	1	3	1,2,3,4	25	2	1,4	1	2	80	1		1	2	1	0	3	3		3
45	1	38	1	1	1	60	2	5	4	10	2	1,3	2	4	100	5		1	1	3	1,3,11,14	1	3		2
46	1	43	1	1	1	100	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
47	2	37	2	1	2	12	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	0	3	3		3
48	2	25	1	1	1	100	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	0	3	3		3
49	1	45	2	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	60	1		1	1	3	1,2,3,4,7,8,11	2	2		2
50	2	27	1	2	1	240	2	5	4,5	10	1	1,3	2	4	100	5		1	2	1	0	3	3		3
51	1	34	1	1	1	300	2	5	4,5	10	2	1,3	1	2	60	2		1	1	3	1,2,3,8,11	2	2		2
52	1	35	2	2	1	300	2	5	4,5	10	2	1,3	1	2	60	2		1	1	3	1,2,3,8,11	1	3		2
53	2	49	1	1	1	12	2	5	4,5	10	2	1,3	2	4	100	5		1	1	3	1,5,6,7,9	2	2		1
54	1	55	2	1	1	120	1	1,3	1,2,3,4	20	1	1,4	1	2	80	1		1	2	1	0	3	3		3
55	1	26	1	2	1	100	1	4	1,2,3,4	30	2	1,4	1	2	80	2		1	2	1	0	3	3		3
56	2	30	1	1	1	50	2	5	4	10	2	1,3	2	4	100	5		1	1	3	1,5,9,10	2	2		2
57	2	52	2	1	1	350	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,2,3,8,11	2	2		2
58	1	53	1	1	1	120	1	1,4	1,2,3,4	25	2	1,3	1	2	80	1		2	2	2	0	3	3		3
59	2	28	1	1	1	120	2	5	1,2,3,4	10	1	2	1	2	80	5		2	1	3	1,2,3,4,5,8,11,12	2	2		1
60	2	38	1	2	1	50	2	5	4	10	2	2	1	2	80	5		1	1	3	1,5,6,7,9	1	3		2

61	1	28	1	2	1	40	2	5	4	10	1	2	2	4	100	5		1	1	3	1,3,6,11	1	3		2
62	2	43	2	2	1	160	1	3	1,2,3,4	25	1	1,3	1	2	80	1		1	1	3	1,7,9,13	1	3		2
63	2	40	1	1	1	400	2	5	4,5	10	1	1,3	2	4	80	2		2	1	3	1,2,3,8,11	2	2		2
64	1	54	1	1	1	350	2	5	4,5	10	2	1,3	1	2	20	1		2	1	3	1,2,3,0,11,22	2	2		2
65	2	25	1	1	1	100	1	4	1,2,3,4	25	2	1,4	1	2	80	2		1	2	1	0	3	3		3
66	1	42	1	2	1	60	2	5	4	10	1	2	2	4	100	5		1	1	3	1,5,611	1	3		2
67	2	38	1	2	1	120	1	1,4	1,2,3,4	30	2	1,4	1	2	80	1		2	2	1	0	3	3		3
68	2	25	2	2	1	200	2	5	4,5	10	1	1,3	2	4	100	5		2	1	3	1,5,6,7,9	1	3		1
69	1	50	1	1	1	300	2	5	1,2,3,4	10	1	2	1	2	60	5		1	1	3	1,5,6,7,9	1	3		1
70	2	46	1	1	1	240	2	5	4,5	10	1	1,3	2	4	100	5		1	1	3	1,2,7,8,9,11	2	2		2
71	2	27	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	2	2		2
72	2	48	1	2	1	160	1	3	1,2,3,4	30	2	1,3	1	2	60	1		2	1	3	1,7,9,13	1	3		2
73	2	38	2	2	1	120	1	1,4	1,2,3,4	30	1	1,4	1	2	80	1		2	2	1	0	3	3		3
74	1	33	1	2	1	300	2	5	6	10	2	1,3	2	4	100	5		2	2	2	0	3	3		3
75	1	35	1	2	1	60	2	5	4	10	2	2	1	2	60	5		1	1	3	1,5,6,7,9	2	2		2
76	1	42	1	2	1	60	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	2	2		2
77	2	53	2	1	1	120	1	1,4	1,2,3,4	30	2	1,4	1	2	60	1		2	2	2	0	3	3		3
78	2	35	1	2	1	400	2	5	6	10	2	1,3	1	2	20	1		2	1	3	1,2,3,4,7,8,11	2	2		1
79	1	38	1	1	1	300	2	5	6	10	2	1,3	1	2	60	2		2	1	3	1,2,3,8,11	2	2		2
80	2	27	2	2	1	120	2	5	1,2,3,4	10	2	2	1	2	80	5		2	1	3	1,2,3,4,5,8,11,12	2	2		2
81	1	29	1	2	1	60	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
82	2	45	1	1	2	350	2	5	1,2,3,4	10	2	2	1	2	80	5		1	2	1	0	3	3		3
83	2	55	2	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	80	2		1	1	3	1,2,10,11	1	3		2
84	1	58	1	2	1	120	1	1,3	1,23,4	30	2	1,4	1	2	80	1		1	2	2	0	3	3		3
85	1	28	1	1	1	100	1	4	1,2,3,4	30	2	1,4	1	2	80	2		1	2	1	0	3	3		3
86	1	40	1	2	1	100	2	5	4	10	2	2	2	4	100	5			1	3	1,5,6,7,9	1	3		2
87	2	30	1	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	80	2		1	1	3	1,2,10,11	2	2		2
88	2	45	2	1	1	120	1	3	1,2,3,4	30	2	1,4	1	2	80	2		1	2	2	0	3	3		3
89	1	29	1	2	1	100	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,2,3,4,5,8,11,12	2	2		2
90	1	44	1	1	1	350	2	5	6	10	2	1,3	2	4	100	5		1	2	1	0	3	3		3
91	1	37	1	1	1	250	2	5	6	10	2	1,3	1	2	60	2		1	1	3	1,2,3,10,11	2	2		2
92	1	47	1	2	1	300	2	5	1,2,3,4	10	2	2	1	2	60	5		1	1	3	1,2,3,8,11	2	2		3
93	1	33	1	2	1	100	1	1	1,2,3,4	25	2	1,4	1	3	80	2		2	1	3	1,2,3,4,5,8,11,12	2	2		2
94	1	51	1	1	1	80	1	2	1,2,3,4	20	2	1,3	1	2	80	4		1	1	3	1,2,3,4,7,8,11	2	2		1
95	1	26	2	1	1	100	1	4	1,2,3,4	30	2	1,4	1	2	60	2		1	2	1	0	3	3		3
96	2	50	1	1	1	200	1	3	1,2,3,4	30	1	1,3	1	2	80	2		1	1	3	1,2,3,4,7,8,11	2	2		2
97	2	38	1	2	1	120	1	1,4	1,2,3,4	30	1	1,4	1	2	80	1		2	2	1	0	3	3		3
98	1	27	1	2	1	150	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,2,3,4,7,8,11	2	2		2
99	2	64	2	1	1	300	2	5	6	10	2	1	2	4	100	5		1	1	3	1,2,7,8,9,11	1	3		1
100	1	54	1	1	1	300	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,3,4,22	2	2		2
101	1	29	1	2	1	80	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	2		2
102	2	44	2	2	1	160	1	3	1,2,3,4	30	1	1,3	1	2	80	1		1	1	3	1,7,9,10,13	2	2		2
103	1	35	1	2	1	100	1	1,3	6	25	2	1,4	1	3	80	2		2	1	3	1,2,3,8,11	1	2		2
104	1	36	1	1	1	150	1	3	1,2,3,4	30	2	1,3	1	2	80	1		1	1	3	1,7,9,10,13	2	2		2
105	1	41	1	1	2	60	2	5	4	10	1	1,3	2	4	100	5		1	1	1	1,5,9,10	1	2		2
106	1	37	1	2	1	60	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	2	2		2
107	2	35	2	1	1	250	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,3,4,22	1	3		2
108	2	38	2	1	1	250	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
109	2	26	1	2	1	200	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,7,9,10,13	1	3		2
110	1	37	1	1	1	300	2	5	6	10	2	1,3	1	2	60	2		1	1	3	1,2,3,8,11	1	2		2
111	1	45	2	1	1	200	1	3	1,2,3,4	30	2	1,3	1	2	80	1		1	1	3	1,2,3,4,7,8,11	2	2		2
112	1	35	1	2	1	100	1	3	1,2,3,4	25	1	1,3	1	2	80	4		1	1	3	1,2,3,8,11	2	2		2
113	2	47	1	1	1	120	1	3	1,2,3,4	25	2	1,4	1	2	80	2		1	2	2	0	3	3		3
114	1	47	1	1	1	120	1	3	1,2,3,4	30	2	1,4	1	2	80	1		1	2	1	0	3	3		3
115	2	32	1	1	1	200	1	3	1,2,3,4	30	2	1,3	1	2	80	2		1	1	3	1,2,7,8,9,11	2	2		2
116	1	38	1	2	1	100	1	1,3	1,2,3,7	20	2	1,4	1	3	80	2		2	1	3	1,2,3,10,11	2	2		2
117	2	37	2	2	1	50	2	5	4	10	2	2	1	2	80	5		1	1	3	1,6,11	1	2		2
118	1	41	1	2	1	200	1	3	1,2,3,4	25	1	1	1	2	80	1		1	1	3	1,2,3,4,7,8,11	2	2		2
119	1	36	1	1	1	300	2	5	6	10	1	1,3	1	2	80	2		1	1	3	1,2,7,8,9,11	2	2		2
120	1	36	1	2	1	100	1	3	1,2,3,4	25	1	2	1	2	80	4		1	1	3	1,3,4,22	2	2		1

121	2	38	1	1	1	350	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,5,6,7,9	1	3		1
122	2	44	1	2	1	150	1	3	1,2,3,4	30	2	1,3	1	2	80	1		1	2	3	1,7,9,13	1	3		2
123	1	48	1	1	1	200	1	3	1,2,3,4	25	2	1,3	1	2	80	1		1	1	3	1,2,3,4,7,8,11	2	2		2
124	1	37	1	1	1	350	2	5	6	10	1	1,3	1	2	60	2		1	1	3	1,2,3,8,11	2	2		2
125	1	37	2	1	1	60	2	5	4	10	1	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
126	2	33	1	1	1	200	1	3	1,2,3,4	30	1	1,3	1	2	60	2		1	1	3	1,2,10,11	1	3		2
127	2	34	1	2	1	60	2	5	4	10	2	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
128	1	37	1	2	1	60	3	1,4	4	25	2	1,4	2	4	80	5		1	1	3	1,7,9,10,13	1	3		1
129	1	41	1	2	1	60	2	5	4	10	1	2	2	4	100	5		1	1	3	1,5,6,7,9	1	2		2
130	1	33	2	1	1	100	1	1,3	1,2,3,6	20	1	1	1	3	80	2		2	1	3	1,2,7,8,9,11	2	2		2
131	1	29	1	2	1	150	2	5	1,2,3,4	10	1	2	1	2	80	5		1	1	3	1,2,3,4,5,8,11,12	2	2		2
132	2	55	1	1	1	350	2	5	6	10	1	1,3	2	4	100	5		2	1	3	1,2,3,4,7,8,11	2	2		2
133	1	35	1	2	1	120	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,2,3,4,5,8,11,12	2	2		2
134	1	55	1	2	1	150	1	1,3	1,2,3,4	30	2	1	1	2	80	1		1	2	1	0	3	3		3
135	2	41	1	1	1	300	2	5	6	10	2	1,3	2	4	100	5		1	1	3	0	3	3		3
136	1	47	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
137	2	55	1	1	1	140	1	1,3	1,2,3,4	30	2	1,4	1	2	60	1		2	2	1	0	3	3		3
138	1	38	2	2	1	120	1	1,3	1,2,3,4,	30	2	1,4	1	2	80	1		2	2	1	0	3	3		3
139	1	39	1	1	1	100	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,5,6,7,9	1	3		2
140	2	27	1	1	1	100	2	5	6	10	2	1,3	2	4	100	5		1	1	3	0	3	3		3
141	2	47	1	1	1	120	1	1,3	1,2,3,4	30	2	1,3	1	2	80	1		1	2	1	0	3	3		3
142	1	27	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,4,6,11	1	3		2
143	2	38	2	1	2	200	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,7,9,13	1	3		2
144	1	51	1	1	1	120	1	1,3	1.,2,3,4	30	2	1,4	1	2	80	1		1	2	2	0	3	3		3
145	1	53	1	1	1	80	1	3	1,2,3,4	20	2	1,4	1	2	80	4		1	1	3	1,2,3,10,11	2	2		1
146	1	36	1	2	1	400	2	5	6	10	2	1,3	2	4	100	5		2	1	3	1,5,6,7,9	1	3		2
147	2	37	1	1	1	150	1	1,4	1,2,3,4	25	2	1,4	1	2	80	1		2	2	1	0	3	3		3
148	1	37	2	1	1	300	2	5	6	10	2	1,3	1	2	80	2		1	1	3	1,5,6,7,9	1	3		2
149	1	61	1	1	1	120	1	1,3	1,2,3,4	25	2	1,4	1	2	80	1		1	2	1	0	3	3		3
150	1	46	1	1	1	80	2	5	4	10	1	2	2	4	100	5		1	1	3	1,5,6,7,9	1	2		2
151	1	66	2	1	1	300	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,7,9,13	1	3		2
152	2	59	1	1	1	200	1	3	1,2,3,4	30	2	1,3	1	2	80	2		1	1	3	1,2,10,11	1	3		2
153	1	58	1	2	1	120	1	1,3	1,2,3,4	25	2	1,4	1	2	80	1		1	2	1	0	3	3		3
154	1	29	2	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	2	2		2
155	1	42	1	2	1	160	1	3	1,2,3,4	25	1	1,3	1	2	60	1		2	1	3	1,7,9,13	1	2		2
156	2	27	1	2	1	300	2	5	6	10	1	1,3	2	4	100	5		1	1	3	0	3	3		3
157	2	43	2	1	1	300	2	5	1,2,3,4	10	1	2	1	2	60	5		1	1	3	0	3	3		3
158	2	44	1	1	1	100	2	5	4	10	2	2	2	4	100	5			1	3	1,5,6,7,9	1	3		2
159	1	28	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
160	2	39	1	1	1	120	1	1	1,2,3,4	25	2	1,3	1	2	80	1		1	2	1	0	3	3		3
161	2	36	1	1	1	300	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,7,9,13	1	3		2
162	2	29	1	2	1	140	2	5	1,2,3,4	10	2	2	1	2	80	5		2	1	3	1,2,3,4,5,8,11,12	2	2		2
163	2	32	1	1	1	200	1	3	1,2,3,4	25	1	1,3	1	2	80	2		1	1	3	1,2,10,11	1	3		2
164	1	41	1	2	1	40	2	5	4	10	2	2	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
165	1	47	2	1	1	120	1	3	1,2,3,4	25	2	1,4	1	2	80	1,2		1	2	1	0	3	3		3
166	1	28	1	2	1	40	2	5	4	10	1	2	2	4	100	5		1	1	3	1,5,6,7,9	2	2		2
167	2	41	1	2	1	150	1	3	1,2,3,4	25	2	1,3	1	2	80	1		1	1	3	1,7,9,13	1	3		2
168	1	39	1	2	1	100	1	1,3	1,2,3,4,7	25	1	1,4	1	3	80	2		2	1	3	1,2,3,10,11	2	2		2
169	1	43	1	1	1	120	1	3	1,2,3,4	30	2	1,4	1	2	80	2		1	2	1	0	3	3		3
170	2	57	2	1	1	120	1	1,4	1,2,3,4	35	1	1,4	1	2	80	1		2	2	1	0	3	3		3
171	2	41	1	1	1	120	1	3	1,2,3,4	25	2	1,4	1	2	80	2		1	2	1	0	3	3		3
172	2	61	2	1	1	300	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,7,9,13	3	3		2
173	1	43	1	1	1	400	2	5	6	10	2	1,3	2	4	100	5		1	1	3	1,2,10,11	1	3		2
174	1	67	2	1	1	300	2	5	6	10	1	1,3	2	4	100	5		1	1	3	1,5,6,7,9	1	3		2
175	1	38	1	1	1	200	1	3	1,2,3,4	25	1	1,3	1	2	80	2		1	1	3	1,2,3,4,7,8,11	2	2		2
176	1	48	1	2	1	60	2	5	4	10	1	2	2	4	100	5		1	1	3	1,5,6,10	1	3		2
177	2	39	2	1	1	200	1	3	1,2,3,4	30	2	1,3	1	2	60	2		1	1	3	1,2,10,11	1	3		2
178	1	38	1	2	2	140	1	3	1,2,3,4,7	30	2	1,3	1	2	80	2		1	1	1	0	3	3		3
179	1	29	1	1	1	40	2	5	4	10	1	1,3	2	4	100	5		1	1	3	1,5,9,10	1	3		2
180	2	42	1	1	1	50	2	5	4	10	2	1,3	2	4	100	5		1	1	3	1,5,7,9,10	2	2		2
181	2	51	1	2	1	120	1	1,4	1,2,3,4	25	1	1	1	2	80	1		2	2	2	0	3	3		3
182	2	55	2	2	1	400	2	5	6	10	2	1,3	2	4	100	5		2	1	3	1,7,9,13	1	3		1
183	1	27	1	2	1	100	2	5	1,2,3,4	10	2	2	1	2	80	5		1	1	3	1,2,3,4,5,8,11,12	2	2		1