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ARG895 & RFS890 Mini-Dissertation

Environmental Sustainability of Construction Practices used in Informal Settlements: A Case of Swaziland

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Abstract

The demand for basic housing and service provision as a result of residents migrating to cities has given rise to informal settlements worldwide which are regarded as being formed and occupied by the poor (Bredenoord 2016, Nassar & Elsayed 2017). Construction practices used in these informal settlements, which can be best described as self-help housing, are believed to have an impact on the natural environment. This impact on the natural environment is observed in the atmosphere, land and water. Construction practices "adversely affect the environment through the over-use of non-renewable resources" (Nair 2005:4430). This study identifies the problem of the absence of control mechanisms in these construction practices in informal settlements which is claimed to have an effect on the degrading environment.

Swaziland, one of the developing countries in Southern Africa, faces the same challenge of the development of informal settlements in which the construction practices used affect the natural environment. This paper details the findings of a study conducted on three purposely selected informal settlements (Msunduza, Mahwalala and Nkwalini) in Mbabane, which were upgraded through the Urban Development Programme, to identify the construction practices used in the informal settlements, and further evaluate their effects on the natural environment. The research is aimed at determining the effects of construction practices used in informal settlements on the natural environment and further propose a possible solution to this challenge.

The three major components of this study are literature review, situational analysis and research output. Literature review was used to gather already existing information on the identified problem in order to understand the problem and further evaluate the sustainability of the identified construction practices. Sustainable and regenerative development was viewed as a solution to the environmental challenges. The situational analysis consisted of a survey where construction practices in the informal settlements were observed through a structured checklist. The study demonstrated through qualitative analysis how the construction practices used in the informal settlements affect the environment and the study results and literature review was used to develop a framework (research output) which is believed to be a solution to the challenges witnessed in the informal settlements.

Keywords: Sustainability, Sustainable Construction, Environmental Sustainability, Low-cost Housing, Informal Settlements

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Mini- dissertation Overview

Chapter 1

The introductory chapter of this research provides the background on urbanisation and how it has contributed to the formation of informal settlements and housing challenges that are faced today. Swaziland's background, where the study was conducted, is provided. Swaziland's policies related to housing issues are discussed with the aim of understanding the context/setting for the study. Three research objectives are listed of which the first one seeks to identify construction practices used in informal settlements. The second objective seeks to determine how construction practices affect the natural environment in informal settlements. And the last objective is to formulate a framework which can be used as a guide towards the use of sustainable construction practices in the development of a neighbourhood for low income households, which will promote a positive use of the natural environment. To achieve the objectives the main research question focuses on the effects of construction practices of informal settlements on the environment. The main research question is reliant on three sub-questions which are put forward to fully address it. Research strategies and analysis for each sub-question are outlined in this chapter.

Chapter 2 [RFS 890]

This chapter mainly reviews existing literature which is related to the study topic with the aim to understand the problem better and also aid in hypothesis testing. This review is focused on literature pertaining to the nature of informal settlements and their upgrading specifically in selected developing countries in Africa and Asia, framing the study to construction practices in informal settlements in developing countries.

The chapter starts by defining and discussing informal settlements for understanding of the concept of informal settlements. This is important as the study will be evaluating housing in informal settlements. Having built an understanding of the formation of informal settlements, the chapter further explores the impact to the natural environment and also highlights theories on the protection of the natural environment. A potential link between construction practices and the natural environmental impact is investigated.

Current approaches and theories on informal settlements upgrade are discussed, and selected examples across the world are analysed. Further assessment methods are reviewed to inform the observation schedule.

After the literature on the above has been discussed, the chapter then focuses more on the informal housing in Swaziland to draw a conclusion on the gap that exists. The settings/cases are described in detail to allow the reader to understand the context and link to theory. The chapter ends with a brief discussion of observation studies, which will feed into the next chapter on the conceptual model.

Chapter 3 [ARG 895]

This chapter defines a conceptual model developed from the research concepts associated with construction practices, most of which are generally discussed in chapter 2. The chapter discusses further selected concepts and criteria for measurement of each concept. This model is developed so as to guide data capturing and analysis in this study. The conceptual model raises guiding questions which inform the schedules used in the observation study. It is asserted that the use of this conceptual model will assist in identifying construction practices used in the selected informal settlements and further give an understanding of the natural environmental conditions in the informal settlements. The concepts are discussed individually and they build-up to form a framework to be shown later on in the chapter.

Chapter 4 [ARG 895]

Chapter four outlines the research methodology used in this study. The study used three case studies purposively chosen with prediction that results will be the same from all the cases achieving literal replication. To fully understand construction practices in informal settlements and effects to the natural environment, a mixed research method was employed which used a structured schedule as a tool of inquiry. Propositions developed in the literature review are tested in the cases selected. The setting of the study, research design, population and sample strategy are discussed in detail in this chapter.

Chapter 5 [ARG 895]

Findings from the research as proposed in chapter four are discussed to answer the research question – “What are the effects on the natural environment of construction practices of informal settlements?” Data of construction practices used was analysed and categorised as discussed in chapter three. Tables and diagrams are used to present data. Challenges encountered when collecting data, failure and success are discussed in this chapter.

Chapter 6 [ARG 895]

The findings from the research are discussed in this chapter by tying the results to the literature review. The discussion allows the last sub question to be answered.

Chapter 7 [ARG 895]

Conclusions are made on the objectives and made understandable to the reader. Recommendations following the research are proposed, mainly on building codes, policies and regulations and future research topics.

Table of Contents

RFS 890

ARG 895

List of Figures

List of Tables

List of Acronyms

EMA	Environment Management Act
LEED	Leadership in Energy and Environmental Design
MHUD	Ministry of Housing and Urban Development
NDMA	National Disaster Management Agency
NHP	National Housing Policy
NLP	National Land Policy
PPP	Physical Planning Policy
PUGP	Peri-Urban Growth Policy
SACU	Southern African Custom's Union
SBAT	Sustainable Building Assessment Tool
SEA	Swaziland Environmental Authority
SNHB	Swaziland National Housing Board
SNL	Swazi Nation Land
SWSC	Swaziland Water Service Corporation
TDL	Title Deed Land
UDP	Urban Development Project
UN	United Nations

Definitions

Note: The definitions listed below are relative to the research field.

- **Affordable Housing – "**entails the relationship between expenditure on housing and household income" (Ezebilo 2017:2).

- **Low-cost Housing -** A low cost house is typically a house that is affordable to low income earning households (Turner 1968).

- **Informal Settlement** – A settlement that does not comply with urban areas' zone planning schemes, and they are constructed on state or privately owned properties without permission from the local authorities (United Nations 2015). Informal settlements in Swaziland are characterized by lack of infrastructure, below standard buildings on public land without tenure and insufficient living conditions (MHUD 2001:43). The United Nations (2015) clarifies that informal settlements are not a poverty peculiarity, but belong to all income levels. That means informal settlements may be luxurious buildings or towns which are illegally located on government or private land, but this paper refers to heavily populated areas with below-standard shelters.

- **Slums -** An urban area without access to adequate water supply, sanitation facilities, and limited living areas (Tester 2012). Slums are a subset of informal settlements, just like the properly built, expensive houses which are constructed without permission from local authorities.

- **Sustainability** – "maintaining well-being over a long, perhaps even an indefinite period" (Kuhlman and Farrington 2010:3441).

- **Construction** – "The broad process or mechanism for the realisation of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment*"* (Du Plessis 2002:4).

- **Construction practices –** The actual processes executed for the realisation of human settlements and the creation of infrastructure that supports development.

- **Sustainable construction** – **"**The holistic process aiming to restore and maintain harmony between the natural and built environments, and create settlements that affirm human dignity and encourage equity" (Du Plessis 2002:8).

- **Sustainable Development** – *"*The development that meets the needs of the present without compromising the ability of future generations to meet their own need*"* (Brundtland 1987:8).

- **Sustainable Housing Development** – The development that aspires to the principles of sustainable development which is a continuous process of maintaining a dynamic balance between man and the eco-system. It applies to the construction cycle from extraction and beneficiation of raw materials, to planning, design and construction of building or infrastructure, until final deconstruction and management of the resultant waste.

- **Sustainable Human Settlement** – *"*A city, town, village and its communities that enable us to live in a manner that supports the state of sustainability and the principles of sustainable development*"* (Du Plessis and Landman 2002:6).

1. Introduction and background

This chapter provides a preamble to the study of the design and condition of informal low-cost housing and its effects on the natural environment in the developing country of Swaziland. The research intends to propose a guide for sustainable low-cost housing construction and planning which can be used by planners and low-cost housing residents.

This section introduces the research by providing the background on urbanisation and how it has contributed to the formation of informal settlements and housing challenges that are faced today. Swaziland's background, where the study was conducted, is provided. Swaziland's policies regarding housing issues are discussed with the aim of understanding the context or setting for the study. Three research objectives are pursued in this research:

- To identify construction practices used in informal settlements.
- To determine how construction practices affect the natural environment in informal settlements.
- To formulate a framework which can be used as a guide towards the use of sustainable construction practices in the development of a neighbourhood for low income households, which will promote a positive use of the natural environment.

To achieve the objectives the main research question interrogates the effects on the environment of construction practices of informal settlements. The main research question is reliant on three sub-questions which are suggested in order to fully address the main research question. Research strategies and analysis for each sub-question are suggested in this chapter.

1.1. General Background

Cities have experienced a rapid increase in population growth globally since the industrial revolution when workers started shifting to manufacturing companies in urban areas (UN 2014). The continuous economic problems escalate the number of migrants to urban areas in search for jobs and a better life. Urban areas are seen to offer many opportunities; they are seen as a gateway out of poverty in that they offer platforms for production and trade. According to the United Nations (2012) in the World Urbanisation Prospects, it is the first time in history for the population to become predominantly urban. The United Nations has estimated that urban population of developing countries alone is expected to rise from "2.7 billion in 2011 to 5.1 billion by 2050" (UN 2012:3).

Urbanisation of developing countries, especially in Africa, Asia and Latin America, has grown to the extent that the local governments are not able to meet the demands of basic housing

and service provision to the residents (Ooi & Phua 2007:30). Urbanisation, amongst other factors, has resulted in the development of informal settlements in the form of slums around cities. Informal settlements are without access to adequate water supply, sanitation facilities, limited living areas, and they do not comply with urban areas' zone planning schemes. They are constructed on state or privately owned properties without permission from the local authorities.

Informal settlements, according to UN-Habitat (2012), are caused by urbanisation, globalisation, poverty and inequality. The number of people living in slums is currently 1 billion worldwide, which is a quarter of the current global population living in cities (UN 2014). The expectation is for the growth of slum population to reach 2 billion by 2030 (UN 2014). The growth in slums is expected to continually increase in the following decades according to Parsons (2010).

The growth of cities and informal settlements is imposing negative impacts on land use, welfare and the environment (Hansen, Knight & Marzluff 2005:1899). The inaccessibility of secure land is forcing millions of people to live in unfavourable areas vulnerable to environmental hazards. At a global level, World Bank and UN-Habitat, amongst others, turned their focus to urban development as a response towards the provision of proper housing and basic services. Literature suggests that International scientific researchers, institutions, industry professionals in the field of Human Settlement are also focusing on the improvement of living conditions in urban areas (Bredenoord 2016; Cole 2012a; Cole 2012b; Muchadenyika 2015).

1.2. Country background (Swaziland)

The setting of the study is in a city (Mbabane) in Swaziland, as shown in Figure 1.1 below (Alvaro 1984:18), which is a developing country in Southern Africa facing housing challenges as evident by the spread of informal settlements in urban areas. Swaziland, newly known as The Kingdom of Eswatini from the year 2018, is a small, developing, landlocked monarchy in Southern Africa, bordered by two countries - The Republic of South Africa and Mozambique. The Kingdom is positioned at roughly 26°30'S, 31°30'E. The Kingdom is known as one of the smallest countries in Africa, with a coverage area of 17, 364 square kilometres. Eleven percent of this land is arable.

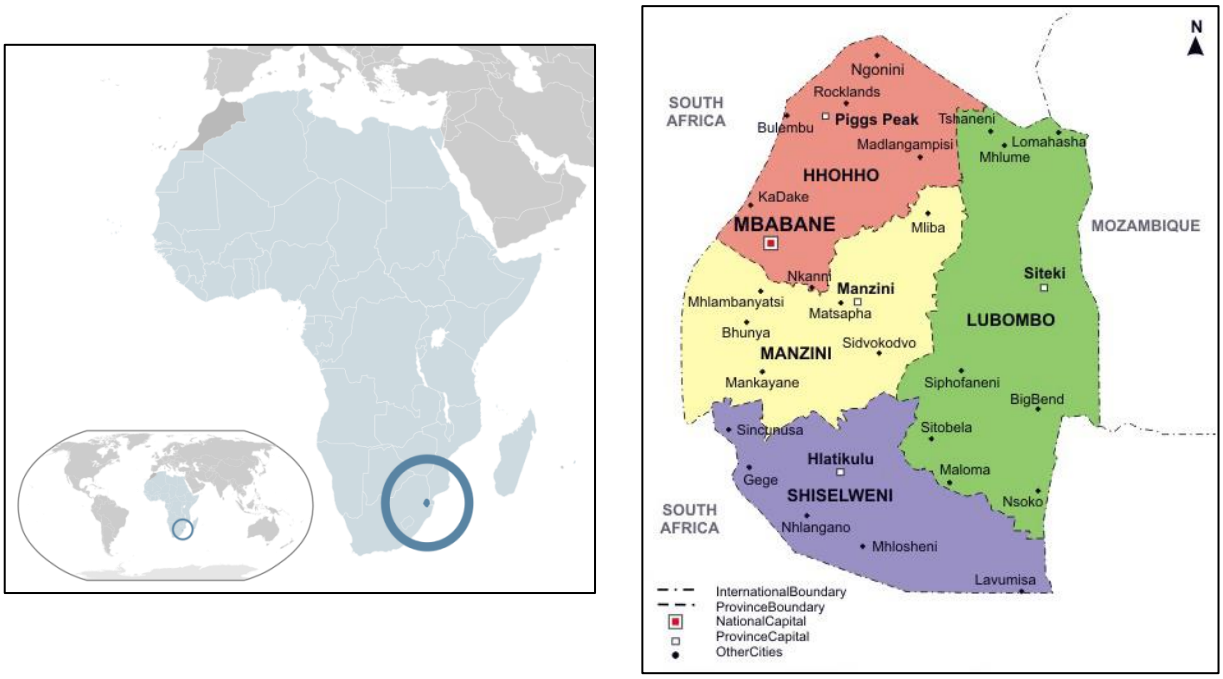


Figure 1.1: Swaziland location map

Swaziland is sectioned into four administrative regions which are: Hhohho, Manzini, Lubombo and Shiselweni. The capital city of the country, Mbabane, is located in the Hhohho district. According to the statistics from the 2017 census presented by the Deputy Prime Minister on November 9, 2017, the population of Swaziland is 1,093,238, with a density of 63 people per square kilometre. The population density of Swaziland is higher compared to the population density of its neighbouring countries, with South Africa having 46.1 people per square kilometer, and Mozambique having 36.6 (World Bank 2016). When comparing the population of 1997 and 2007, it is clear that the population growth declined as a result of HIV/AIDS, among other factors, which was recorded at 42.6% in 2005 according to the Ministry of Economic Planning and Develoment (2006). The annual change was 2.2 percent in 1997 and 1.6 percent in 2007. The population count presentation for the 2017 census showed an annual growth rate of 0.7%. UN (2014), states that the population increased by 74,789 persons between 2007 and 2017, and the increase was due to fertility, mortality and migration rates.

Manzini region has the highest number of people (355 945 inhabitants), followed by Hhohho region with a population of 320 651. Lubombo region follows with a population of 212 531, and the region with the least population is Shiselweni, with a population of 204 111. Table 1.1 below summarises the total population by region and shows population densities per region. From the table it is noted that Hhohho region has the highest density. This is where

Mbabane, the capital city of Swaziland is located. When a comparison is made on the regional population densities of 2007 and 2017 (Table 1.2 below), it is noted that the population is increasing in high percentages mainly in the Hhohho and Manzini regions. The population in Shiselweni decreased, and an assumption can be made that most people in Swaziland are moving from this region to urban areas, probably for employment opportunities. The population in urban areas is now estimated at 21%, with 75% of that population located in the cities of Mbabane and Manzini (Khoza 2006). 60% of the urban population live in informal areas, in structures which are sub-standard, land that has not been surveyed and without title. Just below half of the population has access to clean water and a quarter has access to a waterborne sewerage network (World Bank 2016).

Table 1.1: Population and density by region for 2017

Region	Area (km^2)	Population Count	Population density
Manzini	4 068.4	355 945	87.5
Hhohho	3 569.4	320 651	89.8
Lubombo	5 947.1	212 531	35.7
Shiselweni	3 779.4	204 111	54
Total Country	**17 364.3**	1 367 944	**78.8**

Source: United Nations Swaziland (2018)

Table 1.2: Density comparison for 2007 and 2017 census

Region	Population density 2007	Population density 2017	Difference
Manzini	77.8	87.5	9.7
Hhohho	78.1	89.8	11.7
Lubombo	35.6	35.7	0.1
Shiselweni	55.1	54	-1.1
Total Country	**58.7**	**78.8**	**20.1**

Swaziland's Ministry of Housing and Urban Development (2001) reports that in the country there are three main categories of land use type and ownership:

- Swazi Nation Land (SNL) – this land is held in trust by the King of Swaziland, who is registered in the Deeds Registry as Ngwenyama. Part of this land (51 percent) is allocated by chiefs to Swazi families for use as homes, for farming and commercial purposes (MHUD 2001). The chiefs, under their teams called *libandla*, are given authority by the King to conduct land planning and allocating it as homesteads. Previously, only male heads of families were allowed to acquire land through what is called *khonta* to the chief of the community where normally a single cow is paid for the land. In urban areas there is no SNL, but this kind of land is in rural areas.

- Government Land – this land is owned by government and it is vested in the King. Powers of the King are delegated to the Minister of MHUD who is allowed to sell, exchange or lease the land if the land is required for residential, commercial or industrial processes or development.

- Title Deed Land (TDL) – this land is held under freehold title, and it is divided between citizens of the country, foreigners and companies. This land is about 25 percent of the total area in Swaziland, and it is normally used for businesses since the citizens also have access to SNL. TDL is commonly located in urban areas and controlled by local municipalities.

The European Commission (2006) reported that there is increased demand of land resources because of an increase in population, land demand for agricultural and commercial use, and development. The paper reports that mechanisms of allocation of land and administration are not enough to correctly execute proper physical development planning of the country (European Commission 2006). Probably this is one of the reasons why there are land/housing challenges in Swaziland. One of the serious land challenges observed in Swaziland is land degradation and soil erosion. This challenge comes as a result of poor agricultural land management, forestry management, mining and construction.

Swaziland does not only face the challenges of land allocation, housing provision and services but the country is also unable to adequately provide other socio-economic needs like education, health and employment, amongst others (Matsebula 2012). Matsebula (2012) further states that this may be caused by the over reliance on Southern African Customs Union (SACU) as the main generator of revenue in Swaziland. A change in receipts from SACU greatly affects the country's economy as it happened in 2016. The Minister of Finance, Martin Dlamini, when reporting on Swaziland's budget for 2016/17 stated that the country's Gross Official Reserves declined by 9 percent over the calendar year ended December 2016. This was caused by a great fall in SACU revenue, and also an increase in expenditure for that year (Dlamini 2017:14). Revenue collected in 2015/16 totalled 14.1 billion Emalangeni (E) and SACU revenue was 49% of that amount (Dlamini 2017:14). Revenue is also received from Income taxes (27% in 2015/16) and VAT, which was 15% in 2015/16. Figure 1.2 below shows Swaziland's budget resources in summary.

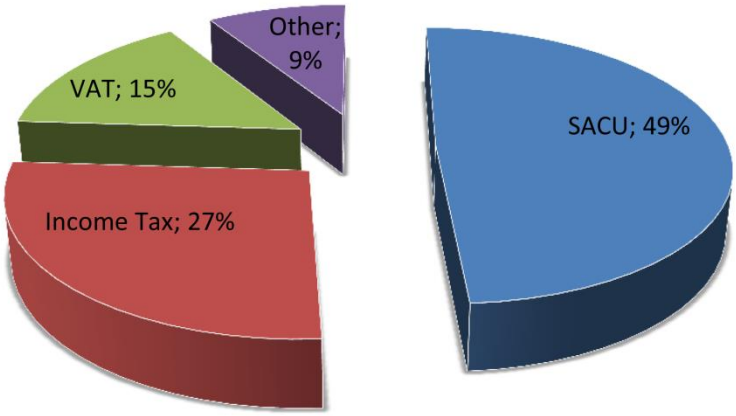


Figure 1.2: Swaziland's Budget Sources

Swaziland also relies on Agriculture and the manufacturing industry for its economic growth. The country employs about 70 percent of the working population. This is also common in most countries in Southern Africa. Reliance on Agriculture for revenue poses a number of challenges as was experienced in 2015/2016 when the nation was hit by the El Nino drought. In February 2016, the country declared the El Nino drought a Natural Disaster, and then launched the National Emergency Response, Mitigation and Adaptation plan (NERMAP). The National Disaster Management Agency (NDMA) conducted a study on the impact of the drought. The study estimated that the drought cost the economy of Swaziland about 3.8 billion Emalangeni (E), equivalent to the same figure in South African Rands (NDMA 2017). This is about 7 percent of Swaziland's Gross Domestic Product (GDP) in 2016 or about 18% of the countries expenditure in the same year. According to the report, this drought affected the Agriculture sector significantly as crop production decreased, with maize production decreasing by 67% which made households depend on the cash economy for food (NDMP 2017). As a result of the drought, the National Disaster Management Agency (2017) also reported that total sugar sales were expected to decline by 22 percent in 2016/2017, and beef production was affected as about 88 thousand cattle died due to the drought. The impact did not only affect the agriculture sector of the economy but also the energy, the environment, and water sector, which are critical areas in this study.

It was noted that the budget speech discussed rural development, as has been the case even in previous years, and a certain amount (110 million Emalangeni in 2016/17) is allocated each year to the success of the programme. This allocation seems low when looking at the number of the unemployed living in rural areas especially in comparison to only 59.7% of employed individuals who are mostly living in urban areas. This programme should be given more attention as it might have an effect in reducing the rate of urbanisation, which could then reduce housing challenges in cities. Creation of jobs in rural areas may decrease the number of people who migrate to urban areas in search for jobs and contributing to the

housing problem and formation of informal settlements. Urbanisation is said by Khoza (2006) to have grown rapidly over the years, but unevenly distributed.

Swaziland's high poverty level has a negative effect on the country's population, and the high number of the unemployed (40.3 percent) clearly shows the level of poverty which has an effect on housing (Census Report 2017). Even though there are twelve urban areas in the whole of Swaziland, 75 percent of the country's urban population lives in Manzini and Mbabane as stated earlier (Khoza 2006). This is where the informal settlements under study (Msunduza, Mahwalala and Nkwalini) are located.

Swaziland and the rest of the countries in Southern Africa are threatened by climate change. A draft report on the country's environment prepared by the European Commission (2006) suggested that by 2050 temperatures and rainfall will have increased by over 2-4 degrees Celsius in Southern Africa. The current climatic conditions are seen to change and get replaced by climatic conditions that are much hotter and drier (European Commission 2006:2). The EC (2006) further states that climate change is expected to negatively impact land degradation (vegetation reduction) and ecosystems (change in species composition) which will lessen productivity and livelihood possibilities unless resilient means to climate change are introduced.

The country, Swaziland, has responded to environmental challenges by developing a legislation framework and acts such as the Environment Management Act of 2002 to combat the environmental challenges encountered. The EMA is for the purpose of providing enhancement, protection and conservation of the environment. It also aims at management of natural resources in a sustainable manner. The EMA transformed the Swaziland Environment Authority (SEA) into a body corporate. SEA has all the authority to stop any constructions that have been assessed and found to be having a negative impact to the environment. However, SEA does not seem to be effective in informal settlements where developments are not formally managed and executed. This may be one of the reasons why the environmental impact seems greater in the informal settlements.

1.3. Relevant Policies in Swaziland

Earlier housing policies were prepared in 1987 and 1993 and they reveal how the approach to housing issues has evolved over time. Problems that were identified by the first policy (1987) included rapid growth of population and urban growth, and increase of informal settlements without basic infrastructure. The policy raised concern on the lack of formal

housing affordable to the low-income group. What is worth noting is that some of these concerns appearing in the 1987 draft policy are still concerns even in the current policies (2001). This policy (1987) was not formally approved but formed a basis for the preparation of the 1993 housing policy which was discussed in a workshop organised by the newly formed MHUD in 1992. The 1993 policy had sections on housing markets, housing finance, institutional development, land, developmental considerations and urbanism. It seemed as if issues of housing construction which touched on building regulations and use of indigenous building materials, and training for local contractors which were included in the 1987 policy are not discussed in the 1993 policy. It also seems there was a lot of reliance on the government in both policies. The environment is also not addressed as a concern in the first two housing policies.

There are also draft policies which do not seem to have been implemented to date but had an influence in the development of the 2002 housing policy. These are: the National Land Policy (NLP), the Peri-Urban Growth Policy (PUGP) and the Physical Planning Policy (PPP) (MHUD 2001). These policies are discussed in the next chapter.

1.4. Housing Challenges in Swaziland

Even though there have been attempts to solve housing challenges, especially through policies, Swaziland is still experiencing the rise of informal dwellings in the city outskirts, mostly along the Mbabane-Manzini corridor. That is a result of the high rate of urbanisation, as acknowledged by the Ministry of Housing and Urban Development (2001) in Swaziland. The Swaziland housing policy (2001) states that housing pressures are a result of job opportunities that are in Mbabane, Manzini and Matsapha (industrial town). The Swaziland Housing Sector Analysis document (MHUD 2001:20) mentions that many of the low income population groups prefer to live in peri-urban areas, mostly in Matsapha, for the following reasons:

- They do not have to buy land,
- There is a possibility of the area being developed at a later stage,
- They do not have to pay rates in peri-urban areas,
- They are escaping the enforcement of building and planning controls that increase the cost of building and increase the cost of living in urban areas.

This has given rise to the challenge of proper shelter provision and development of informal settlements.

The informal settlements in Swaziland are characterised by the lack of infrastructure, below standard buildings on public land without tenure, and unsanitary living conditions (MHUD

2001:43). These include slums with high densities at the edge of urban areas where there are job opportunities. In reference to the Swaziland Standard Building Regulations of 1968, these areas have houses that are below the required standards.

There are great impacts of informal settlements especially in degrading landscapes. The impacts include desertification, bio-diversity threats, water pollution and illegality in housing provision by landlords (Sofianou 2015:4). Landlords have taken over housing provision in high density areas like Matsapha – Manzini peri-urban areas (Matsebula 2012:13). Matsebula (2012:102) describes "factors influencing the growth of informal rental housing in Swaziland", suggesting that housing provision by landlords does not address social, economic, cultural needs of the residents, which is why there is high crime and high mortality rates amongst the residents that live in these areas.

Reportedly, over half of the urban population live in rental units and some of the reasons shaping the desire for this kind of accommodation as quoted from MHUD (2002) include:

- Temporary migration to urban areas
- The desire to minimise the costs of urban living
- A commitment to investing in housing in rural areas
- An effective supply response from persons living in urban informal and peri-urban areas
- Government subsidised rental housing, particularly in Mbabane
- The lack of sectional title opportunities for developers.

The MHUD (2001) further stated that with the decreasing rural housing options, it is predicted that there will be increased pressure to move permanently to urban areas. The prediction made in 2002 seems accurate as from the 2017 population census it is observed that numbers in rural areas were either not changing or decreasing, but the population in urban areas has increased, as earlier noted on Table 1.2. It has been noted previously that rentals are affordable to end-users and it provides income to the poor but this has resulted in the overcrowding normally observed in the informal areas in Manzini and Mbabane. This probably has an effect on the living conditions in some rental units.

Subsidies in Swaziland are mainly to government employees and some company employees. There are a few rental units which are subsidised by the government to any Swazi employee, but the waiting list is usually ridiculously long. With the lack of control of those subsidised units, even the high income group resides in these units, and the low income group is forced to live in informal areas.

The sector with the highest number of housing demand is the low-income informal sector as earlier mentioned that 60% of the urban population fall into this category. The biggest constraint as observed by MHUD (2001:43) was lack of access to affordable, formalised serviced plots. Currently informal areas around Mbabane and Manzini are government owned lands, governed by the Crown Lands Disposal Act, 1911 and the Crown Land Act of 1964. The former legislation allows for the land to be sold, granted, or leased, while the former allows for temporal occupation. Administration of this land is done by local authorities where they are located. These areas were previously not surveyed which led to a decision by government to ban construction. That, according to a survey done by UDP, resulted in overcrowding in these areas. The biggest challenge is upgrading these areas, and incorporating them into formal systems of housing development.

The UDP had the aim of upgrading the informal settlements and providing beneficiaries with secure tenure so that they are able to access formal finance to upgrade their houses and also pay for their plots. This seems like a response to the strategies discussed in the housing policy (MHUD 2001). The beneficiaries would then get a 99-year leasehold. The beneficiaries had questioned why they needed to purchase a plot which is owned by the government. In the informal areas being studied in this paper, UDP upgraded the areas by installing basic infrastructure but the main challenge is that a majority of the beneficiaries are not paying for their upgraded plots. Another challenge is the payment of rates to the city council which are not affordable to the dwellers. The issue of incorporating the land into a formal city planning and regulatory framework is debated. These may be some of the reasons the residents are not willing or cannot afford to pay for the serviced plots. A majority, as shall be seen in the results of the study, are not even able to connect to the sewer, water and electricity systems which are already passing through their plots. There is a possibility that the development of these areas is pushing the residents out of the developed areas.

The main housing issues in Swaziland are managing the urbanization process, providing municipal services and enabling the informal sector to work, including therein the delivery of rental units (Matsebula 2012:45). A conclusion made by the European Commission (2006:68) stated that the unpleasant environmental trends which relates “to land and water management, land degradation and pollution, ecosystem and biodiversity degradation, climate change and living conditions” in the human settlements in Swaziland led to the listed impacts:

- natural resource and biodiversity depletion,

- negative effects on ecosystems,
- loss of affordable energy sources,
- shortages of clean water supply,
- intensity of land, air and water pollution,
- increase in waste, and
- increased negative environmental impact.

Improving human settlements is supposed to be made priority as it also touches on human health. Issues of water safety, sanitation, waste management, pollution, and energy efficiency, need to be urgently attended to in informal settlements. This study suggests that this can be achieved through guided construction which should be sustainable.

1.5. Rationale of the Research

The Housing policy's strategy focuses on affordable housing provision only, and neglects the sustainable development of the neighbourhood as a whole. Theories on regenerative design (Cole 2012a; Du Plessis 2012; Mang & Reed 2012; Zhang 2014) agree that relocation of residents to newly serviced areas by government does not seem to completely attend to the needs of the residents, and it doesn't solve the problem of the destroyed natural systems. The theories propose participation of residents in developing their settlements to achieve a sustainable settlement. Even on the newly formalised areas like Msunduza, it has been observed that there are no plans on how to protect the environment, and having residents design and construct their own dwellings may influence unsustainable use of the environment looking at the fact that they may lack knowledge on sustainable construction practices. If the residents lack knowledge on sustainability, it is possible that they may use unsustainable construction practices. In as much as residents are now required to submit house plans for approval by the local Municipality, issues of sustainability are still not addressed in the Building Regulations (1968) as it focuses on structural integrity, sanitation and safety. The Swaziland Housing Policy (2001) also does not touch on the resilience of the developed neighbourhood. The approach proposed by the policy can be effective until change or disturbance takes place again – since it is vulnerable to change or disturbance. Change may refer to climate, markets, employment, environmental pressures and urbanisation among others.

The result of the study on the effects of construction practices on the natural environment will shed light on how to incorporate the concept of regenerative development in moving towards sustainable housing for low-income economic group. Regenerative development positively contributes to human and natural capitals (Cole 2012:1). It proposes a connection between

social and natural systems. The research provides an alternative approach that doesn't touch only on social and economic sustainability but also on environmental health. The strategies in the Housing Policy (2001) demonstrate that the Swaziland government sees the need to improve the condition of human settlements in the country, especially informal housing. Khoza (2006:8) states that the role of government is to develop an amenable environment for human settlements, and give guidance through the use of policies on certain issues which should be operationalized. The proposed approach, with a focus on construction practices, can be adopted by the local government through the MHUD, and the municipalities and other local authorities under the ministry can include it in their development planning. The Swaziland National Housing Board, which is a parastatal of the Ministry of Housing, can also benefit from the research as they are at the forefront of low-cost human settlement development in Swaziland. The UDP programme shows that government is concerned with the challenge faced by informal settlements, and with the unsuccessful program, other strategies to achieve the goals of the 2001 policy would be considered.

1.6. Research Problem

Construction practices negatively affect the natural environment through the over-use of non-renewable resources (Nair 2005:4430). The effects are on land, air, water and biodiversity (Smets & Lindert 2016:2). The threats posed to the natural environment possibly emanate as a result of the lack of construction quality control in informal areas (Bredenoord 2016:2). Preliminary investigations suggest that sustainable construction attends to the needs and protection of the environment. Sustainability should balance the social, economic and environmental aspects of a settlement. If one aspect is not considered, the settlement cannot be said to be sustainable. The development strategies that have been proposed by the Swaziland government (Swaziland Housing Policy 2001) as a response to low-income housing provision have no measures on how the natural environment will be protected, but focus on the social and economic sustainability part of housing provision. The government and settlers of informal settlements have no control mechanism or guide which can be used to construct sustainable self-help housing which can possibly reduce the degradation of the natural environment within these settlements.

1.7. Research Objectives

In order to address this problem, the research project puts forward the following objectives:

- To identify and evaluate the construction practices used by informal settlers and government in Swaziland.
- To determine how these construction practices affect the natural environment.

- To formulate a framework which can be used as a guide towards the use of sustainable construction practices in the development of neighbourhoods for low-income households, which will promote a positive use of the natural environment.

1.8. Main Research Question

What are the effects of construction practices of informal settlements on the natural environment?

1.8.1. Sub-question one

What construction practices are used in informal settlement areas?

- **Sub-proposition for sub-question one**

The proposition is put forward that construction practices used in informal settlements are practices which lack sustainability aspect and lead to environmental degradation.

- **Method**

In the literature review the phenomenon of construction practices is investigated with the aim to determine characteristics of sustainable construction practices, and also understand current assessment methods that are used.

Through structured observation studies, the construction practices used for houses were identified from sampled houses in three informal housing settlements with the help of a structured coded checklist informed by literature. The physical state of the housing settlement was also established as a whole, with the focus being on settlement planning to determine how the settlement planning by government has an effect on the environmental condition.

1.8.2. Sub-question two

How do construction practices in the informal settlements affect the natural environment?

- **Sub-proposition for sub-question two**

The proposition of this sub-question is that construction practices have a negative effect on the natural environment.

- **Method**

A structured observation study was conducted in the three selected informal settlements, with the aim of understanding the condition of the natural environment – land, air, water and bio-diversity. Maps and pictures are used in recording the traces of environmental impact.

Through qualitative analysis, the theoretical proposition was tested by comparing findings from the environment condition study in relation to a number of related outcomes (framework) that was anticipated. The framework used was derived from the literature discussed in the literature review.

1.8.3. Sub-question three

What measures can be taken to ensure sustainable construction which will also promote a positive use of the natural environment in informal settlements?

- **Sub-proposition for sub-question three**

Measures taken from sustainability and regenerative theories are required to solve the environmental challenges in informal settlements.

- **Method**

A framework for informal housing settlement construction was created using data collected and analysed from the first two sub-questions, and with assistance from evaluated existing frameworks from literature. The framework should act as a guide for incremental self-help housing construction in an informal housing settlement.

1.9. Research Propositions and Hypothesis

In order to address the research problem effectively it was proposed that:

- Construction practices used in informal settlements have an effect on the natural environments we live in.

1.10. Type of Research

In order to effectively determine the components of the research, the research approaches were first determined.

Relevance – The research has scientific relevance because the results can be analysed and presented in a scientific (empirical) manner. Scientific research is the kind of research which constitutes certain organised methods which are used by a researcher to develop knowledge that exists by means of acquiring data on a phenomena (Bordens 2013:2). Naidoo (2011:47) defines scientific research as, "an inquiry of nature and society with the goal to generate or to validate and refine knowledge in a systematic way". A research that is scientific has to have the following characteristics: relevance of teleological nature, research orthodoxies, theoretical orientation of the research, and ethical framework (Singh 2016).

This study follows the research process: a framed problem on construction practices and natural environment which have been further scientifically framed; the study has a hypothesis as detailed in the previous section; collection, analysis and presentation of data are done on later chapters. In scientific research, truths and facts are searched in a logical manner with the help of logical arguments. The results of this research provide knowledge that should assist local municipalities in accommodating and controlling the construction of self-help houses in informal settlements through an update of their current building codes and regulations. The validation of information collected and presented is also done.

Teleological Type – The research comprises of an explanatory study, but a descriptive study is a forerunner to the explanatory research. It was important to get a clear picture of the construction practices first before data was collected on the causal relationship studied. Saunders, Lewis & Thornhill (2016:176) state that in an explanatory research a situation is studied to explain a connection between variables. In this study, construction practices were identified from three informal settlements and they were analysed with the support of information captured from the literature review which framed the construction practices. After the collection of data on construction practices, the natural environment was observed with the help of observation studies and an analysis was made. The natural environment was also analysed in properly constructed and planned settlements so that the effects on the environment could be studied by comparing and contrasting with informal settlements. This provides the data needed to test the hypothesis put forward that "construction practices have an effect on the natural environment."

Research Category – Applied research was conducted. This research type aims to apply knowledge or theory rather than expanding or creating theory. Applied research seeks to solve real-world problems which could be applicable to practical problems that we face (Saunders 2013). This research seeks to find solutions to the degrading of the environment in low cost informal settlements in Swaziland. Once it is understood how construction

practices impact the natural environment, a framework is produced with the aim of assisting informal dwellers on how to construct sustainable self-help housing which can have minimised impacts on the natural environment in these informal settlements. As such, the outcome of this research will be applicable to a real life problem. Applied research differs from basic research in that the latter is aimed at getting knowledge about phenomena in a general approach to create and add knowledge (Saunders 2013).

Linkage to Theory – There is combination of theory testing and, mostly, theory application research, with very little theory building. The main purpose of this study is to apply knowledge in trying to solve issues of the degrading environment in informal settlements as previously highlighted. Theory testing was done in testing the hypothesis which stated that construction practices affect the natural environment. The approach is deductive – development of theory that is then tested through propositions (Saunders et al. 2016:146). The approach progressed through six sequential steps as listed by Blaikie (2009:147):

- Putting forward a hypothesis about the relationship between construction practices and the natural environment (chapter 1 &2).
- Deducing a testable proposition by using existing literature. This is done in chapter two which investigated existing literature.
- Examining the logic of the argument and comparing it with existing theories to see if it offers an advance in understanding (chapter 2 & 3).
- Testing the hypothesis by collecting data to measure the variables and further analyse them (chapter 5).
- If the results do not support the hypothesis, the theory will be taken as false and rejected (chapter 6).
- If the results produced after an analysis are consistent with the hypothesis, the theory is accurate/corroborated (chapter 6).

Theory building is minimal in this study. It only exists for the purpose of hypothesis creation. So it could be estimated at 10%. An estimate in percentages of each component (type of theory) as discussed above is shown below:

- Theory building research – 10%
- Theory testing research – 25%
- Theory application research – 65%

Data Acquisition – Data was obtained through case studies with a combination of surveys, observations and literature review. The literature review informed the research tool (structured observation schedule) which was then used in collecting data on construction practices used in informal settlements, and the condition of the natural environment. Maps and pictures were useful in collecting data on the natural environment by looking for traces of environmental impact.

Saunders (2013) states that structured observation puts the researcher in a position of being a pure researcher, than being a participant as it adopts a detached stance. The author further states that a coding schedule is necessary when doing structured observation, and it should be suitable to answer the research question. In ensuring data quality, there are main issues which relate to aspects of reliability in structured observation and they are discussed in Chapter 4.

Data Analysis – Data obtained for the first sub-research question was analysed through basic descriptive testing, which allowed for the variables to be described and compared numerically. The statistics describe the central tendency – values that are common, middling or average. They are measured in three main ways according to Saunders (2016:529):

- "value that occurs most frequently (mode);
- middle value or mid-point after the data have been ranked (median);
- value often known as the average that includes all data values in its calculation (mean)."

The statistics also allow for testing for significant relationships between the variables under study.

The second sub-research question was answered through qualitative analysis – pattern matching. Pattern matching is described by Yin (2014:53) as follows: "Pattern matching involves predicting a pattern of outcomes based on theoretical propositions to explain what you expect to find from analysing your data". A framework was developed from literature to find expected outcomes which were compared with the real findings from the study.

The above is summarised on Figure 1.3 below:

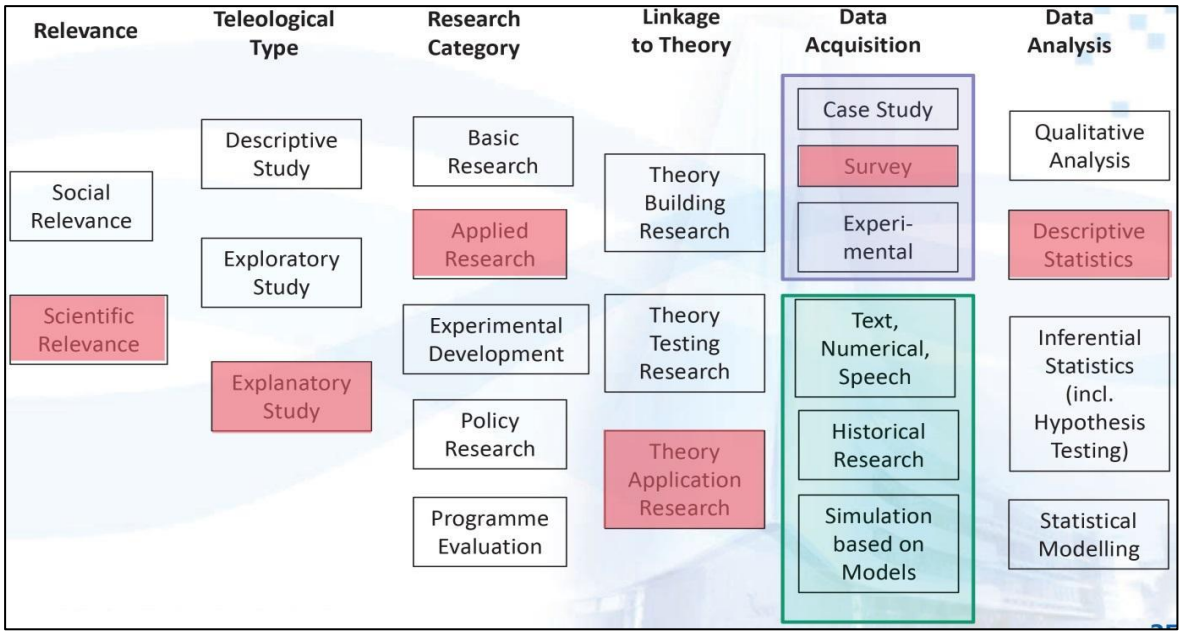


Figure 1.3: Type of research summary

1.11. Delimitations and Assumptions of the Study

The study is limited to three purposely selected study areas, which are low-cost housing settlements in Mbabane namely Msunduza, Mahwalala, and Nkwalini. These are currently the only settlements where the Swaziland Government, through the UDP (discussed in chapter two) led by the Swaziland National Housing Board, intervened by installing basic infrastructure required by the settlement and allocation of surveyed plots to original resident of the areas (Ndlela 2005). The research studies not only construction practices used by the informal settlers, but also those used by government through settlement upgrade.

It is assumed that a comparison between proposed sustainability measures for low-cost housing from literature and construction practices in Swaziland gives an understanding on the level of the sustainability of construction practices in the country. It is also assumed that by evaluating construction practices in low-cost housing and their effects on the natural environment, improved sustainable construction practices can be explored, and the negative impacts on the natural systems will be mitigated.

2. Literature Survey

2.1. Introduction

This chapter mainly reviews existing literature which is related to the study topic, with the aim of understanding the problem clearer and supporting proposition testing. This review is focused on literature pertaining to the nature of informal settlements and their upgrading specifically in selected developing countries in Africa and Asia, framing the study to construction practices in informal settlements in developing countries.

The chapter starts by defining and discussing informal settlements and their formation. This is important as the study is evaluating housing in informal settlements. The study further discusses impacts on the natural environment and theories on its protection. A potential correlation between construction practices and the natural environmental impacts is investigated.

Current approaches and theories on informal settlements upgrade are discussed, and selected examples across the world are analysed. Therefore, the chapter discusses general theories on sustainable development and housing as solutions, then narrows down to current theories on sustainable construction practices and the environment. Current approaches to sustainable low cost housing are discussed, and categories of sustainable housing from literature are identified. Further assessment methods are reviewed to inform the observation schedule.

After the literature on the above has been discussed, the focus moves to informal housing in Swaziland to draw a conclusion on the gap that exists. The chapter ends with a brief discussion of observation studies, which provides a framework for the conceptual model in the next chapter.

2.2. Informal settlements and housing

2.2.1. Definition of Informal Settlements

Informal settlements are described by Ploeger and Groeterlaers (2006:1) as dense spreading of shelter units constructed of diverse materials and built on privately or government owned property without a title deed by the occupants. Ploeger and Groeterlaers (2006:2), claim that informal settlements develop in countries where planning and housing systems are not functioning properly. The United Nations (2014) defines informal settlements as areas that do not comply with urban areas' zone planning schemes, where housing units are constructed

on state or privately owned land to which the dwellers have no legal claim or permission from the local authorities. The UN clarifies that informal settlements are not only for the urban poor, but belong to all income levels. That means even luxurious buildings can be informal if they are built on privately owned land without a title according to UN-habitat (2014).

There are several forms of informal settlements described by Potsiou and Loannidis (2006:4):

- Squatting on government or privately owned property, and shacks. This is common in developing countries in Africa, Asia and Latin America.
- Illegal subdivision of Agricultural land to housing or industrial use, or vice versa. This is observed in Manila and other Latin American countries.
- Construction on legally owned land but without the approval of local authorities.
- Illegal refurbishments or construction of extensions on legally approved structures.
- Illegal subdivision of apartments and rented at high illegal market prices. This occurs in developed and developing countries.

Potsiou and Loannidis (2006) on the third point above seem to agree with UN's claim that even high cost buildings can be informal. The United Nations Economic Commission for Europe (2009:21) characterizes informal settlements as, "illegal residential formations lacking basic infrastructure, security of tenure, and adequate housing*".* Informal settlements are also defined by Dovey and Rose (2011:11) as, "urban neighbourhoods or districts that develop and operate without the formal control of the state, co-existing but not synonymous with 'squatter' settlements and 'slums'.*"* Table 2.1 below compares a few definitions from the literature discussed and seek for similarities in all.

Table 2.1: Definitions of the term *Informal Settlement*

	Ploeger and Groeterlaers (2006)	**United Nations (2014)**	**Potsiou and Loannidis (2006)**	**UNECE (2009)**	**Dover and Rose (2011)**
Building Characteristics	- Dense units built with diverse material	- Any building type at any level	- Any building type at any level	- Illegal -Lack basic infrastructure -Inadequate housing	-illegal -lack basic infrastructure
Title	-Not Title	-No title OR -Title without approval	-No title OR -Title without approval	-No title	-No title
Approval by Local Authority	-No permission/ approval	No permission/ approval	No permission/ approval	No permission/ approval	No permission/ approval

The literature compared on Table 2.1 above agrees on the “lack of security of tenure” and “lack of approval of residential formations from the local authorities.” Informal settlements are understood as for any economic group but most literature seems to refer to low cost housing units (Dover & Rose 2014; Poeger and Groeterlaers 2016; UNECE 2009). Sometimes informal settlements are defined in a way of comparison with the other part of the city which is said to be formal, with the implication that in the future they should also be formalised (Hernandez-Garcia 2013). Formality refers to the planned, institutional, and the city which is said to be legal (Hernandez-Garcia 2013). Legality does not seem to be clearly defined in the literature reviewed, but from the table above (Table 2.1) it can be assumed that illegality is associated with informality, and legality is associated with the properly planned city approved by the local authorities.

This dissertation uses the most applicable definition of *informal settlement* by the World Bank and UN Habitat Programme (2014:2), and which most authors agree on, as observed above – “residential areas with housing constructed on land to which the dwellers have no title.” This dissertation focuses on informal settlements for the urban poor which are mostly in the form of slums, where housing conditions are deplorable. Their main characteristics are, “the lack of basic services, living in inadequate structures, overcrowding, unhealthy conditions and poverty” (UN 2014:2). On overall, informal settlements seem to be described on physical condition and legal status.

2.2.2. Morphology of informal settlements

With the dissertation having a focus on effects of informal settlements on the natural environment, it is important to clearly understand the morphologies of informal settlements as they may have an influence on the natural environmental change. Understanding the formation of informal settlements is important as this may be the stage when degradation of the environment starts. The assumption is that impacts occur from formation (construction) stage up until demolition stage as to be discussed later. This prompts the crafting of proper solutions and sustainable measures which should be implemented in the formation of informal settlements. Dovey and King (2011) after an analysis of literature (Brillemborg and Klumpner 2005; Evers and Korff 2000; Huchzermeyer and Karam 2006; Neuwirth 2006; Turner 1976) argue that there are three primary modes of informal settlements (how informal settlements grow):

- Settling – this occurs on unclaimed land as in the past and it is the way towns were formed.
- Inserting – this occurs when residents occupy abandoned land which was uninhabited

- Attaching – this occurs when informal settlements attach onto structures of the formal city.

Clearly the formation of these forms is not controlled which may be the start of the environmental challenges (among other factors) as there are no formal plans followed which protect the environment.

2.2.3. General location of informal settlements

A typology of eight informal settlement types (typical conditions rather than building types) is listed by the same authors (Dovey & King 2011:14) as follows:

- District – mixed-use districts with retail and industrial functions, which have developed over a long period, as shown in Figure 2.1 (Dovey & King 2011:14).
- Waterfronts – settlements on marginal land between the formal city and the water whether river, canal, lake or harbour frontage. These areas are prone to flooding most of the time. The natural environment may be at risk of water pollution in such areas. An example is shown on Figure 2.2 below (Dovey & King (2011:15).
- Escarpments – settlements are normally on very steep areas which are left undeveloped by the formal city because of their inaccessibility by a car.
- Easements – such areas are located mostly along major urban infrastructure – railways, freeways, power lines, sewer lines (Figure 2.3 below).
- Sidewalks – settlements may follow a public sidewalk and lead to linear housing normally of a single storey and built of cardboards and plastics.
- Adherences – some informal settlements grow within formal settlements and intrude onto public spaces.
- Backstage – such informal settlements are invisible and they develop between buildings of the formal city.
- Enclosures – these informal settlements are physically located within a certain formal shell within the city which forms the boundaries for the extension of the informal cities. Examples are informal settlements within cemeteries in Indonesia and Egypt. An example of an enclosure is shown on Figure 2.4 below (Dovey & King 2011:19).

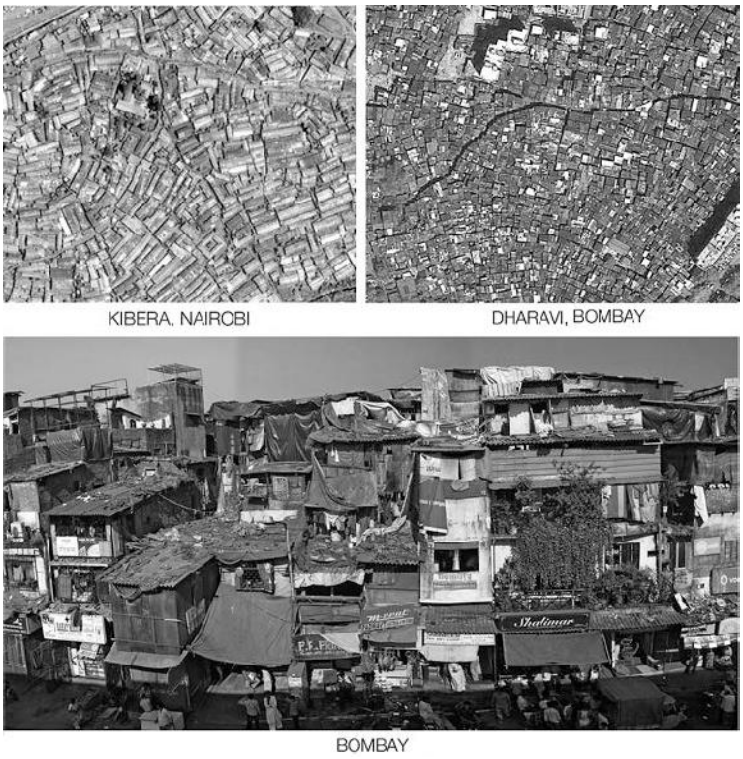


Figure 2.1: Urban districts. Photo by Dovey (2011)

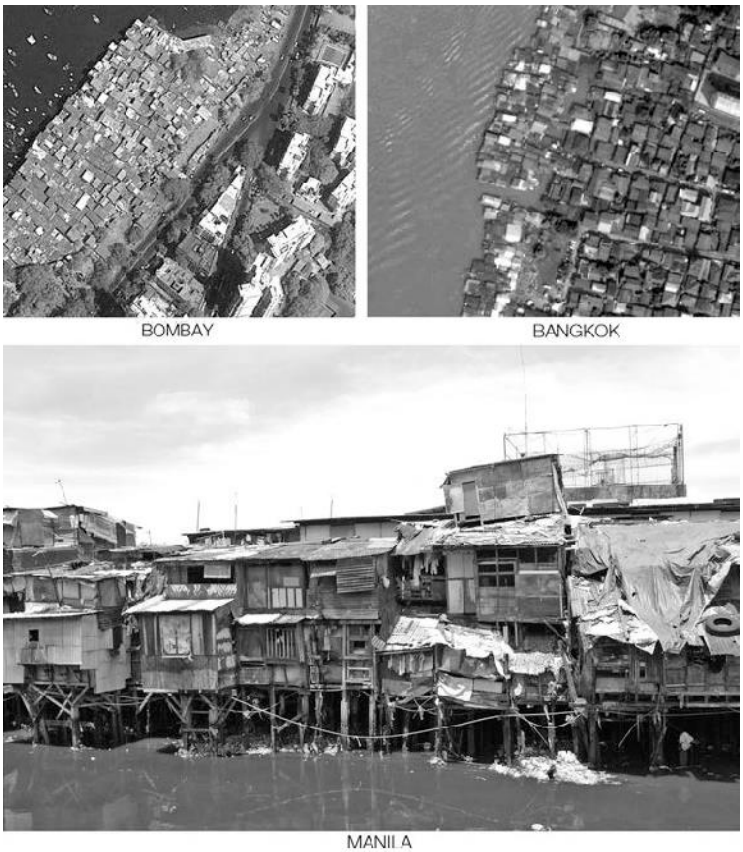


Figure 2.2: Waterfronts. Photo by Dovey (2011)

Figure 2.3: Easements in Manila

Figure 2.4: Enclosures. Photo by Dovey (2011)

Waterfronts, escarpments and easements may pose the most impact on the environment and there may be threats to sanitation and safety. The above types seem to demonstrate how informal settlements mushroom on specific locations and a different classification of types may be developed. Some informal settlements may be a hybrid of the types listed, where infrastructure like a railway may be co-located with a waterfront. The housing found in

informal settlements normally extends horizontally in a room by room accumulation manner, as a result of poverty and slow accumulation of resources (Dovey & King 2011).

2.2.4. Causes of the development of informal settlements

Poverty has been identified as one of the main reasons for the development of informal settlements with low-quality and overcrowded housing, lacking various services and infrastructure (Bredenoord 2016:1; Nassar and Elsayed 2017). Nassar and Esayed (2017) also believe that this kind of housing is caused by the lack of formal response to the housing demand and that makes informal housing the logical response. A summary of several common factors are highlighted on Table 2.2 below.

Table 2.2: Causes of informal settlements

Authors	Factors
Bredenoord (2016)	Poverty
Nassar and Elsayed (2017)	Poverty Lack of adequate formal response to housing demand growth
Napier (2004)	Transition from colonialism Poverty Impacts of structural adjustments "Neo-liberal programs on formal welfare for the low income population"

Poverty has been highlighted by all the authors and seems to be the main reason for the type of housing found in informal settlements. Bredenoord (2016) mentions that poverty influences the growth of self-help housing – the type of housing provision system which is mostly incremental and executed in a step-by-step construction process (Wekesa et al. 2011). On the other hand, informality is accepted now as an alternative method of doing things, and not only associated with poverty and deprivation (Hernandez-Garcia: 2013). Dovey and King (2011), contend that informal settlements are a way in which one out of three people living in cities sustain themselves. Whichever way informal settlements are perceived, most literature seem to directly or indirectly agree that in these areas self-help housing is observed (Bredenoord 2016; Bredenoord 2017; Devi, Lowry & Weber 2017; Dovey & King 2011; Ploeger & Groeterlaers 2006).

2.3. Environmental Impact

The formation of the different types of informal settlements described on the previous section, seem to have a negative impact on the natural environment as they are not formally controlled amongst other reasons. The manner in which they are located and constructed

(like along rivers) might be the first reason of their effect on the environment. Hansen et al. (2005) and Kramer (2013) state that in the development (construction included) of residential housing and other related infrastructure, an impact on ecological systems and biodiversity is witnessed.

Housing and infrastructure remove vegetation and have a negative impact on the remaining habitat. When natural vegetation is removed, nutrient and biogeochemical cycles change (Kaushal 2006; McKinney 2006). Sofianou (2015) enumerates landscape aesthetic deterioration, biotic diversity threats, desertification, forest and open land squeeze, and water contamination as impacts inflicted by informal housing. These statements suggest a causal relationship between construction practices and condition of the environment, as Pullen (2010) has proved that effects on the environment are witnessed during the construction stage, operation stage and demolition stage of a structure.

The effects are also indirect; the growth of housing leads to the growth of transport infrastructure which introduces more pollutants and interruptions (McCarty & Kaza 2015). The most concern observed is on low-density residential development since it spreads the environmental impact of an individual house over a great portion of land, enlarging the footprint of housing development (Hansen et al. 2005). The statement suggests that densification of housing has less impact on the environment. These researchers reveal that the design, planning and construction practices of housing have an impact on the condition of the natural environment. Handy, Boarnet & Ewing (2002), state that the built environment affects physical activity as a link between the built environment and travel behaviour is observed.

The environmental impact linked to construction is possibly greater in developing countries compared to developed countries looking at the reality that developing countries are still under construction (Du Plessis 2002). The linkage between construction and the natural environment comes with the demands of natural resources by the construction industry. It is a fact that as the population increases, more houses are required, and the demand on natural resources increases. If the use of these natural resources is not controlled, a negative impact on the environment may be witnessed.

The environmental impact from development is on the atmosphere, land and water. The following table below (Table 2.3) shows the environmental components and indicators:

Table 2.3: Environmental Components and Indicators

Environmental Impact	Sub-component	Indicator
Atmosphere	Climate Change	Greenhouse Gas emissions
	Ozone Layer Depletion	Consumption of Ozone Depleting Substances
	Air Quality	Ambient Concentration of Air Pollutants in Urban Areas
Land	Agriculture	Arable and Permanent Crop Land Area
		Application of fertilizers
		Application of Agricultural pesticides
	Forests	Forest area as a percentage of land area
		Wood harvesting intensity
	Desertification	Land affected by desertification
	Urbanisation	Area of urban formal and informal settlements
Fresh water	Water Quantity	Annual withdrawal of ground and surface water as a percent of total available water
	Water Quality	Biochemical oxygen demand in water bodies
		Concentration of faecal coliform in freshwater
	Ecosystem	Area of selected key ecosystem
		Protected area as a percentage of total area
	Species	Abundance of selected key species

Source: United Nations Statistics Division (2016:7)

On the other hand, some researchers have a different view on the environmental impact of informal settlements as they believe they have a lesser ecological footprint compared to the formal areas since they are believed to use fewer resources and energy (Devi, Lowry and Weber 2017; Du Plessis 2002; Du Plessis and Landman 2002; Kovacic, Smit, Musango, Brent and Giampetro 2016; Goebel 2007). Grove (2009) supports this view as he argues that these settlements are compact, use less energy and there seem to be practises of waste reuse and recycling in these settlements. The energy consumption has been proven to increase with the increase in economic development in a study conducted in European countries (Jorgenson, Alekseyko and Giedraitis 2014). Clearly these authors still admit that informal settlements have environmental impacts, which are claimed to be lesser when compared to environmental impacts witnessed in formal settlements.

From the above it can be deduced that unplanned or poorly planned housing leads to a negative impact on the environment. It is also understood that if the standard of living in informal settlements is raised, there could be an increased demand on nature. Since the improvement of living conditions is the main goal in informal settlement upgrade, it is advisable to control development in such a way that it limits the impact on nature. The environmental conditions in informal settlements can be improved through upgrading of the settlement (Devi, et. al. 2017).

2.4. Current Intervention Approaches

The reviewed literature (Bredenoord 2016; Bredenoord 2017; Devi, Lowry and Weber 2017; Du Plessis 2002; Du Plessis and Landman 2002; Kaushal 2006; Pullen 2010; Sullivan and Ward 2012) has demonstrated that informal settlements have an impact on the natural environment hence the number of environmental assessment tools and theories that have been developed as responses to this housing problem. The most preferred way to improve environmental conditions in informal settlements is believed to be settlement upgrading (Abbot 2002a; Abbot 2002b; Devi, Lowry and Weber 2017; Walker 2016; Wekesa, Steyn and Otieno 2011). Nassar and Esayed (2017) believe that there are policies, strategies and programs that have been worked out by affected governments, especially in developing countries, to try and solve the housing challenges experienced in urban areas which give rise to informal areas, which then affects the environment. The interventions explained by Nassar and Esayed (2017) are also confirmed by several other authors (Balbo 2001; Huchzermeyer 2003; Wekesa, Steyn and Otieno 2011; UN-Habitat 2005) and they are briefly discussed below.

2.4.1. Public Housing

Provision of public housing, which was common in the 1950s to 1970s and financed by state governments, involved the relocation of informal settlement residence from their dwelling area to the government developed public housing (Wekesa et al. 2011). The author explains that the architecture, size and construction technologies in the development of this kind of housing were influenced by the contractors appointed for these developments.

The public housing programs attracted many challenges which included the challenge of meeting needs of low-income population to the physical characteristics of the programmes (Werna and Keivani 2001:84). The living spaces were not enough for large families, and the houses were located on cheap land which had challenges of access to job opportunities. Ogunshkin and Olayiwola (1992:47) quoted by Wekesa et al. 2011, state another challenge of low completion rates and inappropriate use of resources by contractors of this housing. Corruption was also one of the biggest challenges of public housing, which is one of the reasons Werna and Keivani (2001) claimed that these programmes were a complete failure.

Nassar and Elsayed (2017) still believe that this kind of housing should be adopted but only where locations of informal settlements pose an imminent danger to the lives of the dwellers, and after all other feasible alternatives are seen not to work.

2.4.2. Sites and services

The increasing housing shortage, influences of the World Bank, and inability of governments to provide public housing to the urban poor led to the introduction of sites and service

schemes in the 1970s and 1980s (Balbo 2001; Werna and Keivani: 2001:86). This approach provided developed *greenfields* with secure tenure and infrastructure services to the dwellers of informal settlements who were required to build and self-manage their houses (CSIR 2000:104). Sometimes a small unit was built which the dweller would then develop later on after acquiring resources. This approach seems to replicate the incremental growth method witnessed by John Turner (1976).

These indirect public housing programs also had their challenges as they are said to have failed to improve the situation (Werna & Keivani 2001:87). The failure of this approach was as a result of low output level when compared to the demand and affordability to the target group (Wekesa et al. 2017). This approach shares the same challenge as public housing as the sites were normally cheap, which led to challenges of access to employment areas. The focus seemed to have been on physical upgrading but lacked the social, economic and political components. Nassar and Elsayed (2017:4) defend that by stating that, "socio-economic development activities can proceed afterwards through local and national programs".

2.4.3. Informal settlement upgrading

The failure of the discussed direct and indirect public housing approaches led to the informal settlement upgrading approach (Balbo 2001). The main idea is that the substandard housing environment (brownfield) be upgraded rather than destroying the neighbourhood and relocating residents to a greenfield site as this new approach is seen as cost effective (Wegelin 2004). Initially this approach had a focus on the physical aspect – upgrading infrastructure and services (Nassar and Elsayed 2017). It includes the improvement and installation of basic infrastructure such as "water, sanitation, solid waste collection, access roads and footpaths, storm water drainage, electricity, and public lighting*"* (Imparato and Ruster 2003:2). This approach also includes security of land tenure and dwellers focusing on improving their homes. Akrofi (2001) stated that tenure upgrading requires a lot of work and staff dedication to manage the process. The responsibility for this staff engaged to manage the process includes educating and building capacity for the encouragement of participation, collaboration between the community, municipality and land owners, amongst other responsibilities (Wekesa et al. 2011).

Wegelin (2004:8) explains that the early approach of informal settlement upgrading focused on unrelated projects at neighbourhood level rather than focusing on policies. This approach evolved to include the combination of "physical, social, economic, organisational and environmental improvements" undertaken among all stakeholders (Wekesa et al. 2011:242).

The same author believes that this approach is one of the few which works well and it has been adopted by many non-governmental organisations.

This approach is categorised as *"*partial adjustment in informal settlements*"* in an article titled "From Informal Settlements to sustainable communities," by Nassar and Elsayed (2017:4).

2.4.4. Housing production

There are also other house production and delivery modes providing affordable housing to the poor that are under discussion and have been implemented in some countries like South Africa. These include self-help housing and social housing.

Self-help housing is the cheapest alternative model proposed to replace "built-in labour, time and resources in conventional housing with labour, time and materials to be provided by future dwellers of the self-help housing" (UN-Habitat 2005:2; Wekesa et al. 2011:242). This mode incorporating a large donor component is recommended by the UN Millennium Project's Task Force even though it does not reach the poorest. However it produces housing which is very affordable as the profit component is eliminated (Wekesa et al. 2011). Self-help housing is self-managed by the owner who determines the quality of the building (Bredenoord 2016). The main actors in housing delivery in these areas are the dwellers. Self-help housing can be formalised by government or Non-Governmental Organisations, which was also observed in Swaziland in the UDP programme to be discussed in the next sections. Bredenoord (2016:8) states that many households worldwide have opted for this type of housing but the challenge is that sustainability is not given high priority in this housing system. This may be as a result of poverty and lack of support and knowledge. So possibly if the residents are not knowledgeable on sustainable construction practices, they are likely to build unsustainable self-help housing, which may lead to an unsustainable settlement.

On the other hand, UN-Habitat (2005:166) claims that assisted self-help housing is sustainable and practical as it is affordable to the poor and meets their needs. In the same paper it is argued that suitable supply of building materials is important in incremental upgrading of informal settlements. If self-help housing could be properly managed, there is a chance that environmental impact could be minimised and a sustainable environment could be created.

Social housing is a non-profit initiative in which government involves the private sector to help in providing housing for the poor according to CSIR (2000). This kind of housing is

subsidised so that rent is affordable to the lower-income earners. The advantage of this approach is that it provides security of tenure through rental, but the disadvantage is the assumption that the dwellers have a stable income, which is normally not the case.

2.4.5. Building Codes and standard reforming

Another perspective in solving the housing situation was a recommendation of the reforming building codes and standards to reduce construction costs and make housing affordable to the low-income earners (UN-Habitat 2005:20). By changing the building codes and standards, housing production costs would be cut, and some existing housing stock would be legalised. Under this reform, it is also recommended that small-scale manufacturing and services developments be allowed to be within home premises for the empowerment of the economically poor.

None of the above listed programs have addressed the environmental quality of housing needs on a larger scale (Nassar and Esayed 2017). Upgrading with the aim of developing sustainable informal settlements could minimise the environmental challenges in these areas. The Department for International Development (2000) states that informal settlements are sustainable only when they are resilient – coping and recovering from stresses and shocks. The resilience can only be achieved through the enhancement or maintenance of their capabilities.

Currently common intervention procedures involve these several parameters:

- Informal settlement servicing
- Partial alterations within Informal Settlement
- Development of the brownfield (on-site)
- Development of greenfield and relocation of residents to developed area
- Application of the Millennium Development Goals in Informal Settlement

A sustainable informal settlement should have all the three sustainability components: economic, social, and environment, as emphasised earlier. The sustainability of the briefly discussed interventions is generally tested in Table 2.4 below by observing if all three components exist. It is noted though that some of the interventions, especially informal settlement upgrading, have been developed to accommodate most or all aspects of sustainability.

Table 2.4: Intervention analysis of sustainability components and challenges

Intervention	Sustainability component focus	Challenges
Public housing	Social	Power given to contractors Relocation does not solve environmental challenges
Sites and services	Physical	Relocation does not solve environmental challenges
Upgrading brownfield	All	Implementation
Self-help housing	Economic	Focus is mainly on economic aspect Power given to dwellers without sustainability knowledge and skills
Social housing	Social	Economic aspect missing as there are issues of unaffordability Environmental component has no focus
Building codes	Economic	Focus is only on affordability

Integration of most of the above interventions, excluding those that require relocation, may solve the challenges of informal settlements, especially the environmental component which is the main focus of this study. The application of the above discussed interventions is reviewed on a selected informal settlement improvement in Indonesia.

2.5. Case Study – Kampung Improvement Programme (Indonesia)

The term *kampung* refers to informal settlement in Indonesia. *Kampungs* are described as irregular informal settlements with their housing found in plots with limited space, and have minimal facilities and infrastructure (Combrinck 2017). The *Kampungs* are inhabited by low income dwellers, but have low occupancy qualities. These settlements share the same formation challenges described earlier, as they are said to have formed and expanded under no formal control from local municipalities.

The Kampung Improvement Programme (KIP) is described as, “a neighbourhood improvement programme aimed at facilitating better roads and footpaths, drains, water supply, sanitary facilities, solid waste management and better social and educational conditions amongst the inabitants” (Kenworthy 1997 in Combrinck 2015:62).

The KIP, Indonesia, launched in 1969 was the world's first slum upgrading programme (UN-Habitat 2006:1) which has received a lot of global recognition as it is claimed to have been a success by a number of authors (Dianingrum, Faqih and Septanti, 2017). This is evident by the following received awards:

- Aga Khan Award for Architecture in 1986
- World Habitat Award in 1992
- UN habitat scroll of Honour in 2005 (Silas, 1992)

Its success has been observed in the improvement of environmental quality problems and reduction of urban poverty (Steinberg 1992 and Silas 1992 in Dianinggrum 2017). The purpose of KIP was to improve environmental quality and also support the Long-Term Development Plan (RPJP) 2005-2025 where it is expected that by the end of 2025 the country should not have any slums in cities (Kementrian-PPN 2005 in Dianingrum et al. 2017). KIP began its implementation in Jakarta and Surabaya in 1968, and the improvements were in the aspects listed below:

- Physical improvement aspects: infrastructure improvements, public facility improvement, physical occupancy improvement
- Social improvement: mentoring, training, provision of facilities for human resource development
- Economic improvement: establishment of cooperatives, business capital assistance, stimulant funds, business training, housing finance, and tool assistance (Dianingrum et al. 2017).

The *kampungs* were funded by local, central and provincial governments, and the communities had to provide land and build dwellings having been provided with the following:

- Internal roads and drainages
- Footways with drainages
- Water systems
- Toilet facilities
- *Waste management systems*
- Elementary schools
- Public health centres

(Silas 1992:35 in Combrinck 2015:64).

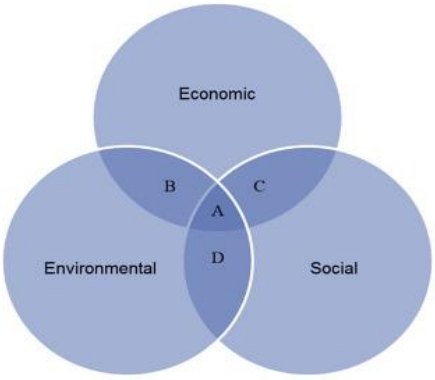
The success of KIP seemed to have been on participation as Winner (1992) explains that the community was involved in all stages of the development. The community cooperated from the time physical condition assessments were made in the early stages of the programme,

and the needs of the residents and future improvement plans were discussed with them. The improvement of the informal settlements was only carried out after an agreement was reached between the government and the community (Winner 1992). The community and government were working as partners in the development of the informal settlements. The natural environmental aspect of development does not seem to have been a focus, as issues of material use and embodied carbon is not discussed in detail in the reviewed literature (Combrinck 2015; Dianingrum et al. 2017; Silas 1992; UN-Habitat 2005; Winner 1992). Winner though does highlight that the community was encouraged to plant trees and flowering plants on their plots, which cleaned the air and cooled the hot dry climate in the *kampungs* (Winner 1992:2).

2.6. Sustainable Development Theories

It is clear from the above sections that there is a concern about the impact of informal housing but the interventions do not seem to completely address the environmental concerns. In response to the degrading environment visible throughout the world, there are different theories that are currently debated in the fields of urban planning and development including sustainability, regenerative development and regenerative sustainability paradigms, amongst other theories.

The discussions on sustainability emerged as a result of concerns in population growth, pollution and non-renewable resource depletion from the second half of the twentieth century (Robinson and Cole 2015). The social, economic and environmental pillars of sustainability should be balanced to achieve sustainable development as shown on Figure 2.5 below (Kibwami and Tutesigensi 2016:35).



'A' stands for sustainable development (3rd order sustainability); 'B', 'C' and 'D' stand for 2nd orders of sustainability. Adapted from Edum-Fotwe and Price (2009)

Figure 2.5: Pillars of sustainable development, Kibwami and Tutesigensi (2016)

The biosphere continues to degrade by being over-exploited and that, according to Robinson and Cole 2015:136), destroys its ability to produce required resources, and its ability to be resilient from the exploitation. So clearly, the functional integrity of the ecosphere should be maintained so that it recovers from stresses caused by human activities (including construction). Rees (1991:208) argues that "the rate of resource consumption currently exceeds the productive capacity of biophysical systems across all continents." He further states that the production of waste exceeds the "assimilative capacity of most ecosystems" at all levels. This concept of sustainability places emphasis on environmental constraints and limits, and has given means of solving the complex environmental problems over the past half century (Du Plessis 2012; Robinson & Cole 2015).

In spite of the solutions it brought, there are still problems that are associated with sustainability. Robinson (2015:133) supported by various authors (Gifford and Comeau 2011; Sabin 2013; Reed 2007) describes four key ways in which this paradigm has been a problem as listed below:

- This concept has a message of "scarcity and sacrifice*"* which may encourage denial instead of engagement. Shellenberger and Nordhaus (2004:16) support this by suggesting, "perhaps the greatest tragedy of the 1990s is that, in the end, the environmental community had still not come up with an inspiring vision, much less a legislative proposal, that a majority of Americans could get excited about*".*
- The emphasis on reduction of harm and damage limitations, or making *less bad* than actually looking for ways to rehabilitate and improve these conditions (Waldron and Miller 2013). The only goal is reaching zero harm which does not encourage the search for other possible outcomes.
- Measurement of *biosphere limits or carrying capacity*, which puts the focus on the environment only, but not on social dimensions of sustainability, even though the aim of sustainability was to integrate ecological, social and economic dimensions (World Commission of Environment and Development 1987).
- Lastly in Robinson and Cole's words: "ecological limits and scarcity arguments have primarily rested on an unproblematic view of scientific knowledge, and unidirectional path for knowledge transmission, which rarely recognize the degree to which such understandings are rooted in cultural, political and other processes knowledge constitution" (Robinson and Cole 2015:134).

In view of these challenges there has been a shift from the concept of doing less or *net-zero* to a concept of *net-positive* – in view of the need to change the perception that a building has an impact on the environment to where it adds value to its context (Robinson and Cole

2015:134). These new approaches to building design (net positive approach to sustainability) which are departing from dominant sustainability narratives are known as regenerative sustainability. This paradigm goes beyond reducing harm, reducing damage and beyond the environmental dimensions of sustainability which were green practices according to Zhang, Platten and Shen (2011). The regenerative sustainability, as stated by du Plessis (2012), has emerged out of the move from "a mechanistic to an ecological or living systems worldview" (Zhang 2014:3). Regenerative sustainability aims to re-enforce and regenerate the global social-ecological system through utilizing designs that are ecologically friendly and engineering methods embedded in the context (du Plessis, 2012).

Challenges that have been raised about regenerative sustainability include issues of measurement, as the current measurement tools are developed to show the magnitude of minimizing environmental impacts of structures. With the lack of measurement tools, application may be a challenge. Robinson (2015) argues that different and complementary approaches are required to discuss 'success' in regenerative sustainability instead of the current approaches on green building performance assessment. Tools for measuring net-positive outcomes should be developed, which gives a sense that this paradigm is still not fully understood in practice.

Regenerative development and design is embedded in ecological worldview and is said to encourage strategies that support "mutually beneficial co-evolution of humans and natural systems in a partnered relationship" (Cole 2012:1). Cole (2012) states that regenerative development builds the social and natural capitals to develop the caring necessary to make sustainability a reality. The author believes that care is important for sustainability to be achieved. As the quality of life is being improved, natural systems should not be left behind, possibly since for humanity to survive their needs are met by the use of resources from the natural environment. The building is not the one which is regenerated, but it is about the method in which the building promotes positive change and adds value to its context.

Regeneration proposes thinking about a building as one that can give back more than it absorbs. In the construction industry, this could mean that resources that have been used up during the construction of a settlement should be restored in excess. They should also be acquired in a way that does not affect the natural environment negatively. Mang and Reed (2015:8) explain the meaning of adding value as, "increasing its systemic capability to generate, sustain and evolve increasingly higher orders of vitality and viability for the life of a particular place". Regenerative design claims and encourages place to be the starting point

for design, and linking people back to the spirit of place in such a way that they are encouraged to promote and take care of it (Mang and Reed 2012:31).

Mcdonald, Malys & Maliene (2009) concluded their paper by stating that it has been realised that regeneration, especially in undeveloped informal areas within urban places, is necessary to assist in generating sustainable settlements. This new concept of regenerative development and design should therefore be applied in the development of informal settlements to restore the degraded environments. The practicality of this restoration should be researched further by scholars in the fields of urban development.

The terms regenerative design/development, and regenerative sustainability are sometimes used interchangeably, and since there is now a lot of interest in the regenerative concept amongst stakeholders in building and neighbourhood development, Robinson and Cole (2015) found it important to put a distinction between the two concepts, which is summarized in Figure 2.6 (Robinson and Cole 2015:140) below. There are many similarities observed with the main one being offering net positive contributions and adding value as discussed earlier in the section.

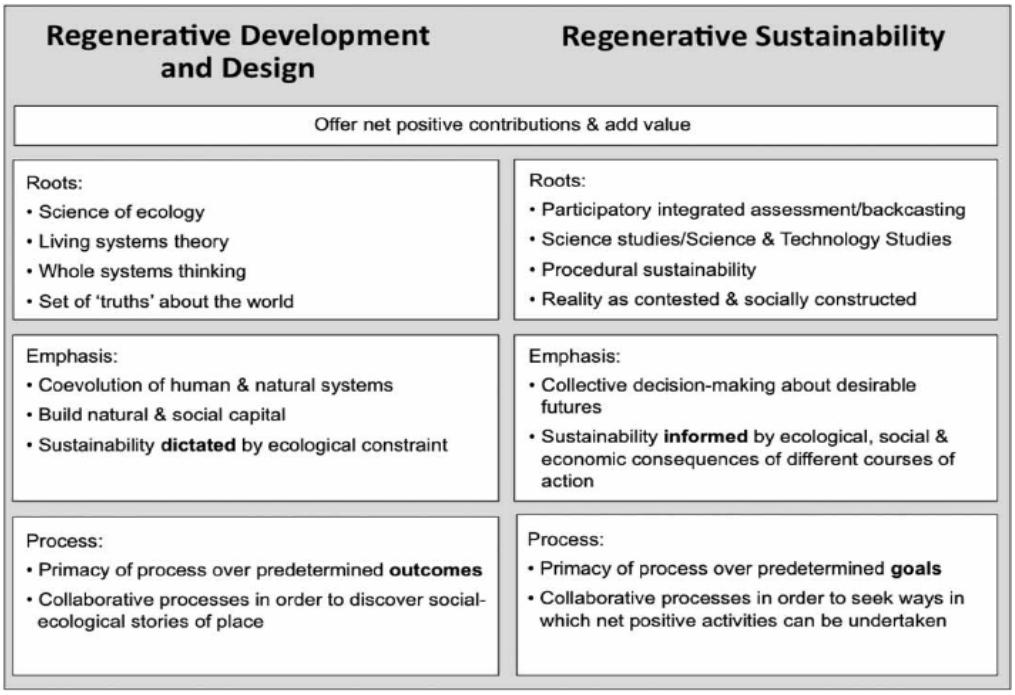


Figure 2.6: Commonalities and distinctions between *regenerative development* and design and *regenerative sustainability*

2.7. Sustainable Housing and Construction

Construction has been defined as taking from Agenda 21:

*"*The broad process/ mechanism for the realisation of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of materials and components, the construction project cycle from feasibility to deconstruction and the management and operation of the built environment*"* (Du Plessis, 2002:4).

Several authors (Tampa 1994; Huovillar and Richer 1997; Lanting 1998 as cited in Du Plessis 2006) have come-up with different definitions of sustainable constructions (SC) but this dissertation uses the definition covering all three sections of sustainability from agenda 21:

*"*A holistic process aiming to restore and maintain harmony between the natural and the built environments and create settlements that affirm human dignity and encourage economic equity*"* (Du Plessis, 2002:8).

Kibwama and Tutesigensi (2016) summarise the definition by stating that sustainable construction is "the application of the principles of sustainable development to construction*"*. Sustainability being broad, SC is seen as the accountability of the construction industry so as to approach sustainability, and also viewed as a subdivision of sustainable development. That means all three pillars of sustainable development should be addressed in SC.

The drivers of sustainable construction are cited by Kibwami and Tutesigensi (2016) from different literature and are organised into environmental, economic and social drivers, but Table 2.5 below has only highlighted practices encouraged to enhance sustainable construction under the environmental aspect which is the focus of this dissertation Several strategies are focusing on energy efficiency and that makes embodied energy and embodied carbon emphasised in the lifecycle of buildings. Embodied carbon refers to emissions produced by actions like material manufacture, transportation, and onsite construction (Cole 1998). So that should be considered in sustainable construction enhancement.

On the environmental pillar, energy consumption, waste treatment, material use, pollution are the main categories highlighted. If enhanced, it is expected that sustainable construction should be achieved.

Table 2.5: Drivers of sustainable construction

	Sustainable construction practice	Reference
	Environmental	
1	Reduce the use of resources such as energy, water, and materials, during in construction	Bourdeau (1999); BRE and Cyril Sweett (2005); Chen, Okudan, and Riley (2010); Hill and Bowen (1997); Kibert (2008); Trufil and Hunter (2006)
2	Optimise lifecycle energy use (i.e. embodied and operating energy) in buildings	Bourdeau (1999); BRE and Cyril Sweett (2005); Chen et al. (2010); Kibert (2008); Nelms, Russell, and Lence (2007); Shen, Tam, Tam, and Ji (2010)
3	Recycling of products	Bakhtiar, Shen, and Misnan (2008); Bourdeau (1999); Chen et al. (2010); Hill and Bowen (1997); James and Matipa (2004); Kibert (2008); Nelms et al. (2007)
4	Reuse of products	Bourdeau (1999); Chen et al. (2010); Hill and Bowen (1997); James and Matipa (2004); Kibert (2008); Nelms et al. (2007)
5	Use of renewables in preference for non-renewables	Hill and Bowen (1997)
6	Minimise pollutants that cause environmental degradation	Bakhtiar et al. (2008); Bourdeau (1999); BRE and Cyril Sweett (2005); Chen et al. (2010); Hill and Bowen (1997); Shen et al. (2010); Trufil and Hunter (2006)
7	Environmental labelling and voluntary rating schemes	Bakhtiar et al. (2008); Bourdeau (1999); Du Plessis (2007); Hill and Bowen (1997); James and Matipa (2004); Manoliadis, Tsolas, and Nakou (2006); Tan, Shen, and Yao (2011)
8	Implementation of environmental management during construction stage such as documenting requirements in contract specifications	Hill and Bowen (1997)
9	Inclusion of environmental aspects in decisions during construction (e.g. buying greener materials)	Bourdeau (1999); Hill and Bowen (1997)
10	Development of comprehensive data bases	Bourdeau (1999); Du Plessis (2007)
11	Enforcement and compliance with environmental regulations	Bakhtiar et al. (2008); Du Plessis (2007); James and Matipa (2004); Tan et al. (2011)

Source: Kibwami and Tutesigensi (2016:66)

Housing shortages as a result of urban population growth cannot be resolved if the focus is not on sustainable low-cost housing (Bredenoord 2016). Sullivan and Ward (2012) also argue that sustainable rehabilitation should not only occur in formal residential development but should also address informal self-help housing to solve the challenge of the environmental impact of housing. The sustainable housing concept has been newly introduced in developing countries and falls under the concept of sustainable development. It aims to achieve and maintain a dynamic balance between humans and the ecosystem. This sustainable housing development is applicable to the whole construction process – from the planning stages to the final stage of deconstruction. Chen, Glicsman, Lin, and Scott (2007), state that when planning for sustainable housing, it is a must to involve economy,

environment, local social buildings and organizing capacity. The authors further suggest that buildings must be developed to be energy efficient by improving their design and construction practices. That can be achieved through the use of improved insulation, reduced wind infiltration, using solar energy for producing electricity and heating water, and natural ventilation for cooling in summer. The above prove that sustainable housing requires environmentally friendly construction practices and invention of new construction methods, and it is clear that construction plays an important part in achieving sustainable housing.

In trying to solve the challenges of construction and the environment, there are proposed efforts on sustainable construction which tries to promote practices that re-instate the balance between the natural and built environments (Du Plessis 2002:21). According to Du Plessis (2002), sustainable construction does not only indicate “environmentally oriented construction practices,” but also “environmentally friendly operations and maintenance methods.” It encourages an addition of value to the quality of life of settlers. Du Plessis (2002:12) states that sustainability depends on the choices made by people regarding their behaviour.

To achieve sustainability, the use of local resources assists in reducing the negative impact on the environment, and the “origin, quality, cost and local suitability of building materials” are aspects which should be considered (Miranda 2009:10). Wilson and Dowlatabadi (2007) state that sustainable applications are costly, and that makes them easily adopted among more economically advantaged sectors. As a result there are now studies about issues that pertain to affordable and sustainable housing for the urban poor, who are mostly located in informal settlements (Bredenoord 2016; Du Plessis: 2002; Myerson 2007; Pullen 2010; Sofianou 2015). Bredenoord (2016) suggests that low income households require affordable housing, and advises that sustainable housing can become a vehicle in providing that kind of housing.

There are different planning levels that have been demonstrated by Bredenoord (2016) and measures which should be taken under each level to achieve sustainable housing for low-income households. The levels are urban planning, house construction and human behaviour. These levels suggest that construction practices and human behaviour are key and should be considered to achieve sustainable housing which protects the environment. Arman et al. (2009:15), cited by Pullen (2010), also list characteristics of an affordable and sustainable dwelling which has similarities with Bredenoord’s measures as shown in Table 2.1. Sullivan and Ward (2012) identifies four different areas of technological sustainable interventions which are believed to be applicable to low-income households, and under each

category there are interventions which were discovered through research to have low maintenance, high savings, low initial cost and require minimal labour. These are:

- *"Microclimate design and technologies to support greater energy efficiency"*

Foil/reflective film in windows, simple cross-ventilation, replacing filters, and kitchen ventilation

- *"Renewable energy technologies to support access to alternative energy"*

Compact fluorescent bulbs and passive water heating

- *"Water and water technologies to promote water conservation and quality"*

In-sink aerators, water efficient showerheads, toilet lid sink, water pipe insulation, rainwater harvesting

- *"Waste systems to promote resource reuse and recycling*."

Contract recycling, passive composting, active composting, vermiculture (Sullivan & Ward 2012:315)

The authors recognise that cost is one of the primary constraining factors which determines the feasibility of a sustainable intervention in low-cost housing (Sullivan and Ward 2012:315). So cost of investment, cost savings after installation, ease of operation and maintenance, and the ability to install without the need of a specialist, were used to evaluate each intervention. Besides using construction practices that are easy to execute and easy to operate, government can also play a part in ensuring affordable housing to informal settlement residents by subsidizing housing, as the case in the Rural Development Programme in South Africa.

Table 2.6 below compares interventions from Bredenoord (2016), Arman (2009) and Sullivan and Ward (2012) under categories adopted from Bredenoord (2016). All the literature seems to focus directly or indirectly on "energy efficiency, water efficiency, construction materials, construction methods, and dwelling size" in the provision of sustainable housing.

Energy efficiency is said to contribute the most to sustainable development as it encompasses means to decrease use of energy and greenhouse gas emissions of houses (Larsen et al. 2008). Energy efficiency measures include the use of passive design, photovoltaic cells and other non-renewable energy sources. These measures are thought to be expensive; however, over time they save energy costs.

Water efficiency includes methods of conserving water by means of water storages, re-use measures and other water sensitive urban design methods.

Construction materials include the choice of materials, like the recycling or reuse of old building materials. It also includes the use of low embodied energy materials which contributes to reduction of the whole life cycle energy consumption of dwellings (Pullen: 2010). One challenge observed by Pullen (2010) and Bredenoord (2016) is that some materials may contribute well to sustainability and affordability but may not be socially acceptable.

Construction methods are also observed as contributing to housing sustainability. That refers to the methods and techniques which include innovations; basically how the methods contribute to sustainability and affordability. Use of construction methods, prefabrication and internal thermal massing are other indicators of sustainable affordable housing but according to Craig (2000), they are not desirable even though they increase energy efficiency.

Density, as discussed earlier, is another frequently debated indicator of sustainable housing in settlements (Paulsen & Silverman 2005; Perkins 2009; Pullen 2010 and Rickwood 2008). Housing density refers to the number of dwelling houses per specified area. High housing density is linked to the improvement of sustainability as the increase in density reduces the costs of infrastructure construction, and promotes walking and cycling among residents (Rickwood 2008; Towers 2002)

The dwelling size is also seemingly another indicator of sustainable housing as shown in Table 2.6 below. It is not clear though on the literature on which dwelling size is affordable and sustainable. But it is without doubt that the larger the dwelling size, the less affordable it becomes and the more it consumes energy. So possibly, the minimum required room sizes, as observed in the building standards in Swaziland, could be used for low income housing – 9 square meters for bedrooms, 4 square meters for kitchens and 3 square meters for bathrooms in floor area (Standard Building Regulations 1969).

Table 2.6: Examples of sustainable housing measures

Categories	Bredenoord (2016)	Arman (2009) and Pullen (2010)	Sullivan and Ward (2012)
Planning/ environmental features	Proper house orientation such that there is proper ventilation, minimal heat, making possible to assemble solar panels and collectors at a later stage Tree lined streets to lower temperature; Availability of parks playing grounds and footpaths Well sized housing plots Environmentally acceptable sanitation solutions Use of septic tanks;	Appropriate location of the house Suitable house size and quality for dwellers Area/plot reducing the loss of biodiversity Area maximising low-energy transportation options Good waste management systems Water conservation (grey water re-use, rainwater storage and reuse)	Proper orientation of the house (simple cross-ventilation and kitchen ventilation) Water conservation (rainwater harvesting) Good waste management systems (Contract recycling, passive composting, active composting, vermiculture)
Design and Construction	Locally available materials Insulated walls and roofing Roof overhangs by verandas Small scale solar panels and/or collectors Shading of vegetation Recyclable building materials	Sun shading Energy efficiency Renewable and recyclable building materials Conventional, Alternative, Pre Fabrication and Internal Thermal Massing construction methods	Foil/reflective film in windows, replacing filters In-sink aerators, water efficient showerheads, toilet lid sink, water pipe insulation Compact fluorescent bulbs and passive water heating

2.8. Assessment of sustainable construction practices

The fact that existing construction practices are not sustainable is now commonly accepted (Sattary 2004). The author states that the energy consumption of a building during its life span is an ideal measure of the total environmental impact of that structure. Energy consumption during construction stage is around 50 to 60 percent, and post-construction energy consumption is also around 50%. Buildings have environmental impacts during pre-construction (production of materials), during construction period, and post-construction (use and maintenance until demolition). So assessment of the environment should be done at those building life cycle stages. There are over twenty common methods for assessing environmental impact in construction from building scale to urban development, but this dissertation will focus on the internationally recognised tools which have been widely adopted and mostly discussed in literature: Lawson method, Twin model and Leadership in Energy and Environmental Design (LEED), BREEAM-community, CASBE Urban

Development, GBI for township and SBTool (Ameen, Mourshed and Li 2015; Charoenkit and Kumar 2014; Sattary 2004; Sharifi and Murayama 2013). These tools assess the construction (development) processes at different stages.

2.8.1. Lawson method

This method, designed for the Australian context, focuses on materials, buildings and systems in the evaluation of the environmental impact. It has two levels – individual material assessment and whole building assessment. The Lawson method assesses impact on the environment in certain stages of the building's life cycle – during manufacturing of materials and embodied energy in the materials; and overall embodied energy of construction. In the whole building assessment, which provides a summary of environmental performance, there are seven criteria: site sensitivity; use of low ecological impact materials; renewable material; use of embodied energy materials; operational energy performance; freedom from maintenance and potential for deconstruction (Lawson 1999:22).

2.8.2. Twin model

This method analyses the life cycle of building components then a score is given for a certain building material or component (Sattary 2004). The criteria are grouped into categories and each is given a numerical score which, when analysed, identifies materials that are environmentally friendly. Buildings are assessed at the design stage and post construction stage, and data collected is used to assess the potential impact of construction products or materials on the environment (Sattary 2004). This tool only applies to materials or construction products, not the construction process.

2.8.3. LEED

This tool was developed to assess constructed buildings to see if they qualify to be labelled *green*. It was developed for several categories so that it suits different building types. LEED touches on three stages: building monitoring and evaluation; building energy analysis; and building inspections and energy audits (LEED 2002). It rates buildings during the design stage and post construction stage and the rating tool used is, "based on established and innovative practices, standards and technologies*"* (Sattary: 2004). LEED was also developed specifically for neighbourhood development (LEED-ND), and has been in use in many different countries across the continents. (Charoenki and Kumar 2014). LEED and BREEAM have formed the basis for all other assessment tools in existence today (Reed et al. 2011).

2.8.4. BREEAM-Community

BREEAM-Community is a sustainability assessment developed by Building Research Establishment Limited (BRE) in the United Kindgdom, in 2009. BRE has developed such assessment tools since 1990, and have developed BREEAM to focus on new development at neighbourhood scale (Charoenki and Kumar 2014). In the early 1990s the focus was mainly on the assessment of individual buildings then the scope was broadened to community level, thus the tool called BREEAM-Community. So housing is considered in the scope of this tool. Housing is believed to have an impact on the environment through "transportation, land-use, social and economic characteristics of existing communities" (Charoenki and Kumar 2014). BREEAM has been used in several countries around the globe to certify their buildings, especially countries in Europe and the Middle East. Several versions exist: BREEAM Canada, BREEAM Hong Kong and BREEAM International (BRE 2011).

2.8.5. CASBEE-UD

CASBEE-Urban Development is another tool developed by the Japan Sustainable Building Consortium (JSBC) with the purpose of assessing multiple buildings and also other aspects in big sites (CASBEE 2007). This tool was only designed for assessing environmental performance of buildings, and its focus is only on exterior spaces with indoor environment excluded (IBEC 2008 cited in Ameen et al. 2015).

2.8.6. GBI for Township

Another sustainability assessment tool designed only to assess a project at the design stage is called GBI, developed by Greenbuildingindex Sdn Bhd in Malaysia. It evaluates new construction, existing structures, and township.

2.8.7. SBTool

This tool, developed by International Initiative for a Sustainable Built Environment, was first known as GBTool and was for the purpose of assessing individual and green buildings, then the name became SBTool later on. The tool started being used to develop design methods and construction methodologies in Portugal, then developed to also assess sustainability of urban planning and design (Ameen et al. 2015).

The above outlined tools have themes – 7 themes for Lawson, 5 themes for LEED, 6 themes for BREEAM, CASBEE and GBI for Township, and 8 themes for SBTool. This is shown in Table 2.7 which illustrates themes including the pillars of sustainability – economical, environmental and social. Clearly the themes have a focus on environmental sustainability, but social and economic sustainability are covered as well. Each theme is measured using

indicators with a designated score, and the level of sustainability of an urban project is assessed using such indicators (Charoenkit 2014). Each tool has over 40 indicators, so the output of the highlighted tools is the ratings calculated by summing all scores of the individual indicators. The overall score gives the overall performance level of the analysed project.

The tools consist of indicators with intent to reduce energy used and greenhouse gas emissions in several categories: building infrastructure, waste management, efficient use of land and transportation. Under each category there are specific issues that are covered. There are also indicators with intent to reduce climate induced natural disasters risks with several categories: water resource, disaster planning, utility planning, and food production. These categories involving utility planning and food production receive less attention as they are only covered by CASBEE and SBTool for utility planning, and LEED and GBI for food production.

Sharifi (2013) observed that the tools (BREEAM, LEED, CASBEE-Community, SBTool and GBI) have a combination of qualitative measures seen in areas which are related to waste management, walkability and disaster management, and qualitative measures (Table 2.7 on the next page). In the use of qualitative indicators, certain requirements are explained to make sure that enough information is given (Charoenkit and Kumar 2014). Then in the use of quantitative indicators, numbers are given to differentiate performance levels.

There are certain limitations in the use of the overviewed assessment tools to low income housing which should be noted and attended to, which include:

- Lack of resilience in the tools, even though they are normally located in sites vulnerable to natural disasters (Charoenkit & Kumar 2014).
- In a review done by Charoenkit & Kumar 2014), it is stated that most of the tools require experts (developers, professionals and planners) to operate which could be costly to low income housing developments. The level of technical knowledge required is very high for all tools as they require complex calculations (Charoenkit & Kumar 2017).
- Most of the tools are said to be developed for urban development but only SBTool has an option to assess residential development. Unfortunately this tool is described as new and still lacks the rating method in a review done by Ameen et al. (2015) in a paper titled: "*A critical review of environmental assessment tools for sustainable urban design*."
- Only SBTool considers criteria related to the financial aspect as affordability is key in low income housing developments.
- Participation of community members is encouraged in low cost housing development and it is expected to appear in all tools. It is the case in most tools except for SBTool.

Table 2.7: Core themes and rating scales of five selected assessment tools

Tool	BREEAM-Community	LEED-ND	CASBEE-UD	SBTool2012	GBI for Township
Theme	1. Governance	1. Smart location and linkage	1. Natural environment	1. Site location, available services and site characteristics	1. Climate, energy and water
	2. Social and economic wellbeing	2. Neighborhood pattern and design	2. Serviced functions	2. Site regeneration and development, urban design and infrastructure	2. Environment and ecology
	3. Resources and energy	3. Green infrastructure and buildings	3. Contribution to the local community	3. Energy and resource consumption	3. Community planning and design
	4. Land use and ecology	4. Innovation and design process	4. Environmental impact on microclimates, facade and landscape	4. Environmental loadings	4. Transportation and connectivity
	5. Transport and movement		5. Social infrastructure	5. Indoor environmental quality	5. Building and resources
	6. Innovation	5. Regional priority	6. Management of local environment	6. Service quality 7. Social, cultural and perceptual aspects 8. Cost and economic aspects	6. Business and innovation
Rating	Outstanding (≥85%)	Platinum (80–100)	Excellent (<0.5)	Best practice (5)	Platinum (≥86)
	Excellent (≥70%)	Gold (60–79)	Very good (0.5–1.0)	Good practice (3)	Gold (76–85)
	Very good (≥55%)	Silver (50–59)	Good (1.0–1.5)	Minimum (0)	Silver (66–75)
	Good (≥40%)	Certified (40–49)	Fairly poor (1.5–3.0)		
	Pass (≥25%)		Poor (≥3)	Negative (−1)	Certified (50–65)
	Unclassified (<25%)				

Source: Charoenkit and Kumar (2014:514)

Clearly an assessment tool that is usable to a non-expert and attends to the above stated challenges of the current tools is required. In an informal low cost housing the above assessment methods could be used after the limitations have been solved and it should be noted, as stated earlier, that informal housing settlements should not only be sustainable but also affordable. So a different assessment method for the sustainability of construction practices of low cost housing could be developed from information on the above tools and the measures from Bredenoord (2016) and Pullen (2010) as shown in Table 2.6 (in the previous section) by taking their strengths and attending to their limitations. Even with the

limitations of the tools in use in low cost housing, the review revealed important categories which are the main sustainability concern.

2.9. Pattern matching

The reviewed literature (Bredenoord 2016; Hansen et al. 2005; Kramer 2013; Pullen 2010; Sofianou 2015) establishes that construction practices have a negative effect on the natural environment. With this correlation having been established, this study is only interested in identifying areas or categories which require enhancement to ensure the use of environmentally sustainable construction practices in informal settlements, than just rating their sustainability. Therefore, the use of pattern matching (qualitative analysis) is advised. Pattern matching method is described in the following section.

2.9.1. The theory of pattern matching

Trochim (1985) describe a pattern as any arrangement of objects, meaning that a pattern is not random but orderly. Trochim (1985) further implies that theory can be used to generate patterns of predictions, like in the case of a theoretical formula which can be used to give a pattern of expectations. The same author claims that all theory that exist can be usable to generate patterns of predictions, even in social sciences.

Pattern matching is described by Saunders (2016) and Yin (2014) as a deductive explanation building approach which tries to construct an explanation by predicting a pattern of outcomes based on theoretical propositions to give an explanation of what is expected from the analysis of data. The aim of pattern matching is described by Sinkovics (2016:1) as to “externalise implicit mental models and assumptions as much as possible.” This better gives an explanation of how and why researchers arrived to certain conclusions as they should be relevant to theories. In some instances the pattern may not be very clear but it may still exist to a certain degree (Sinkovics 2016).

In pattern matching the theoretical pattern is matched with the observed pattern by specifying a number of related outcomes (dependent variables) which the researcher expects to find as a result of a change in the independent variable (Saunders 2016; Trochim 1985). After the expected outcomes had been determined, data is collected and analysed, and if the outcomes that were expected are found (match), then the theoretically based explanation explains the findings. Yin (2014) states that if there was no match of the expected outcomes

and findings of the study, another explanation should be sought. The pattern matching method is described in summary in Figure 2.7 (Trochim 1985) below.

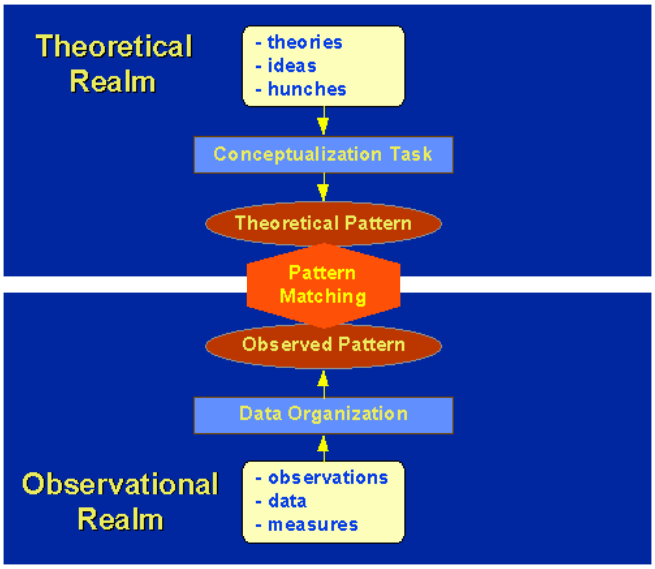


Figure 2.7: Pattern matching diagram

The diagram in Figure 2.7 above is divided into two halves, with the upper one showing the theoretical realm and the lower one showing the observational realm. The upper part or realm represents theory, ideas, hunches or a combination of all which is then translated into a theoretical pattern as shown in Figure 2.7 above. The bottom part (observational realm) includes observations in the form of field notes, measures, impressions and such related information, and this information relevant to the theoretical pattern is said to be the observational pattern as shown in the diagram. The double arrow at the centre of the diagram represents the attempt to link or match the two patterns as shown in Figure 2.7.

When it comes to determining relationships or effects between two variables, in the theoretical or conceptual part of the pattern matching method, it is determined from literature how the dependant variable is expected to change with the change in the independent variable. This means the theoretical effect pattern will consist of expected outcomes, and the relationship between those outcomes and the findings will constitute the match.

The pattern matching method has disadvantages which cannot be ignored, with the main one being that the methods require a detailed and precise specification of theory which is not possible in social science. The assumption is that the researcher is able to construct the theoretical and observed patterns in the same way so that it is possible to correlate them.

2.9.2. Theoretical framework for assessing construction practices

Since there is enough theory establishing the fact that construction practices have negative effects on the environment, a theoretical framework can be formed by determining environmental effects expected (expected outcome) with the use of certain construction practices. These predictions (expected effects) can be compared with the environmental effects found in a study area, and if a match is found, the theoretical explanation (construction practices have effects on the natural environment) can be accepted. The assumption broad forward in the use of pattern matching in this context, looking at the broad definition of 'construction', is that an undeveloped land where there was no human activity previously has a healthy ecosystem (without defects), until construction (realisation of a settlement with all operations in it) occurs on it. The pattern matching method or theoretical explanation would not apply on land where there was human activity previously (like mining, farming, and similar), as it would be difficult to determine the cause of environmental degradation.

Environmental effects expected in an informal settlement formed on land where there was no human activity previously are listed below in categories as taken from the reviewed literature in this Chapter.

Energy

- Carbon emissions from fossil fuels impacting the atmosphere (Du Plessis and Landman 2002)
- Deforestation with the use of wood to generate energy (Kibwami and Tutesigensi 2016)
- Poor natural ventilation and lighting increases the use of energy, and the greenhouse gas emissions from energy based generation which harm the environment is increased (Khan, Su and Riffat 2008; Mochida 2005).

Materials

- Land pollution from unrecyclable old building material (Kim 1998; Recycling and reuse 2018).
- Toxic waste from demolished buildings (Kim 1998)
- Atmospheric impact from materials with high embodied carbon/energy (Bredenoord 2017; Kim 1998; Lawson 2006; Pullen 2010)

Waste management

- Land pollution - lightweight litter like plastic bags and film with hazards for animals
- Chemicals contaminating soil (Kim 1998)

- Water pollution from toxic pollutant (leachate)
- Loss of biodiversity as a result of demand for new landfill sites (Ahern 2011).

Land use

- Vegetation loss and a negative impact on the remaining habitat. Vegetation loss changes nutrient and biogeochemical cycles (Kaushal 2006; McKiney 2006)
- Loss of biodiversity (Hansen et al. 2005; Kramer 2013; Sofianou 2015)
- Infertile soil

Density

- Low density extends environmental impact of each house over a large area, extending the footprint of housing development (Hansen et al. 2005; Paulsen and Silverman 2005).
- Sprawling of a settlement (low density) increases transport of energy, water, materials, products and people (Du Plessis and Landman 2002).

Movement

- Emissions from fossil fuels that impact the environment negatively as they produce more pollutants and disturbance (Du Plessis and Landman 2002; McCarty & Kaza 2015)

Services

- The absence of water management and resilient systems result in erosion (Ahern 2010).

These expected environmental effects are matched with the findings in Chapter 5 to determine areas which require enhancement to ensure an environmentally sustainable settlement.

2.10. The Swaziland Case

Swaziland government's response to the challenges of housing provision to the low income earners focuses on policy regulations and investment programs (Khoza 2006) – Swaziland National Housing Policy (2002) and Urban Development Project (1994 -2006).

2.10.1. Urban Development Project (UDP)

The imperative need to deal with informal housing was recognised in the country as evidenced by the intervention of a project known as the Urban Development Project (UDP) (Khoza 2006:4). UDP's aim was to regularise informal settlements in the main cities of Manzini and Mbabane in the period of 1994 - 2006. This was taken as the first phase of a long term development programme. It relied on World Bank for funding as this was a large scale intervention. The main objectives of this programme were to:

- "provide a basis for sustainable urban development through emphasis on policy reform, institutional development, pilot land reform, participatory development and housing solutions for moderate and low income urban households," *and;*
- "to address critical infrastructure needs - water, sanitation, waste disposal and roads" (Report on UDP 2008:5)

The project consisted of the following four major components (Report on UDP 2008:5):

- *"*policy and institutional reform component,"
- "rehabilitation and expansion of city roads component,"
- "rehabilitation and expansion of water and sewerage services component," and
- "residential housing sites and onsite infrastructure component"

The Swaziland National Housing Board (SNHB), which is a parastatal under the MHUD, was assigned to coordinate the execution of the project. The project was implemented in Msunduza, Nkwalini, Mahwalala (study areas), Moneni and Mhobodleni, which according to Khoza (2006:5) improved the living environment of the beneficiaries, but cost recovery was not attainable.

There are several other challenges that were observed. In this project 2000 plots were serviced and it was expected that all beneficiaries would be given 99 year leases, but by the end of the project only 10 percent of them had been given the leases (MHUD 2008). It should also be noted that the Swaziland Environmental Authority (SEA) had not yet been established at the time of project inception in 1995, meaning environmental issues were not attended to. But SEA came into effect in 1996 when construction of infrastructure was already underway. According to the Report on the UDP done by MHUD in 2008, sustainable interventions were not included in the project. These interventions were required to understand the root cause of infrastructure deterioration, and maintenance of gains which the infrastructure restoration had produced.

From the UDP report it is noted that the development of housing structures were not part of the project as was the case in the Kampung Improvement Programme. Residents still had to construct their own houses without any guidance on the construction practices used, which possibly had a negative effect on the natural environment.

2.10.2. National Land Policy

The NLP has objectives to improve access to land and sustainable use of it, limit land-related conflicts, and grow an efficient and effective land administration system. This policy has

principles which are also seen in the current housing policy, including issues of access to land for all with emphasis on gender equity. This policy was never implemented, and the MHUD suggested the creation of a Land Management Authority to implement these land policies.

2.10.3. Peri-Urban Growth Policy

The PUGP contains means of efficiently controlling the urbanisation process happening in peri-urban areas. It has objectives of affordable service infrastructure provision with the aim to minimize health hazards. It also has an objective of controlling urban expansion and mitigating challenges associated with human settlements through the use of policies and programmes. This policy brings forward proposals to solve the problems of the natural environment degradation, unsanitary conditions, administration challenges and uncontrolled allocation of land, among other challenges. It is doubted though whether this policy will ever be implemented considering the fact that it is trying to disempower traditional structures by moving SNL into leasehold without consulting the traditional authorities.

2.10.4. Physical Planning Policy

The PPP is said to have arose out of the UDP where the project committee was providing action plans for the next phase (Phase 2). The action plans included the development of a policy regarding physical planning and development control. The PPP was completed in 1999 after a physical planning study had been conducted. The PPP was developed as a result of the lack of integration between the physical environment and land use planning, and also lack of integration between the rural and urban policies. The PPP was also a requirement as a result of the disorder and rise of informal settlements, peri-urban areas and urban area expansion in an unplanned way. Therefore, it aims at establishing a hierarchy or plans, introducing more principles-led approach, and extending planning into SNL areas through the Land Policy upon its approval.

2.10.5. The Swaziland National Housing Policy

The current housing policy (2002) was put together in response to challenges which include past rapid population growth which was then slowed down by HIV/AIDS, rapid urbanisations, poverty and lack of resources to manage urban growth. The policy also comes as a response on the weakness of the previous 1993 housing. The introduction to the current policy states that the previous policy had challenges in:

- functioning of housing markets,
- growing the accessibility of finance,

- enforcing institutions that play an important duty in the development of housing and services
- relation with NLP
- administration of areas for housing development,
- devising standards which increase the cost of housing

As such, the response of this policy was to pay attention to policy regulations, institutional development, and investment programs. Its objectives are “to improve access to land, support facilitation of finance for land development, safeguard rights of landlords and tenants in the rental market, ensure sustainable service delivery to the service provider affordable to the household, use of construction practices and local construction materials that cut housing costs, and support formal and informal economic practices within the plot premises for improvement of household income” (Housing Policy 2002:2).

This policy has the following sections with a total of sixteen strategic areas to improve the housing environment:

- Introduction – containing policy focus areas, vision of the policy, objectives of the policy as stated above, and policy principles
- Issues and policy statements – discussing issues of equality and security of tenure, land information system, land planning in urban areas, land availability and planning in urban informal areas, inclusion of peri-urban areas into urban areas, planning for rural growth nodes, gender equality in access to land, removal of market distortions, access of low-income households to finance, subsidies to increase access and reduction of cost of land, provision of affordable services, responsibility for service delivery, addressing HIV/AIDS, and landlord and tenant rights.
- Issues and policy statements – this section discusses issues on housing on urban informal land, peri-urban project, and rural growth node pilot project.
- Conclusion
- Implementation – this section shows an implementation strategy with an objective to have attended all key features of the housing policy within 5 years.

There are three strategies, as seen above, which touch on informal settlement (Housing Policy 2002:8-18):

Strategy 4: Land Availability and Planning in Urban Informal Areas

The main issue addressed is the lack of access to land in urban informal areas as a result of planning standards which raise the cost of housing and reduce affordability of households by

disallowing economic activities on this land. The policy attends to that issue by stating these three policy statements:

- "Government should release Government-owned land in urban informal areas and undertake planning for development of low income housing"
- "Mbabane and Manzini should acquire responsibility for identifying the Government-owned land to be released in these areas and for undertaking the planning for these areas"
- "Town-planning regulations should be applied in urban informal areas in a manner that reduces the cost of settlement in these areas and increases their affordability to low-income households."

Strategy 11: Access of Low-Income Households to Finance

It contains the following policy statements:

- "Cooperatives should become primary market lenders,"
- "All households should be educated with regards to their rights and obligations when they take a home loan,"
- "Incentives are to be made available for innovative lending practices that do not rely on the house as underlying security and that there be a 'level playing field' in respect of concessions"
- "A housing savings scheme to be created to provide security to lenders"

Strategy 13: Provision of Affordable Services

The following policy statements are listed:

- "All low-income households living in urban and peri-urban areas and rural growth nodes should have access to free and basic level of water, sanitation and waste removal"
- "Lifeline tariffs should be introduced for services"
- "Financing mechanisms should be used to provide services to minimise the cost of households"

2.10.6. National Environmental Policy

This policy was created after realisation that the lack of policy on the environment has killed efforts to protect the environment. The actions of human beings, especially in terms of natural resource use, are said to be unsustainable as it impacts the natural environment. The NEP (1998:11) lists examples such as: "polluted rivers, air pollution from industrial and urban areas, land degradation such as deforestation, desertification, soil erosion, and declining range-land productivity, and reduced populations of wildlife." The government of Swaziland,

through the policy, has seen it proper to regulate the activities which have an impact on the environment, including construction. The NEP has a focus on "general principles and approaches which should be adopted by any section in government, traditional structure, organisation and individual, in undertaking any activity which may affect the environment" (NEP 1998). The aim of NEP is to enhance, protect and conserve the environment and to attain sustainable development in Swaziland. The policy is based on four principles: environmental responsibility, *buntfu* (a Swazi translation of the word 'ubuntu' which describes a quality that includes the essential human virtues) and sustainable use, environmental rights, and sustainable development. The principles are supported by seven subsidiary principles: public awareness and participation, community management, preventative action, precautionary approach, polluter pays, proximity principle, and global and regional responsibility.

2.10.7. Observations

The researcher observes a gap in relation to the discussed policies above which the study will stem on:

- Government has attended to most housing issues through policies, but the challenge is their implementation.
- The focus does not seem to be much on sustainable development on informal areas, but more on the release of land already degraded (possibly) to informal settlements, adding infrastructure and cost recovery.
- The use of local building materials has been highlighted in earlier policies, but the focus was in reducing costs not associated with the environment and its sustainability.
- Control of sustainability of construction practices employed by dwellers (self-help housing) does not seem to be touched in all the policies. The local municipalities control structural integrity, fire safety, space planning and sanitary issues (Building Standards, 1969). In the UDP it is also observed that informal settlers were given all power to develop their plots without guidance. As the case even on the other discussed interventions in the chapter, the main gap observed is on the settlers having no guidance on how to construct their dwellings which is viewed as the main cause of the environmental challenges.
- Even though there are environmental concerns, there are no strategies for attending to the environmental problems in informal settlements.

Informal settlements are in actual fact affordable, especially the temporary structures (shacks). They should not be taken only as problems but also solutions (Du Plessis 2002:28). According to Du Plessis (2002), a shack is sustainable in a unique way, it just

needs enhancement. Shacks are almost entirely built of recycled building materials and components, and they also use available skills. That conserves resources and makes their dwellings affordable. It is also easy to build these structures, and their demolition produces recyclable building material waste. Besides recycling materials from waste for their own use, the communities also assist by contributing to the conventional recycling stream. The government of Swaziland and other developing countries seem to be failing to appreciate these sustainability qualities, which may be the reason why they are disregarded in housing developments looking at the fact that the design of houses is determined by the dwellers who are not guided on developing sustainable houses in most of the discussed interventions. Since there is no control over these constructions, the methods are unsustainable and may lead to the degradation of the environment (Du Plessis 2002).

After the MHUD in Swaziland had analysed the critical shelter problems, the incremental upgrading strategy was proposed as a vehicle for change (Khoza, 2006). Khoza (2006:1) backs this strategy and explains that the dwellers use their own savings to construct and develop their shelters incrementally. The dissertation mentions that the approach places the responsibility to municipalities in partnership with their communities. The approach is supported but needs to be enhanced by controlling the sustainability of the construction practices used by the dwellers when constructing their self-help housing, by possibly updating the Standard Building Regulations which neglects the sustainability aspect of houses. House designs submitted to the local municipalities are approved for construction even when they lack sustainable building materials, use unrenewable energy sources, and are built using unsustainable building methods. Construction practices currently affect the environment by the over usage of non-renewable resources (World Sustainable Building Conference: 2005). According to the Worlds Watch Institute by Dimson (1996), building construction uses “40% of raw stone, gravel and sand, about 25% of virgin wood, 40% of energy and 16% of water” (cited in Nair 2005:4431). The provision and use of housing greatly contributes solid waste which pollutes the environment (Nair 2005:4431). The paper further suggests a reduction in material wastage, since that will assist in reducing global material consumption, reducing demolition waste, reducing construction costs, and making houses more affordable.

2.11. Conclusion

Reviewed literature agrees on the lack of security of tenure and lack of approval of residential formations by local authorities as a definition of the term informal settlements. Informal settlements are thus understood as for any income group but the definition relevant

to this study is found in UN-Habitat (2015) as residential areas with housing constructed on land to which the dweller have no title, and with these characteristics:

- absence of basic services,
- inadequate structures,
- overcrowding,
- unhealthy conditions, and
- poverty.

The problem of natural environment degradation in these characterized settlements seems to begin in the initial formation of these settlements which are uncontrolled by local authorities, but fully in the hands of the informal settlement dwellers. Degradation occurs in the whole lifecycle - from the formation to demolition stages of the structures. Serious threats to the environment (environmental degradation, sanitation and safety) are viewed as posed on informal settlements located along waterfronts, escarpments, and easements.

Poverty is viewed as the main cause of informal settlements and the challenges associated with them. Poverty results in the development of self-help housing which has sustainability qualities but a challenge being that their development is not controlled as they are fully self-managed by the owner. Informal housing dwellers are given a chance to freely design and construct their shelters without a particular guide to assist them in constructing sustainable houses with consideration for the impact on the environment, thereby creating a sustainable neighbourhood in the process. This study, after the review of literature, suggests that the design and construction practices used by dwellers of informal low cost housing have an effect on the natural environment, which is what actually leads to the environmental impacts that are observed on the atmosphere, land and water. Housing and infrastructure remove vegetation and have a negative impact on the remaining habitat. It is therefore clear that there is a link between construction practices and the environmental impacts, and the type of construction practices used in housing are a result of choices made by residents.

In an attempt to address informal settlement problems, there are several interventions (public housing, sites and services, informal settlement upgrading, social housing and self-help housing) which do not seem to focus on the environmental aspect of sustainability. Informal settlement upgrade though is seen as the most successful intervention currently possibly as it highlights on all three pillars of sustainability; but implementation is seen as a challenge especially in Swaziland. An integration of upgrading brownfield, self-help housing and adjustment of building codes is seen as a solution to the challenges. Self-help housing in a brownfield being an affordable way of providing sustainable shelter, they need to be

encouraged, enhanced and controlled. To allow for flexibility in the use of sustainable and affordable materials, building codes have to be reviewed in the case of Swaziland especially. It is concluded that if self-help housing could be properly managed, there is a chance that environmental impact could be minimized.

Current literature on sustainable development does not clarify on how informal housing dwellers could be guided in constructing their self-help houses in such a way that there are no/minimised impacts on the environment. Sustainability emphasizes on doing less harm than providing a solution, but regenerative sustainability and development provides solutions as it has an emphasis on adding to the environment, but its measurement is still not clear.

Current sustainable assessment methods discussed focus on reducing harm, and they have certain limitations in the application to low income housing settlements. One of the main challenges is in their complexity in use which makes them require experts. Even though they have limitations, they all reveal similar categories of concern and assessment which has informed the observation schedule used in this study.

The categories which have also been used in the evaluation of informal settlements and its housing in this study are listed below, with issues covered under each:

- Building infrastructure: ventilation, solar radiation, shading by vegetation, energy efficiency, renewable energy, recycled materials, low embodied materials
- Waste management: construction waste, solid waste, and waste water (waste reduction and reuse)
- Efficient use of land: compact, mixed use, brownfield development
- Transportation: walkability, proximity to public facilities, quality of transport

It is noted that the energy use of a structure is the main measure of the environmental sustainability of that structure. Through the support of literature as discussed, it is assumed that the use of these criteria will give an understanding of the construction practices used in informal settlements in the context of Swaziland, especially their sustainability, and their effects on the natural environment will be understood. It is clear that evaluation of buildings should be made at these stages:

- Pre-construction - strategies and design assessment, material and product assessment
- During construction - construction process assessment,
- Post-construction - whole building assessment; post occupancy assessment,
- Post-demolition - after demolition assessment

The selected informal settlements in Swaziland will be assessed on the post construction stage as they have already been formed.

The success of interventions is in the participation of the community as it has been the case in the world's first slum upgrading programme (Kumpung Improvement Programme) in Indonesia. The community should be engaged from the initial stages of settlement condition assessment until the final implementation stages. Swaziland seemed to have missed participation aspect as the residents did not seem to cooperate, which is one of the reasons why the Urban Development Programme was labelled as a failure. The environmental aspect was not a focus possibly since the Swaziland Environmental Authority had not been established when the planning of the UDP occurred. The residents were also given all power to construct their self-help housing which was not assisted, and this is viewed as the main reason why the construction practices in the informal settlements in Swaziland have had an impact on the natural environment.

Observational studies, which were used in this study, are discussed in the next chapter. They are seen as relevant to this research and they are commonly used in environmental studies and studies that involve human behaviour. Direct observation was seen as relevant since signs of human behaviour (physical traces) were searched in the study area.

3. Conceptual Model

3.1. Introduction

This chapter seeks to define a conceptual model that will be used to understand the design and construction practices used in informal housing settlements with the focus being their environmental sustainability. Research concepts associated with construction practices have been included in the model with the support of information discussed in the previous chapter. It is proposed that applying housing measures, from Bredenoord (2016), and assessment tools (discussed earlier), will give an understanding of the construction practices used and their sustainability in the selected informal housing settlement. The housing measures and assessment tools discussed gave an understanding of the categories of assessment and therefore informed the schedules used for data gathering. The environmental condition will give an understanding (traces) of how the environment is being used under the current condition of the built environment in the low cost informal housing settlement.

Data capturing and analysis followed the guidance of the conceptual model. In Chapter 4, it is discussed that data was gathered through structured observation schedules. The conceptual model gives guiding questions which inform the schedules used in the observation study. The concepts below are discussed individually and they build up to form the framework shown in Figure 3.1.

3.2. Site Details

Literature suggests that site details are important in the assessment of the sustainability of a house to understand the geographical location, orientation of the house, ventilation, the use of space, and other similar aspects (Bredenoord 2016; Pullen et al. 2010). The line of questioning and observation to cover the above included:

Plot number, plot size, and the number of houses

Knowing the plot number assisted in identifying the plot and observing the shape of the site and orientation of the buildings in it. The plot size and number of houses give an understanding of the use of space thus highlighting issues of planning within the site, ventilation and amount of sun heat that enters the buildings. This is important as it affects the sustainability of the houses.

House type, number of storeys, and house size

Collecting data on the above informed on the house typology. The types of houses common in Swaziland and which were found on the site were free standing house, semi-detached

house, and row house commonly for rental. This analysis helps reveal the common housing type in the area. The number of storeys which are also common in Swaziland are up to three.

3.3. Building Infrastructure

Having understood the plots where the houses sit, and the overall design of the house, information on specific aspects of the houses was gathered with the assistance of information from Bredenoord (2016), Pullen (2010), and Sattary (2004). It should be noted, as discussed earlier, that evaluation of buildings can be made under four categories of assessments: pre-construction, during construction, post-construction and post-demolition. In this study, evaluation is made under post-construction as the interest is on analysing the impacts of the already used construction practices on the environment. Traces of demolitions were also recorded and analysed. Only aspects which affect the sustainability of a house are evaluated as detailed below.

3.3.1. Levels of perceived natural ventilation and levels of perceived natural light

Natural ventilation is one of very important tools of sustainable development as it depends mainly on natural air movement. Natural ventilation saves energy in a building since it reduces the need for mechanical ventilation which uses energy (Khan, Su and Riffat 2008). As the use of electrical energy is reduced, the greenhouse gas emissions from energy based generation which harm the environment is also reduced. Passive solar and energy efficient buildings normally are dependent on proper natural ventilation as one of means to maintain human comfort in a building.

Natural air movement is affected by three factors within a building namely:

- **Site and landscape features around the house, building spacing also inclusive**

Wind within 500m of height from the ground is normally slowed in speed by physical site conditions, including rough terrains. Generally, there should be light winds in summer and also during night hours for cooling of houses. Topographic features are said to have an influence on the speed of wind and so does vegetation. It is important to keep trees a distant from window openings of buildings, but these could also be strategically used to redirect wind. To understand if there is enough wind speed from right directions for acceptable indoor thermal conditions, an hourly wind frequency analysis could be conducted in that area.

- **Design of the building – form and envelop**

Mochida, Yoshino, Takeda, Kakegawa and Miyauchi (2005) in their paper titled, "Methods for controlling airflow in and around a building under cross-ventilation to improve indoor thermal comfort," explain a few points on cross ventilation worth noting. A building that uses cross ventilation should be oriented to be exposed to the summer wind, as shown in Figure 3.1 below (Aynsley 1979:30) and the plan should be narrow so as to reduce resistance to the flow of air in cross ventilation through the building. For cross ventilation to be possible, the windows should be located on both sides of an occupied space. Since wind slows down in speed as it enters the building, the total air outlet areas should be larger than the air inlet areas. In understanding the behaviour of air movement, for a building where ventilation is allowed on one façade, ventilation openings or windows should be positioned at different heights such that air enters the building on the lower windows and escapes on through the upper windows or openings. Taller buildings normally receive stronger winds on the upper floors, but that could be counterproductive in the case when windows are shielded by trees. A high porosity on a building wall or a number of openings, are required to ensure proper natural ventilation distribution (Mochida et al. 2005). The minimum size of window openings is specified in Swaziland's building regulations, as to be explained below.

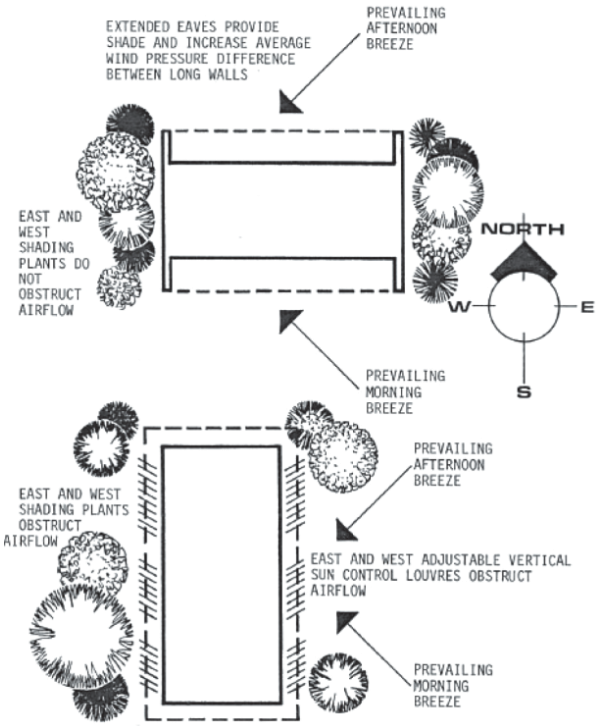


Figure 3.1: Orientation of long walls to minimize obstruction of openings by shading devices

- **Internal planning of the building**

In order to allow for proper natural ventilation within a building, the resistance to the flow of air within the building should be minimized (Studio B 2017). That could be through the reduction of the number of rooms air would have to pass through and have large openings for the movement of air. To achieve direct cooling to occupants of the building, airflow path should pass through regions which are frequented by the occupants which is normally within two metres from floor level.

The building regulations of Swaziland (1968:35) state that a habitable room should have one or more ventilation openings so contracted that if such openings are provided in:

- One wall only, the total area of such openings shall not be less than 10 percent of the floor area of the floor area of such room, and in any event not less than 1.2 square metres
- Two or more walls – the total area of such openings shall not be less than 7.5 percent of the floor area of such room; and the openings in each wall shall be at least one third of the minimum permitted total area of such openings
- Two walls which meet the middle of each opening shall be at least half the length of the wall in which it is located from the corner where the two walls meet.

An assessment of natural ventilation on the low cost housing was made with assistance from the information above and Swaziland's building regulations. An ordinal scale was used for measurement.

3.3.2. Use of renewable energy

Natural energy surrounds building sites in the form of: wind, solar radiation, and geothermal heat (Kibwami & Tutesigensi 2016). Renewable energy can be used in place of conventional energy by the use of the listed natural energy above. Solar power is usable in the generation of electricity and for heating purposes.

The use of passive solar design has the following advantages:

- Reduction of energy demand
- Limits the use of conventional energy sources

Passive solar design has an effect on the orientation of buildings and form of the built environment. Wind power can also be used to generate electricity for heating and to pump water.

It has been noted and concluded from the previous chapter that the energy consumption of a building is the main measure of the environmental sustainability of that structure. All the discussed assessment methods highlight on energy consumption of a building. Since the use of renewable energy is expensive to low income households, what could be reasonable to them is the use of small scale solar panels and/or collectors (Bredenoord 2016).

A nominal scale was used to gather information on the use of small scale solar panels or collectors:
1 - Representing 'available' (the use of any renewable energy in the house for supplementing or totally eliminating electricity use). If available, the type of renewable energy is noted down from common options in Swaziland.
2 - Representing 'not available' and if not available the energy sources in use were noted from common options in Swaziland: coal, petroleum/gas, water, wood and other sources.

3.3.3. Construction Materials

Sustainable (local) building materials are listed by Bredenoord (2017) as one of the options of importance in trying to implement affordable and sustainable housing. The author further states that the building's environmental impact can be reduced by the use of locally produced building materials. Materials labelled as sustainable and suitable for low-cost housing construction include the following groupings: bamboo, timber, compressed earth bricks and blocks, adobe blocks, interlocking blocks of recycled materials, and improved concrete panels (Bredenoord 2017). For affordable and sustainable construction, Pullen (2010:54) advises on the use of *"*low embodied energy, new materials and the re-use and recycling of old materials."
To understand the environmental impacts from building materials, it is important to note that materials have life cycles which could be organised into three phases as described by Kim (1998).

- **Pre-building phase**

This is the process from production of the materials, delivery and all other processes up to but not including installation of the material in construction. Extracting, manufacturing, packaging, and transportation of the material form part of this phase. This phase has the most environmental impact observed (Kim 1998; Pullen 2006). When these environmental impacts are understood, it will be easy to make the right selection of materials that will not cause measurable impacts, and also it will be easy to identify the materials that cause impacts in the evaluated informal settlements.

During the manufacturing of certain building materials, natural resources are mined or harvested from renewable or finite sources. Mining is defined by Kim (1998:8) as "extraction of metals and stone from the earth's crust, where the materials exist in finite quantities and are not considered renewable". To produce small quantities of ore, large amounts of rock are required, and in the refining process there are gases produced which have an impact on the environment.

The mining or harvesting of natural resources and manufacturing of building materials has the following impacts: depletion of wildlife habitat, erosion, and water and air pollution. Cutting down of trees damages the habitat of animals and plant species, and leaves areas vulnerable to erosion, amongst other impacts.

- **Building phase**

This phase is the material's useful life which begins at the installation of the material, and includes maintenance, repair, and life of the material as part of a building. During construction (actual activity on site) the materials normally produce amounts of waste which may or may not be recyclable. Subjection to certain materials may be harmful to the occupants, and some chemicals used in maintenance of the building materials may also be hazardous to the occupant's health.

- **Post-Building phase**

In this phase it is when the materials are no longer useful and the material can either be reused or discarded. Demolition and disposal of the waste has a great impact on the natural environment as some may produce toxic waste (Pullen 2010). Reuse of building materials preserves the energy that went into the building during construction. It is a fact that some materials are reusable but some are not.

There are certain qualities which building materials should have to be considered environmentally sustainable, and three groups of criteria were identified by (Kim 1998) which could be used to evaluate the environmental sustainability of building materials:

Pollution prevention measures in manufacturing

Certain methods used during the manufacturing of building materials could contribute to environmental sustainability. Governments have regulations which should be followed by manufacturing companies, but some companies go beyond that to ensure their processes pollute much less by doing research and applying measures. Some companies select materials that were manufactured using sustainable means even though they may be costly.

Proper packaging which is environmentally sound can prevent pollution. Other companies use a lot of water during the manufacturing process, and that water is disposed into streams, which causes pollution. So it is important to be aware of manufacturing practices used by manufacturers so that architects and other professionals may specify and encourage the use of materials that were manufactured using sustainable methods.

Waste reduction measures in manufacturing

This shows responsibility of manufacturing companies by making production efficient by reducing waste that results from the manufacturing process when trimming, moulding, finishing and similar processes. Some companies may use waste as fuel to power their machinery in the manufacturing process. That process reduces the amount of waste that ends up in landfills. The reduction of waste in production increases resource efficiency of construction materials. Kim (1998:13) lists these measures which are encouraged for selected materials:

- Chip boards and other composite materials are composed almost completely of waste emitted during the activity of milling trees
- Kilns for drying wood can be powered through burning sawdust produced on site lowering the use of refined fossil fuels and reducing the amount of waste to be deposited in landfills
- Fly ash from smelting operations can be incorporated in concrete
- When brick has been fired, it does not react with the natural environment. This process can be used to contain low-level toxic waste into the brick which reduces disposal of waste in landfills
- Waste used in the manufacturing process can be filtered and reused instead of discharging it into streams.

Recycled Content

The use of recycled materials reduces waste on-site and pressure on natural resources, and the embodied energy the materials contain is preserved (Recycling and Reuse 2018). Energy consumed in the recycling process is said to be far less compared to that used in the original manufacturing process. There are certain materials which can be recycled including: glass, plastics, metals, concrete, brick, and wood. Plastics, glass and metals can be reformed through heating, then concrete and bricks can be ground then used as aggregates to form new concrete or bricks.

Embodied energy reduction

Embodied energy is the total amount of energy required to produce certain materials which includes the extraction of raw materials, energy required for "mining, harvesting, processing and transportation of the building materials" (Lawson 2006:34). Most of that energy is from burning of fossil fuels which are non-renewable energy and limited. Burning of fossil fuels has been described earlier that it affects the environment – turning localised smog to acid rain. The higher embodied energy contained in a material, the higher the amount of energy needed to produce the material (Lawson 2006). Wood for example, requires less energy in production than iron extracted from mined ores. A material with high embodied energy can take the place of a material with low embodied energy. The use of manufacturing processes which saves energy can also reduce embodied energy.

Use of Natural Materials

Natural materials in most cases have low embodied energy and their use is encouraged in informal settlements. They require less energy as compared to other man-made building materials and their use results in a more sustainable product.

Local Materials

The use of local materials, either natural or man-made, reduces the amount of energy required in the transportation of the material, which reduces air pollution produced by vehicles (Kibwami & Tutesigensi 2016). In Swaziland, most of the building materials used in the construction industry are imported from neighbouring countries.

Therefore, this dissertation finds it important to analyse the materials used in the low cost housing settlement to assess their sustainability. Firstly materials used for walls, roofing, flooring and window frames were identified. The sustainability of these materials was then assessed using the criteria in the table below (Table 3.1).

Table 3.1: Green features of sustainable building Materials

Green Features		
Manufacturing Process (MP)	**Building Operations (BO)**	**Waste Management (WM)**
Waste Reduction (WR) Pollution Prevention (P2) Recycled (RC) Embodied Energy Reduction (EER) Natural Materials (NM)	Energy Efficiency (EE) Water Treatment & Conservation (WTC) Nontoxic (NT) Renewable Energy Source (RES) Longer Life (LL)	Biodegradable (B) Recyclable (R) Reusable (RU) Others (O)

Source: Kim (1998:25)

The table can assist in comparing sustainability of various materials used for the same purpose. The use of a single or more green features will assist in understanding its relative sustainability.

Before the formal observation study was undertaken, the researcher visited the study area to understand the context of the informal settlements for ease of development of the research tool (checklist). There are several building types that were found which used different building materials as shown in Figure 3.2, Figure 3.3, Figure 3.4, Figure 3.5 and Figure 3.6 below.

One of the building types that was found had walls constructed of timber panels, but with a concrete slab for the floor (Figure 3.2 below). The roof material used was corrugated iron, and steel for window frames.

Figure 3.2: Building using wood panels as walls at Mahwalala

The second type found at Msunduza used a combination of wood (sticks) and mud for wall construction, corrugated iron for roofing and wood or steel for window frames. Floor material found in use was compressed earth or concrete slabs for such houses. This building type is shown on Figure 3.3 below.

Figure 3.3: Building using stick and mud for wall construction at Msunduza

The third identified informal building type used corrugated iron sheets for wall construction nailed on internal wooden framework (poles). The corrugated iron sheets are also used for roof covering. Steel window frames are used for the windows on this type shown in Figure 3.4 below.

Figure 3.4: Building using corrugated iron for wall construction at Nkwalini

Another type observed had its walls constructed of compressed earth blocks - blocks composed of damp soil compressed using mechanical equipment and left exposed to air and heat to dry up, then burnt in open fire. Some of these houses are plastered with concrete plaster to cover the earth blocks as seen in the building on Figure 3.5 below.

Figure 3.5: Building using compressed earth blocks for wall construction at Nkwalini

It was noted that some buildings used a mix of compressed earth blocks and concrete blocks for wall construction as shown in Figure 3.6 below.

Figure 3.6: Building using combination of concrete blocks and compressed earth blocks for wall construction at Mahwalala

Part of the study areas was formalised through the UDP by installing infrastructure and services, and further allocating plots to residents who had to purchase the serviced plots. A house built on the serviced plot purchased by the resident, and approved by the Mbabane municipality is taken as formal by the study. Such houses use plastered concrete blocks for wall constructions, IBR roof sheets or Harvey tiles on wooden trusses for roof construction, concrete slabs for floors and steel or aluminium frames for windows as shown in Figure 3.7 below.

Figure 3.7: Formal building using concrete blocks for wall construction at Mahwalala

The identification of the building types informed the checklist on the expected types of materials to be found in the study areas. Therefore, possible building material options which were expected to be found in use were: concrete blocks, compressed earth blocks, timber, corrugated iron, stick and mud, for walls. Available possible options for flooring material were concrete slab and compressed earth, and for window frames – wood, steel, aluminium, and vinyl. IBR roof sheets, corrugated iron sheets, thatch, tiles, asbestos products, were expected for roofing. If there was a different material from the options, it was specified.

To better understand the use of the roofing material and shading, the study found it important to identify the roof type. Available roofing types in Swaziland are flat (Figure 3.6 above), gable (Figure 3.7 above) and hip roofs (Figure 5.3 in Chapter 5) in urban areas, but there are also indigenous forms like rondavels, dome-shaped thatched structures which should not be ignored. Roof angles could be anything from 1 degree to 45 degrees. The roofing type informs us on which roofing is affordable to the residents and how they shade direct sun rays. An ordinal scale was also used.

The materials were analysed to understand whether they are sustainable and affordable to the residents with assistance from the discussed information in this section.

3.3.4. Water efficiency

Water efficiency includes the use of water conservation means, storage and water re-use, and it also encompasses urban design methods (Kibwami & Tutesigensi 2016). Water's quality is either increased or the amount of water used on site is reduced. But the focus is on the reduction of the amount of water which should be treated by municipality with the

chemicals and energy costs. This can be achieved by limiting the use of water, or by recycling water within the site.

Harvested water from roofs can be used to flush toilets and for irrigation purposes. Water can also be stored in tanks for later use, but this water cannot be used for consumption unless there is a water purification system on-site.

Under this section, observation was made on the availability of water storage tanks using a nominal scale:

1 – Available (availability of water storage tanks connected to gutters),
2 – Unavailable (no single water storage facility is available)
Where water storage was available, the type of storage was identified and noted.

3.3.5. Physical condition of the house

The condition of housing in the built environment on overall is subjective since it depends on personal judgement, but some researchers have tried to minimize the subjectivity (Ghaleb Bagaeen 2006). To limit subjectivity on this study, evidence in the form of pictures of the houses and maps of the study area is provided to support the results.

The physical condition of the houses was assessed based on structural condition. In the evaluation of the construction practices, the researcher found it proper to also understand the physical condition of the house using the following criteria:

1 – Very Good: representing good condition which is under proper maintenance, and a structure without visible structural faults
2 – Good: a structure which is stable and in good condition but needs maintenance
3 – Medium: visible structural problems which require immediate interventions
4 – Bad: visible deep cracks or building does seem dangerous and unfit for use

3.4. Waste Management

3.4.1. Signs of demolition and onsite waste

As noted earlier, the buildings were also analysed on post demolition life cycle building stage to see if there were any visible traces of such in each plot. Wherever any signs were identified, they were recorded. Where there are signs of demotion usually material waste is

observed. The type of old material which seemed like waste was recorded. Other on-site waste was also recorded.

3.4.2. Waste water

Greywater from kitchens, for instance, may be used to flush toilets or for irrigation. The same applies to harvested water from rain.

Vacuum-assisted or composting toilets require minimal use of water which results in less waste production. There are advantages of using composting toilets including that absolutely no waste goes into the waste streams, and the compost is usable as fertilizer. In plumbing, it can be useful to separate greywater from kitchens and washing, and sewage. In some areas in Japan restrooms channel water from the sink drain to toilet tanks so that it can be used to flush toilets.

Under this section, observation was made on the availability and condition of the water drainage system using an ordinal scale:

1 – 'Very good' (Drains to public sewer and other proof of re-use of greywater),
2 – 'Good enough' (use of septic tank or other formal drainage systems),
3 – 'Not good' (means of water drainage available but faulty),
4 – 'Not available' (no means of water drainage, and it should be specified how water is disposed).

3.5. Land-use/ Settlement Planning

From the literature review in Chapter 2, it was observed that another category that should be noted in achieving a sustainable settlement or neighbourhood is the overall planning of the settlement. Bredenoord (2016 & 2017), Pullen (2010), the book titled, "Guidelines for human settlement planning and design," by CSIR, and other reviewed literature in the previous chapter informed the observation schedule in this section, and the line of observation included densification, waste management, land use and movement networks. A map of Msunduza, Mahwalala and Nkwalini was necessary to properly understand those aspects. Figure 3.8 below is a map example used for the analysis – a diagram of plots for the study areas overlaid on a topographic image of the same study areas.

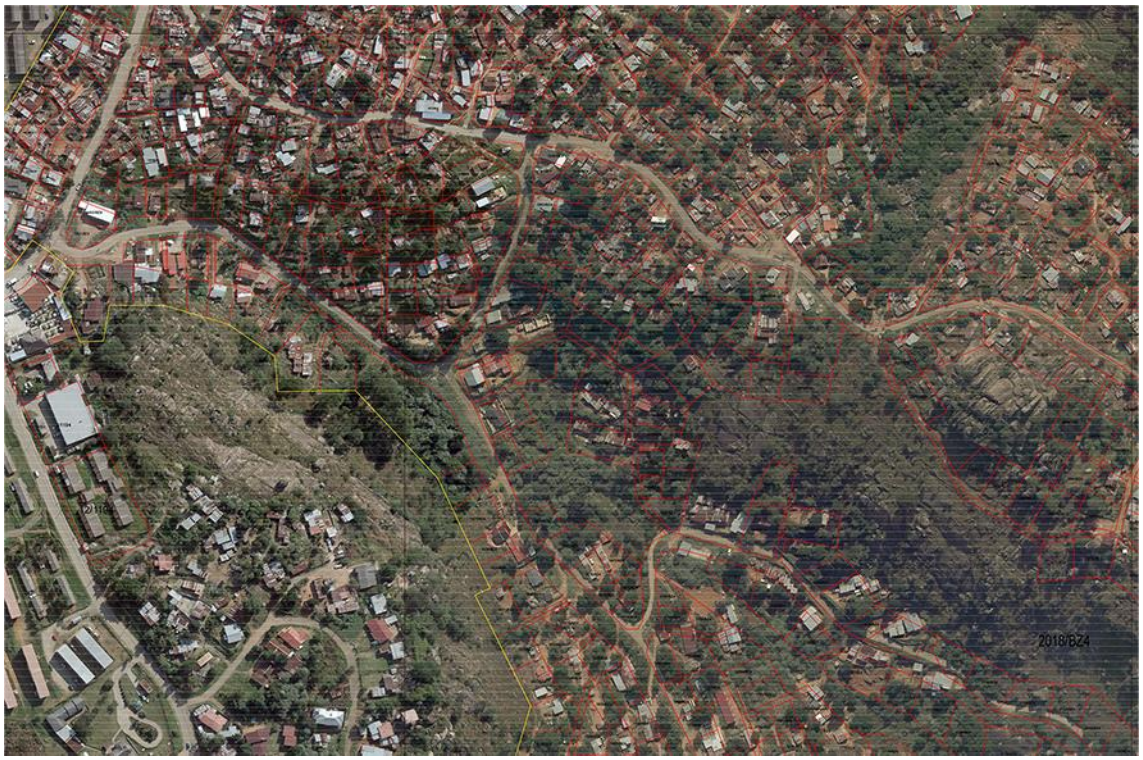


Figure 3.8: Topographic map portion of Msunduza settlement

3.5.1. Densification

Densification has been put forward as a sustainable measure, as explained in the first chapter. When housing is dense around certain nodes or along development corridors, it increases accessibility and maximises economies. Travel time and costs are saved by the dwellers, which could be an advantage to low income earners of informal settlements. Further sprawl is also contained in compactness of settlements. Concentration of urban areas can lower transport of energy, water, materials, products, and people (Du Plessis & Landman 2002). Densification also saves land from environmental impacts as the impacts (if they exist) are experienced on a smaller scale of land. In summary, Du Plessis and Landman (2002) list four themes on compactness:

- Rural protection
- Quality of life promotion - through social interactions
- Reduction of energy consumption
- Lowering greenhouse gas discharge – by the reduction of transport use which produces greenhouse gas emissions

It is therefore important to encourage densification in informal settlements for the advantages listed above. Normally informal settlements are dense, which is currently a disadvantage as there is higher probability of the spread of diseases as highlighted earlier.

There is a concept of densities important to understand for efficient planning of services in densified areas which states: *"*At certain densities (thresholds), the number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable*"* (Jabareen 2006:41). The required densities for particular services are shown on Table 3.2 below.

Table 3.2: Required density for particular services

Required density for particular services		
Density gradient	**Dwelling units/ha**	**Persons/ha**
Minimum density for a bus service	25	100
Minimum density for a tram service	60	240
Sustainable urban density	69	275
Central accessible urban density	93	370

Source: Better Neighbourhoods (2006:7)

3.5.2. Water management

Under this section water management is observed on a larger scale – settlement level. On water management, multi-functionality (resilience) is encouraged, where for example drainage water systems can act as irrigation means for gardens. This is observed in a sustainable neighbourhood in Malmo, Sweden, where channels which are narrow receive water from downpipes and sheet flow, and transport it to gardens (Figure 3.9 below) and also to a strait which is used to cool the neighbourhood in high temperatures (Figure 3.10 below).

Figure 3.9: Drainage channel receiving water from the spouts and directing them to gardens. Photo by Ludwig, S.

Figure 3.10: Strait which helps in cooling the area. It contains different water species. Photo by Ludwig, S.

To understand water management, the availability of a public sewer and drainage channels along streets was observed. A nominal scale was used:
1 – available
2 – unavailable).
Main water source of the area was observed.

3.5.3. Mixed use development

Mixed land refers to diversity of functional land uses such as residential, commercial, industrial, institutional, and those related to transportation. Diversity of function within a settlement is a sign of sustainability in that area. Mixed use development ensures matching land uses to position close to one another which creates less travel distances between activities. Mixed use developments encourage greater accessibility and integration since all services are found within the same area. So mixed land use is encouraged in sustainability development because of the following:

- Reduction on the use of cars since all activities are nearby
- The close proximity of activities encourages residents to cycle and walk
- Encourages social interactions and safety

3.5.4. Open space system

Open spaces are the opposite of hard spaces in settlements, as within them there are no constructions but are natural and have vegetation cover. Open space system, which are green areas, are needed to promote ecological diversity (CSIR 2002). They can be sports

facilities or natural – forests, rivers, plantations, hills, and streams. Other benefits of an open space system are listed below:

- Allows ecosystem processes to constantly occur sustainably without disturbance within environments
- Accommodates socio-economic need of community
- Provides barrier to settlement growth

Location, quantity (size and dimension), connection and vegetation are considered in the planning of soft open spaces.

The area of open space was calculated and the percentage of the open space against hard space was discovered.

3.6. Transportation/ Roads and movement

Urban form that is sustainable must be suitable to walking, cycling and efficient public transport (Du Plessis & Landman 2002). Sustainable transportation is defined as:
*"*Transportation services that reflect the full social and environmental cost of their provision, that respect carrying capacity, and that balance the needs for mobility and safety with the needs for access, environmental quality and neighbourhood livability" (Jordan and Horan 1997:72).
The advantages of using sustainable transportation include:

- Less emissions and waste
- Powered by renewable energy
- Less use of land
- Healthy population
- Affordable

Moveable networks are defined widely as "public right of way networks accommodating land-based movement by a range of movement modes*"* (Du Plessis & Landman 2002:18). In sustainable movement networks, there is a shift from "network of roads to networks of public right of ways, and a shift from car oriented roads to pedestrian movement networks," examples being footpaths, roadways, cycle-ways and railways.

The condition of roads was observed using an ordinal scale:

1 – Very good (for tarred roads),
2 – Good enough (for properly maintained gravel road),

3 – Medium (for tarred or gravel road with signs of erosion or pot holes), and

4 – Bad (for roads with dongas on sides).

The condition of movement was also observed using the same scale. Lastly, the movement type was analysed based on these options:

1 – rectilinear multidirectional,

2 – distorted rectilinear multidirectional,

3 – radial multidirectional and

4 – looped hierarchical

Du Plessis and Landman (2002) states that Open networks (rectilinear multidirectional) are sustainable compared to closed networks (moving towards looped hierarchical) as shown in Figure 3.11 and 3.12 below (Du Plessis & Landman 2002:15). The movement networks of the roads were analysed. The diversity of movement routes was analysed, as encouraged in the theories of sustainable development and resilience in cities. Lastly the type of transport was also observed: public, private cars, and bicycles. The use of private cars increases the amount of gases which deplete the ozone layer and contributes to global warming. The use of bicycles is usually encouraged on a neighbourhood level as explained above.

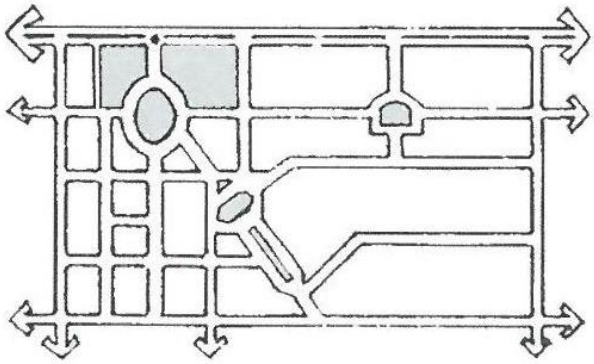


Figure 3.11: Open network

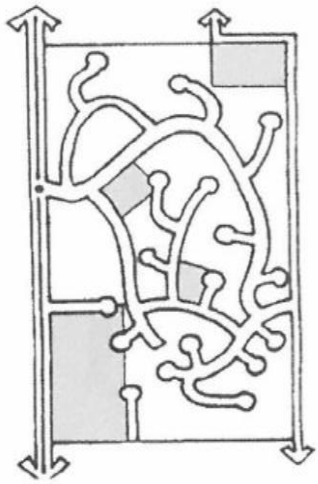


Figure 3.12: Closed network

3.7. Environmental condition

Another objective of this study is to understand how the environment is being used under the existing conditions of the settlement (design, planning and construction practices). So, human behaviour is observed but this study observed it indirectly. By observing physical traces, the use of the environment is understood. Zeisel (1984) states that when observing

physical traces, it is important to look for by-products of use, which include signs of erosion, left overs and missing traces. Observing behaviour in physical settings provides information about people's actions and requirements to sustain them; uniformity or consistency in behaviour, expectations in use and abuse of a place; and about chances in behaviour and limitations environments provide (Zeisel 1984:111). To understand the use of the environment, traces of common human impacts to the environment was observed:

3.7.1. Land/soil condition

An observation was made on whether the following exists: gullies along roads, signs of loss of vegetation, deposit of slit in low-lying areas, pot holes on roads, and other soil impacts. There was also an option of 'land/soil is in good condition', meaning no signs of the above were observed. Traces of land pollution were also searched for: litter on streets and around dumpsites, whether disposal sites exist or not.

3.7.2. Air and water condition

It was observed whether air or water was polluted or not. Traces meant to be observed were: signs of smoke, signs of dead fish in water, visual discoloured water, foam in water, visible litter on water surface, unpleasant odour from lakes and rivers, and other observations. The condition of wetlands was also part of the checklist.

3.7.3. Biodiversity and wildlife

Diversity in biological systems is defined as "the diversity of species within functional groups that have different responses to disturbance and stress" (Ahern 2011). Biodiversity and wildlife is encouraged in a sustainable neighbourhood as it is a strategy towards achieving urban resilience. Searches were made on signs of dead fish and other creatures, signs of deforestation, signs of birds and other signs proving existence of biodiversity. An analysis was made to understand if construction has an effect on biodiversity.

3.7.4. Vegetation cover condition

Greening in an urban area ensures that nature is part of the urban context through diversity of open landscapes. Greening also makes the urban area attractive and pleasant. There are more advantages including:

- Encouragement of biodiversity through conservation of habitats
- Moderation of climate from extremes and reduction of pollution
- The image of the urban area is improved with the quality of life
- Economic attractiveness of a city

Removal of the vegetation cover therefore reduces the sustainability of the area. In search of evidence on the condition of vegetation, the following were searched and analysed: signs of uncontrolled fire, signs of agriculture practice, availability of a green area and its area in the study site, and other similar signs.

3.7.5. Signs of food production

Lastly, urban agriculture should be part of a sustainable settlement. Urban agriculture is integrated into the urban economic and ecological system which differentiates it from rural agriculture. An example is Oranjezicht City Farm, Cape Town, which is a non-profit organisation practising urban farming by growing vegetables along footpaths. Dischem corporate garden by Dischem Foundation is another example which feeds more than five thousand people regularly with healthy organic produce, and also creates employment for the local residents. So signs of agricultural practices were searched with the use of a topographic map of the area.

A summary of the model is shown on Figure 3.13 below.

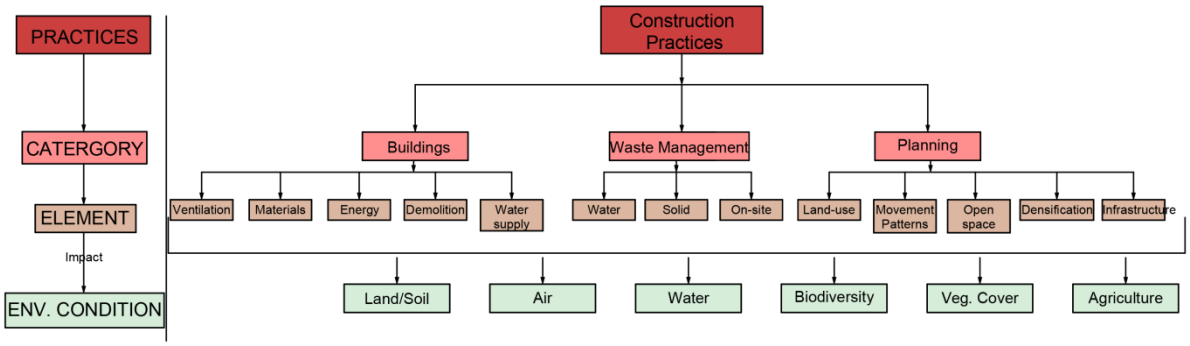


Figure 3.13: Conceptual model summary

3.8. Conclusion

The categories discussed in this chapter were used in the evaluation of construction practices used for the housing and overall selected informal settlements to identify the practices and analyse whether they are sustainable or not. In the development of a guide for use in informal settlements, the same criteria will be useful. The model in Figure 3.13 was used to guide the observation study in the field to make sure that unnecessary conditions were not recorded. To ensure that, a structured checklist was developed which only contains necessary categories of observation.

The following chapter will be discussing the research methodology and design which was used in this study. The methodology follows a positivist approach and the design follows a

quantitative approach. The way a sample was selected and target group is discussed. Chapter 4 will further discuss data collection, analyses and data interpretation. Lastly, a consistency matrix that summarises and shows the logic of the research is presented.

4. Research Design and Methodology

4.1. Introduction

The chapter describes the research methodology used in this research. Methodology of a study is a way in which the study attends to an identified research problem by finding means of collecting data and controlling it and how it tries to understand meaning from the data (Leedy & Ormrod 2001). Further, the research design, population and sample strategy are described in the following sections. The instrument used to collect data, validity and reliability of the instrument is discussed.

4.2. Research Methodology

The three major components of this study are literature review, situational analysis and research outputs.

4.2.1. Literature review

The literature review provided the context and theoretical framework of this study – framing it to sustainability, construction practices and natural environment in informal settlements. Literature review was used to understand the study's problem much better, and also to support the hypothesis which states that construction practices have an influence on the natural environments we live in. Literature review was also used to gather existing information on the nature of informal settlements and their formation in general. Sustainability principles applied in housing and assessment methods currently discussed in the field were reviewed to come-up with the categories of assessment – energy, materials, waste management, water management and land-use. These categories informed the observation schedules and were used to collect data on the physical state of housing and the informal settlements as a whole, and also for understanding the sustainability of the construction practices used. The literature review assisted as well in determining the expected outcome of environmental impacts (pattern matching).

4.2.2. Situational analysis

This part consisted of a survey where the researcher observed the houses and the natural environment in the selected informal settlements by the use of structured observation schedules to record their condition. This section formed the data collection and the assessment part of the study. The study used mixed methods (quantitative and qualitative) to collect and analyse data with the use of criteria informed by the literature review as specified in the previous section. After quantitative data was obtained through the schedules, it was further analysed through SPSS software to understand the statistics of the housing

conditions and further assess their sustainability. Qualitative data collected with a structured schedule was analysed using pattern matching discussed in the next sections.

With the use of observation studies, the physical conditions of the houses were established against the following list of parameters discussed in the previous chapter:

- Building Infrastructure
  i) Ventilation
  ii) Lighting
  iii) Energy
  iv) Materials
  v) Water
  vi) Physical condition

- Waste management
  i) Waste water
  ii) On-site waste
  iii) Solid waste

- Land-use
  i) Movement patterns
  ii) Open space planning
  iii) Densification
  iv) Infrastructure

The main aim was to answer the first two sub-questions on identifying construction practices and the effects of those practices on the natural environment. The observation studies were conducted on three purposely selected informal settlements – Msunduza, Mahwalala and Nkwalini. The selected informal settlements were selected based on accessibility and the fact that the UDP began in these settlements.

4.2.3. Research outputs

The main output of this study is a framework model for the construction of sustainable low cost housing in informal housing in Swaziland which should be usable by informal dwellers and government in developing sustainable low cost housing settlements. This framework should encourage affordable and sustainable housing which should not have an impact to

the natural environment but instead add to the environment. The discussed theory of regenerative development is helpful in the development of this framework.

The output forms a base for the development of future guidelines which should be included in the building regulations and building acts of the Kingdom of Eswatini. The output should therefore be useful to the MHUD, SNHB and Municipalities of all towns in the country.

4.3. Research Design

This study followed mixed methods research design as it mixes quantitative and qualitative data collection and analytical methods. The method is influenced by the pragmatism philosophy followed by the study. The study's research questions and context are the driving forces determining the most appropriate methodological choice, which is the approach by pragmatists (Nastasi 2010).

Data collection and analysis, to answer the first sub-research question, use a quantitative design. Quantitative design is defined by Grove and Burns (1993:777) as "a formal, objective, systematic process to describe and test relationships and examine cause and effect interactions among variables." A survey was done within the three cases to gather information on construction practices used by informal dwellers. Since the population is large, it made sense to describe it using a sample. In this study, information was collected using a structured observation study. A checklist was prepared and the researcher collected data on each of the sampled households which was quantitatively analysed using Statistical Package for Social Sciences (SPSS). A descriptive survey was chosen as it gives an accurate view of the characteristics and understanding of a certain group under observation. The design was selected to achieve the objectives of the research, which are to identify and evaluate the construction practices used by informal settlers and government in upgrading informal low cost housing settlements.

The second sub-research question was answered through the use of qualitative methods for data collection and analysis. A qualitative research helps to understand processes underlying various behavioural patterns (Maree 2007). A structured observation study was used to gather information on the condition of the settlement. The condition of the environment was further captured through the use of photographs and maps. Explanation building and testing method was used to analyse the data through pattern matching. Pattern matching entails "predicting a pattern of outcomes constructed on theoretical propositions" to describe what you expected to discover from the data analysis (Yin 2014:53). A framework for use in

pattern matching was developed by utilising data from the literature review on environmental impacts caused by construction practices. If the pattern of data collected from the study area matches the explanation which was predicted through the framework, an explanation is found.

A discussion of the findings from sub-question one and two answered the third sub-question. Literature review in chapter two provided basis for the development of a framework for use by low cost housing settlers and governmental bodies.

4.4. Strategy of inquiry

Research sub-question 1:
Which construction practices are used in informal settlement areas?

Research strategy for question 1:
Through literature review:

- Determine characteristics and parameters of sustainable construction practices.
- Determine and understand categories of measurement for sustainable construction

Through observation studies:

- Using a checklist created through the use of literature, establish the physical state of the randomly selected houses in the purposely selected informal housing settlement, against a structured coded checklist
- Using a checklist created through literature review, determine the planning and construction used by government in developing the informal settlements.

Through mapping:

- Observe housing densification (houses per hector) in the settlements under observation.

Research sub-question 2:
How do construction practices affect the natural environment?

Research strategy for sub-question 2:
Through a structured observation study:

- Observe the condition of the natural environment with the help of a structured checklist.

Through literature review:

- Based on theoretical propositions drawn from literature, determine a number of related outcomes that are expected to be found as a result of the used construction practices, for pattern matching analysis.

Research sub-question 3:
From the findings of the first two sub-questions, what measures can be taken to ensure sustainable construction which will also promote a positive use of the natural environment in informal settlements?

Research strategy for sub-question 3:

- Create a framework for informal low cost housing construction that should be informed by findings from sub-question one and two. The framework will act as a guide for incremental self-help housing construction in an informal housing settlement.

4.5. Research Setting and Unit of Analysis

This study was set at Msunduza, Nkwalini and Mahwalala informal settlements all which fall under the Hhohho region, Swaziland. These areas were chosen as they were priority for the upgrade done by UDP as previously discussed. The UDP aimed at formalising these areas by installing basic infrastructure and allocating leases to residents. As described in the previous chapters, over 66% of these areas are still informal as a majority of the residents (2848 plots out of 4328) have not been able to pay the development fees for them to receive title deeds (MNRE 2018).

Msunduza is the most densely populated and oldest informal settlement in Swaziland therefore the study assumes it will give the most accurate information on informal settlements in Swaziland. It covers about 21 square kilometres in area and is divided into several neighbourhoods namely, Mntulwini, Gobholo, Mncozini, Mncitsini and Maqobolwane. Currently in this area there are 1828 plots divided during the UDP. Mahwalala and Nkwalini on the other hand, are located on the north west of Mbabane and are divided into 6 zones – Zone 1 – 6. The total plots formed during the UDP are 1700 at Mahwalala and 800 at Nkwalini.

The analysis for sub-question one used data from sampled observed houses in these selected informal low cost housing settlements. These houses formed the unit of analysis and sampling for the first sub-question. The natural environment of the same settlements

was the unit of analysis for sub-question two. The remaining question will be answered by analysis of the findings from the first two sub-questions.

4.6. Sampling and Target Group

Target population is known as the population which is the actual focus of the inquiry (Saunders 2016:274).The target population for this study is houses which are built within unregistered plots as they are claimed to be informal by the study. The total number of unregistered plots is 2848, but those with homesteads (target population) are 1605: 748 at Msunduza, 160 at Nkwalini and 697 at Mahwalala. The study was framed on informal residential houses within homesteads, where the main house was selected for study per homestead within a plot. This study used a probability sampling which consists of simple, systematic, stratified and cluster sampling. Probability sampling is when cases have an equal chance of being selected for inquiry (Saunders 2016). Systematic random sampling was chosen for this study. It involves the researcher choosing the sample at regular intervals from the targeted sample. The targeted sample for this study consisted of 140 houses in the study area – 60 at Msunduza (Appendix A), 50 at Mahwalala and 30 at Nkwalini (Appendix B). This sample size was enough to identify materials used by the residents. The results were also compared to a previously done study by MHUD (2008) to confirm the findings. With the help of a topographic map of the area, the houses were numbered with a unique number and the first house was selected using a random number. Every fifth house was then chosen until the 140 sample size was reached. These houses included free standing houses, row houses, and semi-detached houses. Since the collection of data was self-recorded by the researcher, a 100% response rate was achieved.

4.7. Sampling criteria

The chosen subjects had to meet the following criteria to be included in the sample:

- Completely constructed house
- House which is operating, functioning
- Informal residential house – this is a house in a plot that was not registered with SNHB or Mbabane Municipality. This plot will not appear in the list of registered plots from the Deeds Registry for Swaziland.

4.8. Data Collection

4.8.1. Data Collection Instrument

Observation studies were done at Msunduza, Mahwalala and Nkwalini, and a structured checklist was used to capture the data for sub-question one and two (Appendix C). Some of

the houses and mostly the condition of the environment were captured using a camera, and physical traces of environmental impact were also mapped. Zeisel (1987:123) states that photographs are actually useful throughout a study because of their illustrative qualities. Zeisel (1987) further states that maps and diagrams help to give a better understanding of how a whole area is used at once than analysing statistical information.

4.8.2. Data Collection Procedure

The observation schedule was personally filled out by the researcher for every house in the sampled population. Same procedure occurred in the observation of the environment. The data was collected over a period of two months. Houses along streets were first observed as they were easily accessible. The last visits were to homesteads that were not easily accessible. Traces of environmental impact were marked on a map for analysis at a later stage.

4.9. Data Analysis

The collected data for sub-question one was analysed using a computer program called Statistical Package for Social Sciences (SPSS). Statistical analysis was used to analyse the collected data. Tables, pie diagrams and bar graphs were used to present the data. The open ended sort of inquiry (which required written responses) were analysed with quantitative content analysis in order to quantify emerging characteristics.

The collected data for sub-question two was analysed using qualitative methods – pattern matching. The expected outcomes were determined from literature and compared with data collected through the checklist to determine the environmental condition.

4.10. Reliability and Validity

Saunders (2016), states that validity and reliability are key in judging the research quality in a quantitative research.

4.10.1. Reliability

Reliability refers to replication and consistency of an earlier research design and obtain the same results or findings (Saunders 2016:202). The same author lists four main issues for structured observation which are related to reliability: “observer error, informant error, time error and observer effects.” Data collector bias should also be minimised in order to ensure consistency.

To minimise observer error, the researcher visited the study area to be familiar with the setting before data was collected. Reports on past developments (UDP) were read, and dissertations (Ndlela 2005; Khoza 2006) on the same study area were analysed for the purpose of understanding the setting. Earlier observations and analyses were revisited during the process of observation and analysis to ensure consistency.

To avoid observer bias, a subjective view was avoided by ensuring an understanding of the setting by the use of site information from the reports (MHUD 2008) which was somehow a way of triangulation. In the interpretation of data, possible ways of interpretation of an observation were looked at and the researcher tested which interpretation appeared to fit best.

Observer effect refers to the change of behaviour of what is being observed as a result of the presence of the observer which gives unreliable data (Spano 2005 cited by Saunders 2016). Since the residents were observed indirectly, by actually observing the environment they are living in, observer effect was avoided.

There was no informant error as the condition of the built and natural environments that were being observed could not change in the period when observation was done.

Time error was also minimal as it would take quite a long time to change the condition of the built environment. Possibly the condition of the natural environment could change with seasons as residents are mostly out on the streets in summer, and indoors in winter. Collecting data in different seasons was impossible since the research had to be submitted within limited time.

4.10.2. Validity

Validity of an instrument is said to be an instrument that measures what it was designed to measure (Polit & Hunglar 1993:443 cited by Saunders, 2016). Saunders (2016:343) further states that content validity is “when an instrument represents the factors under the study.”

The researcher established content construct and face validity of the instrument with assistance from experts from the MHUD, and a statistician from the University of South Africa. Comments that were received from these specialists were used to create a valid instrument. The content of the schedule was based on information from the Literature review in Chapter 2 to ensure that they are representative of construction practices. Content validity was also ensured by consistency in collecting data, as it was only done by a single

researcher. Generalisation of the results was ensured by collecting data from all selected sample population. It is not easy to justify generalisation of the results if some of the sampled population is not observed.

4.11. Consistency Matrix

The Consistency Matrix shown in Table 4.1 below shows links in the study problems which need to be addressed, the literature reviewed/involved, research methodologies, designs and data analysis methods that were used.

Table 4.1: Consistency Matrix

Problem Statement: The settlers in informal low cost housing have no guide which can be used in the construction of sustainable self-help housing the current construction practices probably affects the natural environment.					
Sub-problems	**Literature Review Article**	**Research Question**	**Data to be Collected**	**Methodology and Data Collection**	**Data Analysis Method**
Knowledge of construction practices used by settlers and governments in informal settlements is lacking especially in Swaziland.	Bredenoord (2017) Bredenoord (2016) CSIR (2005) Cole (2012) Du Plessis (2002) Kim (1998) Lawson (1999) Pullen (2010) Sattary (2004)	Which construction practices are used in informal settlement areas?	- Condition of informal housing at the study areas: house type, size, levels of perceived natural lighting and ventilation, use of renewable energy, construction materials, water efficiency, physical condition of the house, signs of demolition and onsite waste. - Planning of the settlement: densification, water management, movement and road networks, mixed use development, open space system.	Design: Quantitative Population: Informal low cost housing and Natural Environment. Sample: Informal housing and Natural environment at Msunduza, Mahwalala and Nkwalini in Mbabane, Swaziland Research Instrument: Structured observation schedule Data collection Procedure: Observation studies, mapping and photographs.	Basic Statistical Analysis. SPSS was used to give statistics on the mostly used construction practices, and their sustainability was determined.

Table 4.1: Consistency Matrix (continued)

Sub-problems	Literature Review Article	Research Question	Data to be Collected	Methodology and Data Collection	Data Analysis Method
It is not clearly understood how/if construction practices affect the natural environment so that the construction practices could be changed. Knowledge of how the natural environment is used is important in order to propose interventions. The way dwellers use the natural environment in their dwelling areas is not known.	Hansen (2005) Kaushal (2006) Kramer (2013) Mang (2009) McKinney (2006) McCarty & Kaza (2015) Nair (2005) Sofianou (2015) Zhang (2014)	How do construction practices affect the natural environment?	To answer sub-question two, the condition of the natural environment in the settlement will be assessed using the following criteria: land/soil condition, air and water condition, bio diversity and wild life, vegetation cover, and signs of food production	Design: qualitative method Population: informal houses and the natural environment. Sample: natural environment at Msunduza, Mahwalala and Nkwalini. Research Instrument: Structured observation schedule, maps, pictures Data collection Procedure: Observation studies, mapping, photographs to record traces.	Qualitative Comparative Analysis (QCA)/ Pattern matching
There is no guide for informal settlers to use in their cheap self-help housing construction which may reduce natural environmental impacts.	Bredenoord (2017) Bredenoord (2016) Sofianou (2015)	What measures can be taken to ensure sustainable construction which will also promote a positive use of the natural environment in informal settlements?	To answer question five, an analyses of the collected data for sub question one and two will be done, and a skeletal framework for informal housing settlement construction will be created.		

4.12. Conclusion

There are three major components of this study: literature review, situational analysis and research outputs. Literature review was done to understand the problem better and test the hypothesis of the study. The literature review also informed the observational study. Situational analysis consisted of the data collection and analysis part of the study. The research output is the development of a framework to be used in the construction of sustainable low cost housing for informal settlers.

The methodology which was used for this design was mainly of a positivist nature with a quantitative design and a very minor portion of qualitative design for triangulation and for informing the tool of inquiry. A quantitative strategy of inquiry was used in the study. The effect of construction practices on the natural environment in informal was studied by analysing the condition of dwellings (houses) and that of the natural environment. An observation study was conducted with the help of a structured observation schedule, camera and a map of the area. The houses were assessed against criteria informed by the literature review: building infrastructure, waste management, and land-use. Upon collection of data on the physical condition of houses in informal settlements, the data was analysed to identify the construction practices used by informal dwellers, and assess their sustainability. Basic statistics were used to analyse the data with the use of SPSS.

The researcher conducted the observation studies and carried out the analysis with a focus mainly on trying to understand the sustainability of the informal settlements. The analysis was then used to develop a framework for use in the construction of affordable and sustainable low cost housing in informal settlements in the context of Swaziland. It is believed that the framework will form a skeleton for the development of future guidelines and Swaziland's building regulations. The output of the research (framework) should therefore be of assistance to several bodies in Swaziland: MHUD, SNHB, and Municipalities.

The challenge encountered was on the period in which data was collected. It is not known whether the condition of the environment does not change with seasons. Also, the sample might not be enough to fully conclude on the condition and use of all informal settlements in Swaziland. Triangulation was done though to verify and validate the results of the study.

Quality assurance was done by making sure the design used is reliable and the instrument for collecting data was validated. To ensure the data was reliable, certain issues which are related to reliability when conducting a structured observation were attended to: observer error, informant error, time error and observer effects. To avoid observer bias, a subjective

view was avoided by ensuring an understanding of the setting by the use of site information from the UDP reports (MHUD 2008). The following chapter presents the results obtained with the use of the methodology discussed in this chapter.

5. Results

5.1. Introduction

This chapter presents results from the observation study that was conducted. The purpose of the observation study was to gather information to respond to the first two sub-questions: “Which construction practices are used in informal settlement areas?” and “How do construction practices affect the natural environment?” Findings from these two questions are discussed in the next chapter to answer the third research question – “What measures can be taken to ensure sustainable construction which will also promote a positive use on the natural environment in informal settlements?” And the main research question – “What are the effects on the natural environment of construction practices of informal settlements?” The observation study was conducted by the researcher at the three purposely selected informal settlements in Swaziland – Msunduza, Nkwalini and Mahwalala, all located in Mbabane. The observation study checklist (Appendix C) that was developed from the conceptual model in Chapter 3 was used to guide the data collection process.

The checklist points were useful in identifying construction practices used in the selected informal settlements as required by the first objective of the research. The construction practices were identified within the building infrastructure by observing the construction materials, energy source and waste management used in the settlement. The construction practices were also identified at settlement level in terms of waste management, land use, diversity, movement and services. Traces of environmental impact were studied on land, atmosphere, water, bio-diversity and food production to receive enough information to answer the second sub-question. Tables, diagrams and pictures are used to present the data.

5.2. Statistics on Case Studies

Information on plot sizes, number of houses per plot, types of houses, number of stories and sizes of the houses, was first gathered through the first section of the checklist tool (Appendix C) for the results to be understood in depth.

Table 5.1 below shows statistical housing information at Msunduza. Msunduza has 1828 plots divided during the UDP (MHUD 2008), but out of these plots 989 are not registered or informal (MNRE 2018). An analysis of the 60 sampled plots from the population of 748 (informal plots with houses) is shown in Table 5.1 below.

Table 5.1: Housing information at Msunduza

Plot sizes	**Number**	**Percentage**
0 - 400 m^2	25	41.7%
401 – 1000 m^2	34	56.6%
1001 - above	1	1.7%
House type	**Number**	**Percentage**
Free standing	50	83.3%
Semi detached	1	1.7%
Row house	9	15%
Area of buildings	**Number**	**Percentage**
9-100 m^2	36	60%
101 m^2 and above	24	40%
Number of storeys	**Number**	**Percentage**
Single storey	60	100%
Double storeys	0	0%

Source: Own study

Mahwalala has 1700 plots in total (MHUD 2008), but 1207 of those plots are unregistered plots (MNRE 2018). The target population at Mahwalala is 697 (unregistered plots with houses) and a sample of 50 plots with homesteads was taken for observation. Table 5.2 below shows statistical housing information at Mahwalala.

Table 5.2: Housing information at Mahwalala

Plot sizes	**Number**	**Percentage**
0 - 400 m^2	14	28%
401 – 1000 m^2	34	68%
1001 - above	2	4%
House type	**Number**	**Percentage**
Free standing	34	68%
Semi detached	0	0%
Row house	16	32%
Area of buildings	**Number**	**Percentage**
9-100 m^2	31	62%
101 m^2 and above	19	38%
Number of storeys	**Number**	**Percentage**
Single storey	50	100%
Double storeys	0	0%

Source: Own study

Nkwalini has 800 plots in total, according to MHUD (2008), and out of those plots 652 are informal or unregistered (MNRE 2018). The target population at Nkwalini is 160 unregistered plots with houses. A sample of 30 plots with homesteads was taken for observation (Table 5.3 below).

Table 5.3: Housing information at Nkwalini

Plot sizes	**Number**	**Percentage**
0 - 400 m^2	1	3.3%
401 – 1000 m^2	27	90%
1001 - above	2	6.7%
House type	**Number**	**Percentage**
Free standing	20	66.7%
Semi detached	0	0%
Row house	10	33.3%
Area of buildings	**Number**	**Percentage**
9-100 m^2	21	70%
101 m^2 and above	9	30%
Number of storeys	**Number**	**Percentage**
Single storey	30	100%
Double storeys	0	0%

Source: Own study

The statistical information across all study areas shows that over 90% of the plots have an area less than 1000 square meters and most of the houses have a footprint of less than 100 square meters. All the houses are single storeyed and a majority of them are free standing buildings (as opposed to semi-detached and row houses). The row houses identified seemed to be for rental purposes as per the common practice in such areas in Swaziland. The results of identified construction practices used for these houses and settlement upgrading are presented in the following section.

5.3. Construction Practices

5.3.1. Building Infrastructure

Figure 5.1 below presents a summary and comparison of the identified construction practices within selected categories (energy, building materials and waste management), used in all three informal settlements. The practices are shown in percentages in each settlement. Detailed results on the observational study are shown in Appendix D.

- **Energy**

The results show that about half of the houses in all the settlements are not well ventilated with the use of window opening area size measurement criterion (Building Standards 1969), and the same amount of houses do not receive adequate natural lighting, which was measured by the area of glazing and orientation of the building in reference to the Building Standards (1969:35). Therefore, these findings reveal that about half of the houses have

high energy consumption compared to the other half. Generally small scale solar panels are not used in all the settlements as only 3% of the observed houses use small scale solar panels. The main source of energy is electricity as 75% of the houses have access to electricity, and the remaining seems to use wood as a source of energy. The analysis also shows that there is less control of strong sun's rays into the houses as 63% of the houses have a roof overhang of less than 300 millimetres. A majority of the houses (56.7) have roof angles of less than 3 degrees which has an effect in the way the sun's rays are reflected.

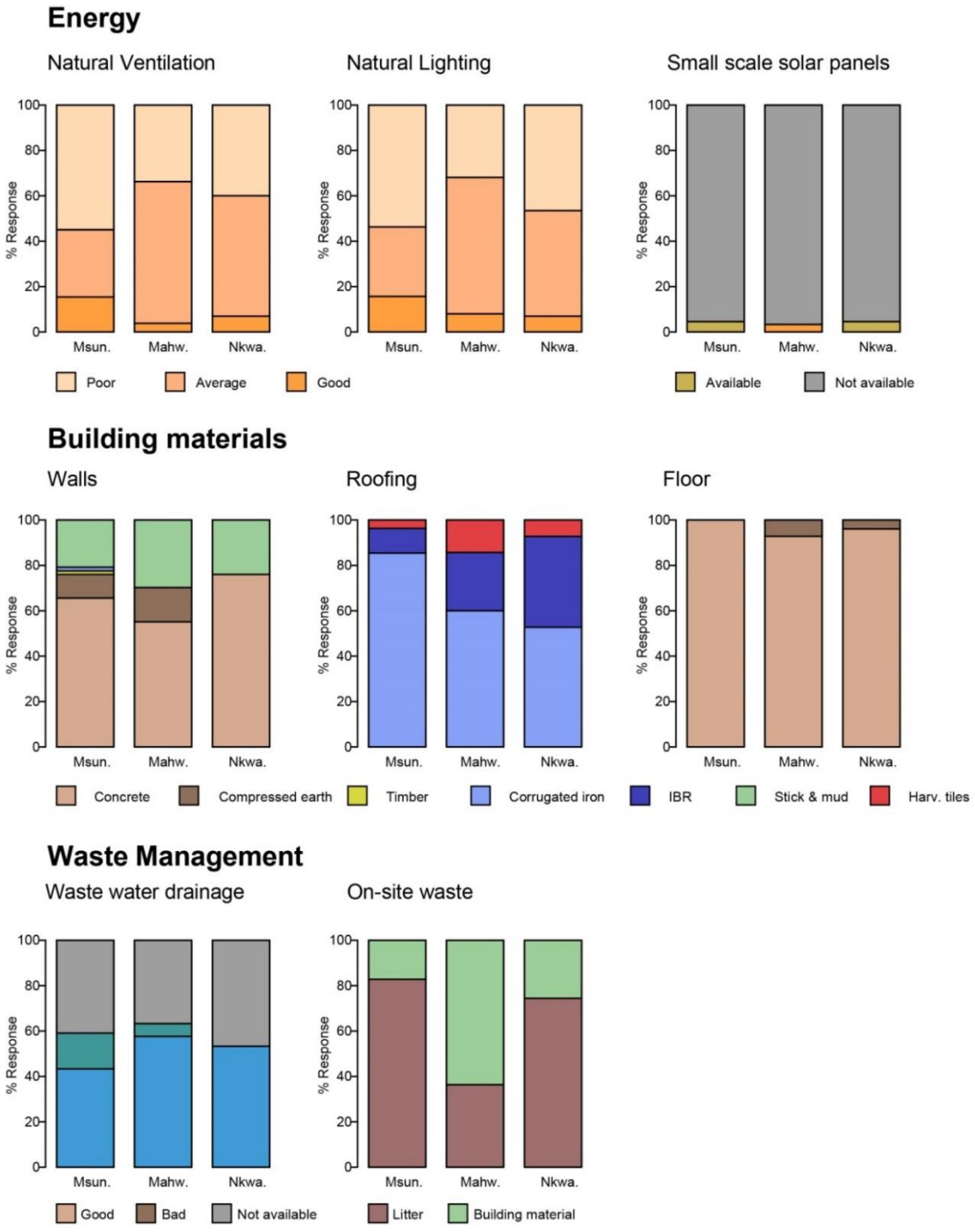


Figure 5.1: Results of identified construction practices used at Msunduza, Mahwalala and Nkwalini

- **Building materials**

The mostly used building materials across all settlements as shown in Figure 5.1 above are: concrete for the floor (over 90%), concrete blocks for walls (over 60% in average) and corrugated iron sheets for roofing (over 60%). Almost all the houses use steel window frames. It was noted though that some of the buildings (21%) use stick and mud for their wall construction, which is a material that is economical, friendly to the environment and easily accessible. An example of a stick and mud house captured at Msunduza is shown in Figure 5.2 below.

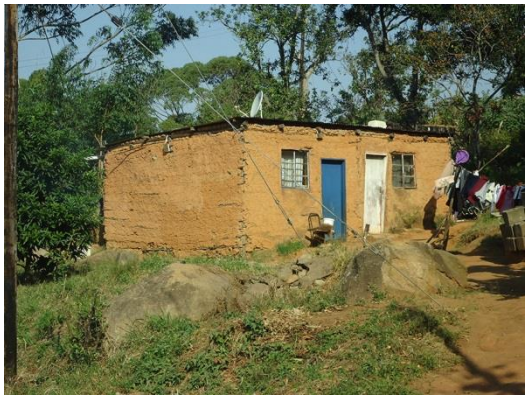


Figure 5.2: Stick & Mud wall building at Msunduza

It was also noted that a few buildings which were approved for construction by the local municipality, used more expansive materials, as shown in Figure 5.3 below which shows the contrast between formal and informal houses. Such houses, even though they are part of the settlement, were not selected for observation as the study focuses on the informal houses.

Figure 5.3: Concrete walled formal building with Harvey tiles for roofing at Mahwalala

- **Waste Management**

Solid waste from kitchens and toilets, building materials, and liquid waste from houses were under observation in this category to understand the operation of waste management systems in place in all the settlements. There are two types of solid waste that were observed – litter and building material. Litter is mostly saturated at Msunduza as 83.3% of the observed house premises were saturated with light weight litter. Mahwalala on the other hand is mostly saturated with waste building material. The building material waste is possibly from demolished houses and buildings that had been recently finished. Signs of demolition were observed in 21.7% of the observed homesteads. Figure 5.4 below shows remains of a stick and mud demolished house at Msunduza. At Nkwalini most of the solid waste is clearly from building material from recently built houses as there are very few signs of demolitions (3.3%).

Figure 5.4. Remains of a demolished house at Msunduza

At Mahwalala and Nkwalini the analysis shows that there are houses at a percentage of 38% to 44% which have no waste water drainage systems possibly as a result of affordability. That means water is disposed on yards or latrines visible in some premises (Figure 5.5 below).

Figure 5.5: Pit latrine at Nkwalini

5.3.2 Settlement planning

Building practices in this category were observed and analysed in terms of waste management, efficient use of land, diversity and transportation and the results are presented in Table 5.4, Table 5.5 and Table 5.6 below.

Table 5.4: Results on settlement planning observation at Msunduza

Category	Observation
Waste management	• A great percentage (41.7%) of houses are not connected to the public sewer and do not have any means of waste water disposal • Waste disposal containers are placed in several locations along streets only (Figure 5.6 below) • More than half of the observed homesteads had evidence of solid waste in the form of litter and building materials (Figure 5.7 below)
Land use	• Settlement area is estimated at 143 hectares and 118 hectares is built area. • Mixed use land use and access to other functions as it is attached to CBD • Soft open spaces on steep areas • Proper land use but requires enhancement
Diversity	• Less diversity in plots • Less diversity in house type (standalone, row houses) • Green area exists to allow for diversity but under threat • No diversity in movement (no cycle paths, few walkways)
Movement	• Main means of transport is public transport • Bitumen and concrete finished roads (Figure 5.8) • Bicycle paths missing • Street ways condition – very narrow, steep and rough • Movement network – hierarchical
Services	• Public sewer installed at Msunduza • Electricity, street light systems and water systems installed • A great portion is not connected to these systems possibly because of financial challenges

Figure 5.6: Waste containers

Figure 5.7: Litter

Figure 5.8: Concrete finished road

Table 5.5: Results on settlement planning observation at Mahwalala

Category	Observation
Waste management	• No public sewer. Residents expected to construct septic tanks • Waste building material from new sites • Lightweight litter visible along streets
Land use	• Settlement area is estimated at 143 hectares and 118 hectares is built area. • Mixed use land use (main function is residential) – two schools, one clinic, a church and an orphanage (Figure 5.10 below) • Soft open spaces exist (48% of land is unbuilt) • Poor land planning – dispersed land uses
Diversity	• Less diversity in plots • Less diversity in house type (standalone houses) • Diversity in land use • Green area exists (almost half of the settlement) to allow for diversity but under threat with the constructions happening • No diversity in movement (no cycle paths, few walkways)
Movement	• Main means of transport is public transport, but private cars exist • Bitumen finished roads, but some are not developed (Figure 5.11 below) • Poor road maintenance • Movement planning does not allow use of bicycles and walking • Movement network – hierarchical
Services	• Available utilities: electricity, water drainage channels, public water systems, and street lighting systems (Figure 5.12 below) • No public sewer • A great portion is not connected to these systems possibly because of financial challenges

Figure 5.9: Waste disposal Mahwalala

Figure 5.10: Saim Christian High School

Figure 5.11: Gravel road

Figure 5.12: Light system

Figure 5.13: Litter at Nkwalini

Table 5.6: Results on settlement planning observation at Nkwalini

Category	Observation
Waste management	• No public sewer. Residents expected to construct septic tanks • Waste containers and waste sites exist • Waste building material from new sites • Lightweight litter visible along streets (Figure 5.13 above)
Land use	• Mixed use land use – residential use, stores, a school, an institution, one clinic, a church and an orphanage • Soft open spaces exist (48% of land is unbuilt)
Diversity	• Less diversity in plots • Diversity in land use – residential, commercial, institutional • Bio diversity exists but under threat • No diversity in movement (no cycle paths, few walkways)
Movement	• Main means of transport is public transport, but private cars exist • Bitumen finished roads, but some are not developed (Figure 5.11 above) • Roads condition is not good. Poor road maintenance • Movement planning does not allow use of bicycles and walking • Movement network – looped hierarchical
Services	• Available utilities: electricity, water drainage channels, public water systems, and street lighting systems • No public sewer • A great portion is not connected to these systems possibly because of financial challenges

The results on settlement planning show similarities across all study areas as the following points were noted:

- Most houses are not connected to the installed public sewer
- Waste disposal systems are not effective enough
- All settlements are mixed-use planned, but a greater part of them is residential zoned.
- There is still a great portion of soft space (even though under threat) encouraging biodiversity
- The main means of transport is public transport, and the movement network is looped hierarchical which is not sustainable (Du Plessis and Landman 2002).
- Biodiversity is assumed to exist, and there is diversity in land use (missed use)

5.4. Sustainability of the identified construction practices

Sustainability of the construction practices is evaluated, as shown on Table 5.7 and Table 5.8 below, with assistance from literature reviewed in Chapter 2. Qualitative analysis is done through pattern matching by developing a framework from literature of expected sustainable practices on the use of energy, materials, waste management and planning of the settlements (land use, diversity, movement and services). These sustainable expected

practices are sought within the identified construction practices. Where a match is identified, it means sustainability is identified in that aspect, and if a match is not identified (observed) it means that area or aspect is not environmentally sustainable.

Table 5.7: Evaluation of sustainability (Building Infrastructure)

	Factors	Sustainability		
		Msunduza	**Mahwalala**	**Nkwalini**
Energy	Natural Ventilation	Average	Available	Available
	Natural Lighting	Available	Available	Available
	Small scale solar panels	Missing	Missing	Missing
	Energy conservation	Missing	Missing	Missing
	Renewable source	Missing	Missing	Missing
	Local source	Missing	Missing	Missing
	Affordable source	Available	Available	Available
	Roof overhangs	Average	Average	Average
Materials	Affordable	Available	Available	Available
	Recyclable/ reusable	Missing	Missing	Missing
	Less pollutants	Average	Average	Average
	Local materials	Average	Average	Average
	Insulation	Missing	Missing	Missing
	Reflective film in windows	Missing	Missing	Missing
	Natural materials	Average	Average	Average
	Low embodied energy	Average	Average	Average
	Prefabrication	Missing	Missing	Missing
Waste Management	Waste water drainage	Average	Average	Average
	Reusable waste	Missing	Missing	Missing
	Recycling	Available	Missing	Missing
	Passive composting	Missing	Missing	Missing
	Active composting	Missing	Missing	Missing
	Vermiculture	Missing	Missing	Missing
		Missing = Evidence to support availability of the factor is missing Average = Evidence to support availability of factor is available at an average level Available = Evidence to support the availability of the factor is strongly available		

Table 5.8: Evaluation of sustainability (Settlement level)

	Factors	Sustainability		
		Msunduza	**Mahwalala**	**Nkwalini**
Waste management	Public sewer	Available	Missing	Missing
	Drainage channels	Average	Average	Average
	Recycle centre	Available	Missing	Missing
Land use	Mixed land use	Available	Average	Average
	High density (compactness)	Missing	Missing	Missing
	Soft open spaces	Available	Available	Available
Diversity	Housing type	Missing	Average	Average
	Bio diversity	Average	Average	Average
Movement	Footpaths & cycle paths	Missing	Missing	Missing
	Public transport	Available	Available	Available
	Open movement network -rectilinear multidirectional	Missing	Missing	Missing
Services	Multifunctionality (resilient)	Missing	Missing	Missing
	Affordable	Average	Average	Average
		Missing = Evidence to support availability of the factor is missing Average = Evidence to support availability of factor is available at an average level Available = Evidence to support the availability of the factor is strongly available		

5.5. Effects on the natural environment

Having established the available and missing sustainability aspects of the construction practices used in the informal settlements, effects on the natural environment were then assessed through pattern matching, on land, atmosphere, water, biodiversity and food production.

Pattern matching was conducted by identifying possible impacts of construction practices on the natural environment in literature, and matching them with the findings on the environmental condition of the study areas done with the use of a structured checklist as shown in Appendix C and Appendix D. Table 5.9 shows pattern matching of the expected environmental impacts (from literature) with the actual impacts observed in the informal settlements. The findings gave information to answer the second sub-question.

The observational study was effective in identifying the construction practices used by residents of informal settlements in Swaziland. The results from the observations made in the case studies are shown and compared in Appendix D to identify practices used in general across all informal settlements observed. The similarities observed and also discussed in the next chapter are taken as the general construction practices used in all the settlements.

The next chapter presents a discussion of the results shown in Chapter 5 to fully answer all sub-research questions and the main research question which requires identification and evaluation of construction practices used in informal settlement areas. That is done by tying the discussion to the reviewed literature in Chapters 2 and 3. The discussion will then allow the last sub question to be answered, as it requires measures that can be taken to ensure sustainable construction within informal settlements.

Table 5.9: Pattern matching of expected environmental impacts (literature) with actual impacts observed in the informal settlements

Practices (categories)	Environmental impact expected	Environmental impact from settlements
Energy	Carbon emissions from fossil fuels impacting the atmosphere (Du Plessis and Landman 2002)	Observed (assumed) from the public and private vehicles
	Deforestation with the use of wood to generate energy (Kibwami and Tutesigensi 2016)	Observed – land cleared to allow for construction and fuel wood
	Poor natural ventilation and lighting increases the use of energy, and the greenhouse gas emissions from energy based generation which harm the environment is increased (Khan, Su and Riffat 2008; Mochida 2005).	Observed – statistics show about half of the housing population with poor natural ventilation and lighting.
Materials	Land pollution from unrecyclable old building material (Kim 1998; Recycling and reuse 2018).	Observed – building material waste was observed as presented
	Toxic waste from demolished buildings (Kim 1998)	Not observed
	Atmospheric impact from materials with high embodied carbon/energy (Bredenoord 2017; Kim 1998; Lawson 2006; Pullen 2010)	Observed – the materials mostly used like corrugated iron, steel, concrete blocks have high embodied energy, which affect the atmosphere negatively. It is noted though that there are local materials (21%) used with low embodied energy, like compressed earth.
Waste Management	Land pollution - lightweight litter like plastic bags and film with hazards for animals • chemicals contaminating soil (Kim 1998)	Observed – litter as a form of building materials and lightweight materials along streets and within household premises
	Water pollution from toxic pollutant (leachate)	Not assessed
	Loss of biodiversity as a result of demand for new landfill sites (Ahern 2011).	Observed – landfills were observed at Msunduza and the assumption is that there was a loss of biodiversity
Land use	Vegetation loss and a negative impact on the remaining habitat. Vegetation loss changes nutrient and biogeochemical cycles (Kaushal 2006; McKiney 2006)	Observed – land cleared to allow for construction processes
	Loss of biodiversity (Hansen et al. 2005; Kramer 2013; Sofianou 2015)	Partly observed – assumption is that the loss of vegetation observed reduces the natural habitats, and the primary effect of habitat destruction is reduction in biodiversity
	Unfertile soil	Not observed as agriculture is not practised

Practices (categories)	Environmental impact expected	Environmental impact from settlements
Density	Low density extends environmental impact of each house over a large area, extending the footprint of housing development (Hansen et al. 2005; Paulsen and Silverman 2005).	Observed – the settlements have low density of 10 – 12.6 houses per hectare.
	• Sprawling of a settlement (low density) increases transport of energy, water, materials, products and people (Du Plessis and Landman 2002).	Clearly before UDP the construction was not controlled, but since government has divided land into plots, expectation is that this will now be sorted.
Movement/transport	Emissions from fossil fuels that impact the environment negatively as they produce more pollutants and disturbance (Du Plessis and Landman 2002; McCarty & Kaza 2015)	Observed (assumed) – transportation use fossil fuels which produces emission that impacts the natural environment. Lack of bicycle tracks encourages everyone to either use public transport or private vehicles.
Services	The absence of water management and resilient systems result in erosion (Ahern 2010).	Partly observed – gullies along roads as drainage channels are one sided • water disposal on yard caused erosion on steep areas

6. Discussion

Msunduza, Mahwalala and Nkwalini are informal settlements which have been upgraded by government through the UDP. These studied settlements were observed to have characteristics of the *district* type of informal settlements described by Dovey and King (2011) – mixed-use districts with retail and industrial functions, which have developed over a long period. The informal settlements (study areas) were developed by government to improve the quality of life of informal dwellers. The approach followed by the UDP in developing the settlements is claimed by the study to be the one described by Imparato and Ruster (2003:2) – "installation of basic infrastructure such as water, sanitation, solid waste collection, access roads and footpaths, storm water drainage, electricity, and public lighting." The approach also includes security of tenure and dwellers focusing on improving their self-help houses where sustainability is not given high priority (Bredenoord 2016:8) as attested by the results that are discussed in the next sections.

A large section of the settlements is still viewed by the study as informal even after the intervention by UDP. In Chapter 2, the study agreed with the definition of informal settlements by the UN (2014:2) which states: "residential areas with housing constructed on land to which the dwellers have no title." The Swaziland government through the UDP tried to formalise the land by giving the residents 99 year leases and bringing infrastructure development to the areas but by the end of the UDP Phase 1, only 10% had been given these leases. Unfortunately the development of the areas escalated the costs such that a majority of the residents could not pay the required rates (90%) and therefore not receiving leases (MHUD 2008). In 2018 the number of registered plots were 1480 out of 4328 (34%) plots at Msunduza, Mahwalala and Nkwalini according to the Ministry of Natural Resources and Energy (MNRE 2018). Therefore, in view of the definition, these settlements are still partly informal as a majority of the residents have no title (66% of the plots) and the practices within their plots are not approvable by the local authorities as they do not meet their standards. There is a possibility that even some of the registered plots still have informal houses which were built before the UDP. In view of the building regulations, meeting the required standards requires a professional architect or technician who renders expensive services. The expectation is the same across all income groups as the building codes were not reformed to reduce construction costs and make housing affordable to the low income earners.

This study discovered that the middle income group are now taking over the informal settlements that have been partly developed through the UDP. This observation was made

on the contrast in housing that was found in the settlements, mostly at Mahwalala. Some of the housing had a very low budget as they used stick and mud for their wall construction and corrugated iron for roofing. The other structures, claimed to be occupied by middle class residents, used more expensive material – blockwork, aluminium windows, IBR roof sheets and roof tiles (Figure 5.2 and 5.3 in Chapter 5). To confirm this claim, a further study was done on the local newspaper (Times of Swaziland 2018) to find out if there are plots sold in these settlements. From a sample of 20 newspapers in a pile of 2018 newspapers, twelve of the newspapers (60%) showed either vacant plots or plots with newly built houses being sold at a price range of E80 000 to E120 000 for plots only, and E450 000 to E950 000 for plots with houses. Clearly these plots can only be affordable to the middle and higher income population as MHUD (2008) presented that 56% of the low income population in these settlements is unemployed. Selling these plots is illegal yet the Municipality of Mbabane accepts drawings and property rates from these new dwellers. A further study, beyond the scope of this dissertation, should be done to verify this claim in depth. The following sections discuss findings about construction practices used within informal settlements so as to provide an answer to the third sub-research question.

6.1. Construction Practices

The results in Chapter 5 identify the construction practices that are used by dwellers of the studied informal settlements – Msunduza, Mahwalala and Nkwalini. The sustainability of these practices was briefly analysed with the purpose of discovering which sustainable aspects were missing so that they are recommended. The practices which were broken down into themes within bigger categories viz: “building infrastructure and settlement planning” are discussed in this chapter. The main purpose of the discussion is to give meaning to the results and gather enough understanding and information to answer the last sub-research question – “What measures can be taken to ensure sustainable construction which will also promote a positive use of the natural environment in informal settlements?”

6.1.1. Building Infrastructure

A discussion is made on identified practices (energy, materials, waste management) and their sustainability to uncover how each aspect could be enhanced to ensure and increase sustainable practices in informal settlements.

- **Energy**

The results across all settlements reveal that about half of the houses are well ventilated and the other half is not. Literature review revealed that natural ventilation saves energy in a building, which is a very important aspect in low cost housing to improve affordability by

limiting energy use for heating up the houses (Khan, Sue and Riffat 2008). In the efficient energy design of buildings, natural ventilation is now one of the fundamental methods for consideration (Khan et al. 2008). The results on natural ventilation and lighting are therefore presenting over usage of energy in a section of the houses as half of the buildings from the sample consume a high amount of energy making them less affordable. With about half of the houses receiving poor natural light, it means more energy is required to light up the buildings. The building form and envelop therefore requires enhancement by making it narrow to reduce resistance to the flow of air. The narrow typology also allows maximum sunlight into the building to minimise the use of electricity especially during the day.

The results show that electricity is supplied by the Swaziland Electricity Company (SEC) in all the settlements, but a quarter of the residents are still not able to connect to the transmission lines. 80% of this traditional source of energy in Swaziland is imported from South Africa (Eskom) which makes it expensive and may not be affordable to very poor residents. Energy efficiency measures such as the use of passive design, photovoltaic cells and solar water heating methods are not used probably because of affordability. An alternative renewable and affordable energy source could be small scale solar panels. Only 2.9% of the houses on average use solar panels. The results are therefore showing lack of renewable energy sources in these areas which makes them not environmentally sustainable in this aspect as energy consumption of a building is claimed to be the main measure of environmental sustainability of that structure (Larsen et al. 2008). The overall energy consumption requires improvement.

- **Building Materials**

In general the results from Chapter 5 identified the following materials used in all the settlements as presented in Appendix D: concrete blocks for walls, corrugated iron for roof covering, concrete slab for the floors, and steel window frames. Materials which are so far considered sustainable by literature (Bredenoord 2016, Bredenoord 2017) and proper for use in informal settlements are grouped as follows: “bamboo, and timber, compressed earth bricks/blocks, adobe blocks, interlocking blocks of recycled materials, and improved concrete panels.” In trying to implement sustainable and affordable housing, Bredenoord (2017) stresses that sustainable local building materials are one of the important options to be considered. Bredenoord (2017) further states that these materials assist in the reduction of the building’s impact on the environment. Pullen (2006), as discussed in Chapter 3, advises the use of low embodied energy materials, and materials that are re-usable and recyclable. In the movement towards sustainable housing, the use of local materials is encouraged to reduce air pollution produced during transportation of the materials.

The existence of these characteristics of sustainable materials from theory was checked against the materials identified in the informal settlements (pattern matching) and the results showed lack of these sustainable characteristics. Steel is one of the highly recyclable materials, and it can be recycled over and over again without losing its properties (Recycling and Reuse 2018). Corrugated iron used as roof sheets also falls under the same category. The challenge with steel is that it has high carbon emissions and high energy consumption (high embodied energy) which Pullen (2010) discourages. Steel is viewed as environmentally harmful when measured by weight. In the case of window frames, wooden window frames would be a better option as wood is listed amongst sustainable building materials by Bredenoord (2017).

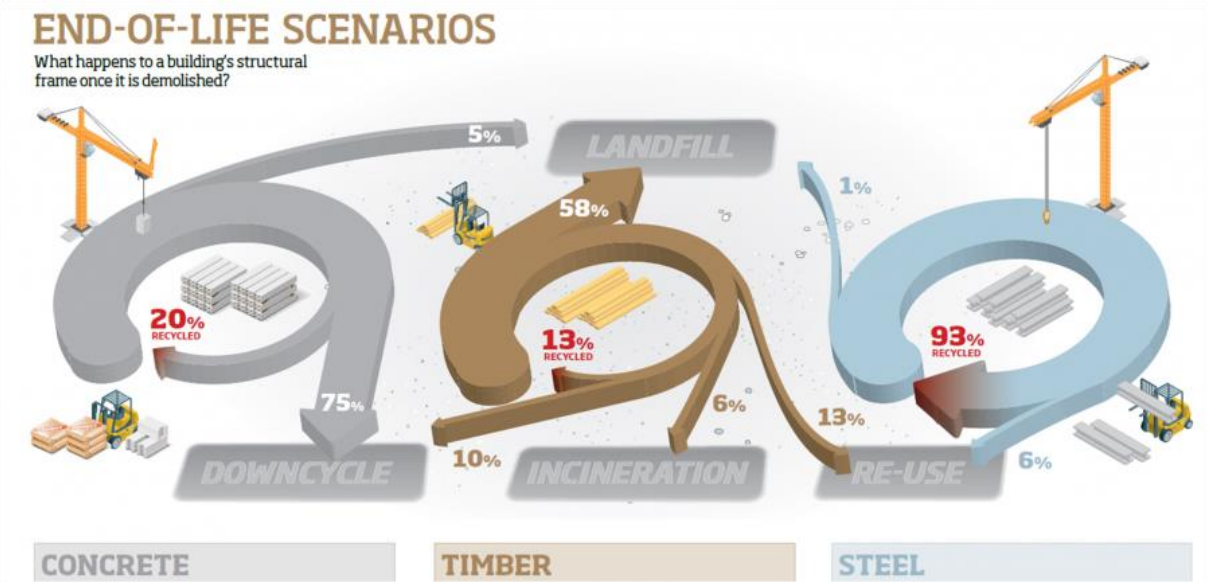


Figure 6.1: End of life outcomes for concrete, timber and steel

Concrete on the other hand, which is used in large amounts in the settlements studied, is said to get scattered and downgraded when recycled, and it does not match with the virgin aggregate (Figure 6.1, Dowling 2013). Reuse of concrete is also difficult and probably the reason why it does not appear in the list of sustainable building materials presented by Bredenoord (2016). Very few houses were found to use earthblocks (12%) and stick & mud (21.7%) for their wall construction. These materials are environmentally friendly as they are locally found, retain energy, have very low carbon emissions (low embodied energy) if any, and they are recyclable. This is probably the reason why they are considered sustainable. The only challenge raised in literature is that dwellers feel as if the use of these sustainable materials is a sign of poverty, and possibly the reason why they are less in use when

compared to concrete (blocks) in the informal settlements. This makes their promotion difficult.

The lifecycle of the building materials (pre-building phase, building phase and post building phase) is discussed below as several strategies are focusing on energy efficiency which has made embodied energy prominent.

Pre-building phase – this phase normally has the most environmental impacts according to Kim (1998) and Pullen (2006). Cement which is one of the ingredients in preparing concrete bricks and slabs is imported from South Africa by Swazi suppliers (BuildIt, Baceth, Builder's Hardware, Cashbuild). The manufacturing of cement causes environmental impacts through pollution during this stage. Transportation of cement to Swaziland causes an impact to the environment through emissions from fossil fuel, and transportation also raises the costs of the products. The manufacturing of concrete blocks is local but the final product has high embodied energy by the time it is ready for use on site. The extraction of metal and processing of steel also occurs outside the country but the window frames are manufactured in Swaziland. According to the quoted suppliers, the corrugated iron sheets are also imported from neighbouring countries. Some residents of Msunduza manufacture steel products within the settlement as a way of making a living. This phase shows that most of the materials used in the settlement are not local, and they have high embodied energy.

Building phase – building material waste was observed within and just outside the premises of households. The waste from steel has been discussed as re-usable, but the high embodied energy in steel makes its use discouraged. Concrete is seen as having low recyclable quality as discussed above (Figure 6.1). At this stage, there is environmental impact to a certain extent.

Post-building phase – half demolished houses have been observed, and some old waste building material was clearly from demolished houses. Concrete waste was observed as having an effect on the fertility of the top soil. Since most of these materials are not reusable, energy that went into the building is not conserved. The use of recycled materials reduces waste on-site and the demand of natural resources, and the embodied energy the materials contain is preserved. It is noted though as discussed above that some of the materials (compressed earth) used are sustainable (Figure 6.2 below).

Figure 6.2: Compressed earth blocks (left)

The results and the discussion shows that most of the identified building materials used in the informal settlements have low qualities of sustainability thus an intervention is required to enhance the selection and use of sustainable building materials for self-help housing.

- **Waste management**

The results show that sewer lines were installed by SWSC only at Msunduza but not at Nkwalini and Mahwalala. Surprisingly it is at Msunduza where most houses were assessed to have bad drainage (56.7%). This confirms a study done by MHUD (2008) where 61% of respondents said water borne sewerage did not exist in their houses. A fraction of the houses in the other settlements (Nkwalini and Mahwalala) drain waste water to septic tanks in combination with French drains, and the remaining have no formal way of disposal. In such households there are pit latrines but water from kitchens seems to be disposed on bare ground which may affect the natural environment negatively. Clearly the installation of sewer systems by the UDP did not assist all the residents and the explanation brought forward is affordability. Residents are expected to buy plumbing material and further hire a plumber to connect to the public system. The study claims that the residents who afford to connect to the sewer system are the middle class residents, meaning this water drainage system is not helpful to the low income group who are the original residents of the areas.

On-site waste was observed in all settlements in the form of lightweight litter and building materials within premises and along streets. Some litter is buried on landfills within plot premises. The lightweight litter is believed to affect animal health since they eat some of it, cause land pollution and affects the fertility of soil. Litter is observed even though there are waste containers located along internal streets in the settlements, possibly the challenge is reaching the bins because of various reasons the settlers may have. Refuse collection points are 100m – 1km away from homesteads (MHUD 2008). 54% of respondents also felt that

waste collection containers are benefitting those next to the road (MHUD 2008). Clearly sorting the lightweight waste issue by locating bins along streets may partly solve the problem but does not completely eliminate the problem as lightweight litter is still saturated at Msunduza. Surprisingly there is also a recycle centre at Msunduza which is not completely helpful in this issue.

Most of the building materials used in housing are not environmentally sustainable – not re-usable and recyclable which increases the amount of old building material waste. The type of material used, among other reasons, is responsible for the deterioration of the environment. The Literature review revealed that when sustainable materials are used, there should be less impact to the natural environment as waste would be recycled and reused and in the process reducing embodied energy of the materials. The current systems used for waste management require enhancement towards a sustainable approach which will reduce the environmental impacts.

The waste management failures in informal settlements may be as a result of the Swaziland Environmental Authority being inactive as it came into being in 1993 but their regulations were effective from 1996. The drafting of waste management regulations started in 2000 when the UDP was 5 years from completion.

6.1.2. Settlement Planning

The environmental conditions in informal settlements can be improved through their upgrading, according to Devi et al. (2017). This upgrading does not seem to completely eliminate the environmental problem in Swaziland though as the results show that even the approach used by government influences the degradation of the environment. The sustainability of the construction practices used at Msunduza, Mahwalala and Nkwalini were assessed in the following categories to answer the last sub-question.

- **Land-use**

Land use in all the three settlements is mixed as other functions, besides residential, were also observed. Schools, clinics, retail shops, and workshops were observed within the settlements in a small percentage proportions. However, these commercial and social areas are dispersed, which still limits the social interactions and safety of residents. The lack of cycle and walk paths do not allow residents to cycle and walk to these areas which makes the mixed use development not helpful. Changing land use in a brownfield is a challenge as structures are already built and operational in the area. Since there are still open spaces an

advantage could be taken to develop part of them for commercial use and further create access to them through bicycle paths and walk paths supplementing the road-ways.

- **Diversity**

The open spaces available in the settlements help in promoting ecological diversity, but they seem to be under threat with the rate at which construction is booming in these areas. In the development of residential housing and other related infrastructure, an impact on ecological systems and biodiversity is witnessed (Hansen et al. 2005 & Kramer 2013). With the development of the informal areas by government fortunately there are now areas which have been preserved as open areas.

There is limited diversity in plots with most of them having areas ranging from $50m^2$ to $1000m^2$. There are very few big plots (above $1000m^2$) across all settlements with an average of 4.1% in total. Bigger plots would have encouraged agricultural practices as previously understood that Swaziland relies on agriculture and manufacturing for its economic growth.

There is little diversity in architectural styles as similar typologies have been observed in all settlements. It is clear that there was no involvement of professional architects possibly because of affordability. It is only in the new houses built by the middle income group which seem to have professional design flair. A possibility of providing professional house plans to informal dwellers with all sustainable properties should be viewed, not only to increase diversity but also to encourage the use of sustainable materials.

Lack of diversity in movement encourages the use of vehicles only, and discourages the use of other means of movement, like bicycles and walking.

- **Movement/Transportation**

In the informal settlements government developed road ways with bitumen finish, but some roads are still gravel. The challenge discovered is that the roads are not properly maintained as a number of them were observed to have pot holes. Along the untarred roads gullies have developed through erosion. The assessment therefore rated the roads ‘not good’ as they lack proper maintenance.

The existence of roadways only encourages the use of vehicles which produce emissions that have a negative impact on the atmosphere. In the previous study done by MHUD (2008) the residents stated their concern as they felt that road construction left them worse off as they now do not have direct access to their homes through driveways. Government should,

in addition to the roads, develop cycle paths and walkways to promote a healthy natural environment and a healthy population at the same time. These paths also encourage social interactions which are encouraged in the development of sustainable settlements.

The overall movement network was viewed as looped hierarchical which is a closed system. This closed system has been explained by Du Plessis and Landman (2002) as establishing "clear defined movement routes between two points but offers no equidistant alternatives" and reduces the viability of smaller neighbourhood activities. Rectilinear multidirectional movement networks (open system) are preferred since they offer options of "alternative equidistant routes between two points" and so levels of accessibility to local destinations are improved and car travel total distances are reduced (Du Plessis and Landman 2002:5).

- **Services**

The focus of the UDP development was also the installation of basic services in the informal settlements. Sewer lines were installed at Msunduza only. Public water systems were installed in all the informal settlements, as well as electricity lines. It has been observed with concern though that these services are not very helpful to some of the residents (over 30%). The UDP left the homes to be developed by the owners who seem to not have access to these utilities possibly because of financial challenges as a high percentage of the residents are unemployed. This means government did not do enough to assist the residents who are now disposing waste water onto the streets, which causes erosion. Results from MHUD (2008) study confirm this claim as it stated that poor drainage also exacerbated soil erosion in the informal settlements.

Secondly, resilience of the services is missing. Resilience has been linked to sustainability by certain authors in the field as they are claimed to have low environmental impact (Lallau 2011; Walter & Salt 2006). Multiple renewable energy sources like small scale solar panels, and wind turbines can be used simultaneously so that a failure on one system gets backed up by another (redundancy) and in the process reducing natural environmental impact. Bo01 neighbourhood in Malmo, Sweden, provides a good example in multi-functionality of drainage water systems which also act as irrigation means for gardens. Narrow channels receive water from downspouts and storm-water draining as sheet flow, and direct it to gardens, and to a pool which cools the neighbourhood in high temperatures. That means less energy is used in cooling the buildings.

The results and discussion have identified the construction practices used in the areas under study, and further revealed how these practices affect the natural environment individually. Since the environmental issues were left out during the planning stages, there was lesser attention given at the design stage, which resulted in practices that are environmentally unfriendly. MHUD (2008) also confirmed that sustainable interventions were not included in the UDP. The complaints presented in MHUD (2008) on deterioration of the natural environment are a testimony for the need of such studies as the one presented in this report to come up with measures to solve the natural environmental issues. The next section suggests possible solutions to the problem which identified a gap in the absence of guidelines to self-help housing constructions within informal settlements which leads to environmental degradation.

6.2. Measures

Government is now regulating activities (including construction) that have an effect on the natural environment through the National Environment Policy, but its application in the informal settlements is not clear. The practices used in the study areas have been observed to have low level of environmental sustainability, therefore having an impact on the natural environment. The last objective of the study seeks to formulate a framework which can be used as a guide towards the use of sustainable construction practices in the development of a neighbourhood for low-income households, which will promote a positive use of the natural environment. The challenges observed which might require attention are in government's interventions level, settlement planning level, self-help buildings. Therefore, using the discussion in the above sections and reviewed literature in Chapters 2 and 3, the following measures are recommended at building scale and neighbourhood scale to meet the last objective:

6.2.1. Informal settlement regeneration

The practices at this level are expected from government. Informal settlement upgrades have a sense of improving or making less bad as the case with green practices, instead of rehabilitating these conditions. Therefore the concepts of regeneration and resilience are seen as solutions. Mcdonald et al. (2009) also stated that regeneration in deprived urban areas is required to create sustainable communities. The following measures are recommended:

Physical:

- Installation of basic services (water, sanitation, solid waste collection, access roads, footpaths, cycle ways, storm water drainage (permeable surfaces, drainage channels on both sides of roads), electricity from renewable sources, and public lighting powered by renewable energy) as had been the case previously

Governance:

- Security of land tenure (full ownership) replacing 99 year leases and cutting rates (subsidise).
- Reforming building codes and policies to make housing sustainable and affordable to low income earners without compromising building integrity
- Enforcement and compliance with environmental regulations even in informal settlements
- Strategies on attending to the environmental challenges in informal settlements should be devised.

Social:

- Encouraging participation, provision of facilities for human resource development

Economic:

- Establishment of cooperatives, housing finance, business training, schools and health centres

Review and devise new implementation procedures

6.2.2. Sustainable planning

The practices at this level are also expected from government.

- Mixed land use: residential, commercial, industrial, institutional should locate close to one another to reduce travel distances between activities and in the process reduce emissions which negatively affect the natural environment.
- Densification: to save land from environmental impacts and encourage quality of life through social interactions
- Rectilinear multidirectional movement network: promotion of walking instead of driving
- Sustainable transportation – use of public transport: promotion of bicycle use and walking to reduce emissions
- Open space system: sports facilities, forests, rivers, plantations, to promote ecological diversity and to accommodate the socio-economic needs of the community
- Waste systems which promote resource reuse and recycling, and also promote the use of waste to manufacture new products
- Water management – multifunctionality where water from drainage channels (sheet flow) and gutters is directed to storage for irrigation purposes

6.2.3. Sustainable self-help buildings

The practices at this level are expected from residents and should have low maintenance, high savings, low initial cost and require minimal labour. Sullivan and Ward (2012:315) recognise that cost is one of the primary constraining factors determining the feasibility of a sustainable intervention in low cost housing.

- Energy: Use of small scale solar panels; optimise lifecycle energy use in buildings; use of renewable energy for buildings; passive water heating; proper house orientation; sun shading; simple cross ventilation and proper orientation of buildings.
- Materials: Recycle and reuse construction materials; encourage the use of local materials and workforce; use of natural materials; non-toxic building materials; means of making materials socially acceptable; materials resistant to corrosion and salt water.
- Use sustainable floor plans of minimal allowable sizes from a pool of designs produced by government. Modifications of the plans can be acceptable on condition they go under approval. This will cut the costs of hiring professionals (architects and engineers) and also promote the use of sustainable building materials. A bill of quantities for every building type can also be provided at no fee.
- Water: water harvesting (buildings to have gutters); reuse measures; water storage
- Construction Methods: Pre-fabrication and Internal and thermal massing construction methods; avoid practices causing erosion
- Waste management: use of vacuum-assisted or composting toilets; where possible, water from sinks should be directed to toilet tanks for reuse; let waste equal food
- Anticipate future design evolution
- Control of all the above construction practices through local authorities. In the UDP and other informal settlement upgrades, the dwellers are given all power to develop their plots without guidance and advice which leads to the choice of unsustainable construction practices as the study has revealed.

6.2.4. Resilient systems

The following practices apply at all levels:

- Create buildings that will not affect the environment when demolished
- Create infrastructure with redundancy
- Plan multiple sources for each service (e.g. multiple renewable energy sources)
- Design systems that will adapt under any condition

Table 6.1 summarises the briefly discussed measures in a framework form proposed to give direction in the development of a sustainable settlement for the low income group.

Table 6.1: Measures for sustainable construction and regeneration of informal settlements in the Kingdom of Eswatini

	Building Scale	Neighbourhood Scale
a. Settlement Regeneration (Government's role)		Installation of sustainable basic services
		Good governance supporting sustainability & regeneration development practices
		Encouraging participation during development
		Establishing sustainable social & economic systems
		Devise implementation strategies
b. Sustainable Planning (Government's role)		Mixed land use practice
	Use land appropriately	
		Densification
		Open movement networks
		Sustainable Transportation
		Open space systems
	Waste management systems supporting recycling and reuse of waste	
	Educating residents	
c. Sustainable self-help buildings (dweller's role)	Proper building orientation	
	Energy efficiency (eg. small scale solar panels, sun shading)	
	Sustainable materials (eg. local, low embodied energy, natural)	
	Use already prepared (by professional architects and engineers) construction drawings with inclusion of sustainable practices	
	Anticipate future design evolution	
	Control of construction practices by local authorities	
	Construction methods with minimal environmental impact	
d. Resilient systems (Applies to all practices)	Buildings with less environmental impact at demolition stage	
	Build infrastructure with redundancy	
	Multiple sources for each service (eg multiple renewable energy sources)	
	Systems that adapt under any condition	

7. Conclusions and Recommendations

7.1. Conclusion on objectives

In conclusion, the objectives of the research were:

- To identify and evaluate the construction practices used by informal settlers and government.
- To determine how construction practices affect the natural environment.
- To formulate a framework which can be used as a guide towards the use of sustainable construction practices in the development of a neighbourhood for low-income households, which will promote a positive use of the natural environment.

In order to achieve the first objective, sub-research question 1 was used to obtain this objective. To achieve the second objective, sub-research question 2 was used and to achieve the third objective, sub-question 3 was used to obtain the objective. The conclusion is written in light of each of those questions.

Sub-question 1: Which construction practices are used in informal settlement areas?

The construction practices identified to be used in informal settlements were framed in a way to easily test their sustainability and were found to be:

Energy – lack of use of renewable energy sources and lack of sun shading. Passive cooling is averagely used.

Materials – corrugated iron for roofing; concrete blocks for walls with a quarter of the houses using stick and mud; concrete for slabs; and steel for window frames.

Waste management – availability of waste water drainage systems; water systems; waste bins along streets.

Land use – mixed land use with the major function being residential.

Diversity – minimal in plots; bio diversity under threat; no diversity in movement.

Movement – poor movement networks (closed systems), poor road conditions; use of public transport; poor overall movement.

Services – public water system is used; availability of electricity; drainage channels along a single side of tarred roads.

The comparison of expected sustainability aspect of construction practices from literature, with identified construction practices used in the study areas (pattern matching), revealed that the practices used in the study areas have low environmental sustainability and requires enhancement as in all the observed categories of assessment most of the sustainability aspect was missing (Table 5.11 in Chapter 5). The sub-proposition, "construction practices used in informal settlements are practices which lack sustainability aspect and leads to environmental degradation" is therefore accepted. It has been noted though that the few sustainability aspects which exist should not be neglected but enhanced. The basic services used are not accessible to a majority of the residents as a result of affordability. Even though there are waste management systems in place, they are not used by some of the residence because of accessibility. New systems should be devised to solve this problem.

Sub-question 2: How do construction practices affect the natural environment?

Literature assisted in revealing how certain practices affect the natural environment. The construction practices identified affect the environment as stated below:

Energy – carbon emissions are released from vehicles when burning fossil fuels which affects the atmosphere by depleting the ozone layer and increasing atmospheric temperatures. It was noted though that a majority of the residents use public transport. Residents using wood as a source of energy cut down trees (deforestation) and leave bare land which is then eroded as a result. The loss of vegetation also increases the amount of carbon dioxide and affects the ecosystem.

Materials – old waste building material (concrete blocks, corrugated iron sheets, etc) causes land pollution as the materials used are not biodegradable, and disturb the growth of vegetation cover where they are dumped and that may lead to the loss of ecosystems. The materials used have high embodied energy which affects the natural environment as described above. Materials friendly to the natural environment were also found – compressed earth, wood and mud.

Waste management – the waste management systems in place are not accessible to residents who then dispose waste on bare ground. The waste is in the form of building materials and lightweight litter. Building materials have been explained how they affect the

natural environment. Lightweight litter causes land pollution and are hazardous to animals and vegetation, causing loss of biodiversity. Some of the litter produces chemicals that contaminate soil. And lastly the demand of landfill sites causes loss of bio diversity.
Land use – the poorly planned settlements (sprawl) cause loss of vegetation and biodiversity as the impact is spread over a large area.

Density – the low density has the same impact as described in the previous point.
Movement/transport – the lack of diversity in movement (roadways only) encourages residents to use vehicles only which produce emissions that affect the natural environment as previously described.

Services – the absence of drainage channels along some streets causes soil erosion as gullies were observed.

The condition of the natural environment as observed earlier, confirms the effects and literature explains how the conditions were caused by the practices. The sub-proposition – “construction practices have a negative effect on the natural environment” is accepted in view of the discussion.

Sub-question 3: What measures can be taken to ensure sustainable construction which will also promote a positive use of the natural environment in informal settlements?

The government of the Kingdom of Eswatini should enhance their approach to informal settlements upgrade by introducing the concept of regeneration instead of improvement. Improving does not solve the problem as it only changes levels, yet regeneration has the sense of solving and further adding to the natural systems. Government should further introduce resilient systems so that when one system fails, there will not be effects on the environment as the second system will then take over. Government should further assist residents by giving out free floor plans produced by professional architects trained in low cost housing design and construction. Government should further control construction processes in these informal settlements to monitor the use of sustainable methods which should be stressed in reviewed building codes and regulations. Participation during informal settlement regeneration is important as it was seen to work in the Kampung Improvement Programme. Lastly, it was observed that the country has thought of certain systems through policies but the challenge was implementation, meaning government should devise implementation strategies as part of the planning process before construction.

The dwellers after being educated on sustainability, should use properly oriented buildings; use energy efficient methods; use sustainable building materials; use already prepared building plans; anticipate future design evolution; and use construction methods with minimal environmental impact.

The last sub-proposition which states, “measures taken from sustainability and regenerative theories are required to solve the environmental challenges in informal settlements” is also accepted from the reviewed literature which revealed that sustainability and regenerative development practices bring possible solutions to the degradation of the natural environment.

7.2. Limitations and recommendations

The study was conducted on informal settlements located in Mbabane only as that is where the UDP started before running out of funds. This means the study was conducted in the same geographical area with residents coming from the same work environments, and the area is under the same Municipality, which affects the construction processes. It would be beneficial for the study to do observations in other areas outside Mbabane.

It is therefore recommended that a further study be made in all the geographical areas of the country. The study used mixed method for data collection and analysis. It is recommended that the study be done using a different methodology – either qualitative methods only or quantitative methods only for data collection and analysis.

The study discovered that the upgrade of informal settlements attracts the middle income group; a study should be done to further understand the causes of middle class intrusion and how it could be prevented.

A study on the production of sustainable building materials that can be socially acceptable yet still affordable should be done as there is a concern from literature (Bredenoord 2016 and Pullen 2010) that materials claimed to be sustainable are not socially acceptable by residents of informal settlements. This study also surprisingly revealed that most of the informal houses in the study areas used concrete for their wall and floor construction even after the Ministry of Housing had advised the settlers to use temporal materials as the areas were still to be upgraded. This on its own shows that the settlers might not be comfortable using the sustainable building materials like stick and mud, compressed earth blocks, amongst others.

A role that could be played by the Construction Industry Council (CIC) of Swaziland in the development of informal settlements should be studied in future. The newly formed (2016)

CIC currently has not shown interest in the development of informal settlements as its regulations do not touch on issues of low cost self-help housing. All clients (owners) are treated the same way in the regulations, and are expected to pay the same amount of the construction tax (levy).

Challenges preventing the Swaziland National Housing Board from providing affordable and sustainable housing to informal dwellers should be viewed as currently the government's parastatal is developing housing accessible to the working class even though it was mandated to provide affordable housing to all groups.

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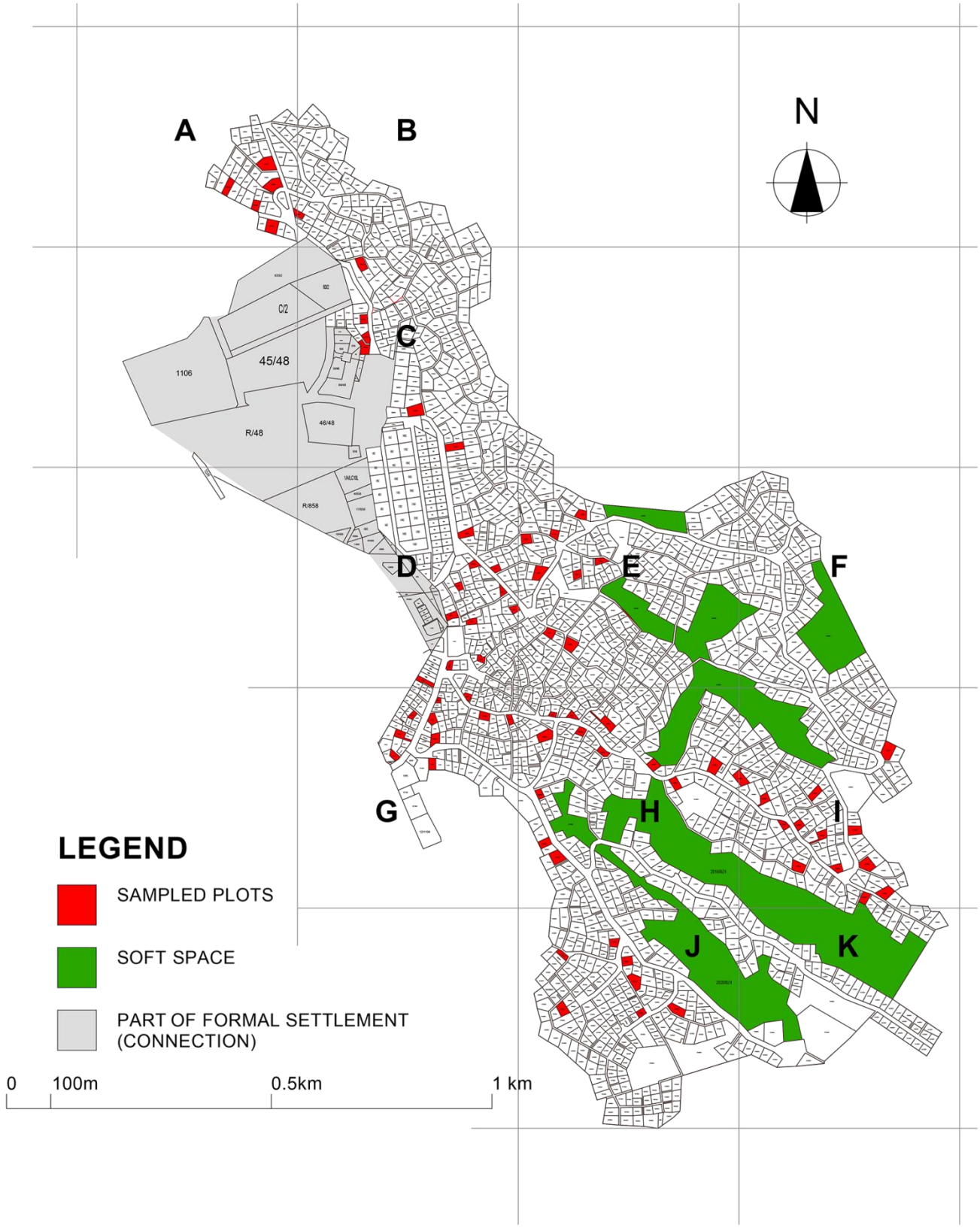
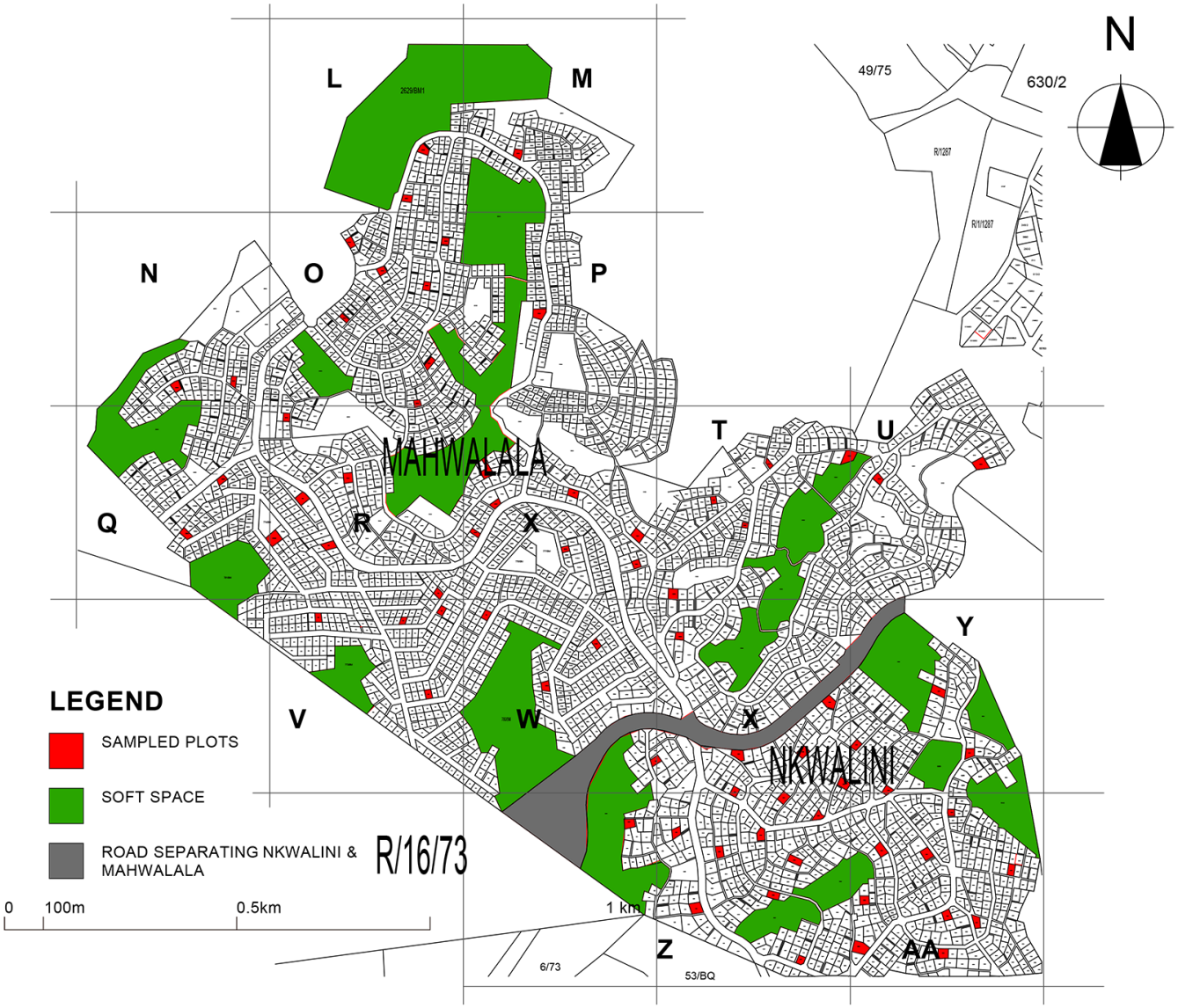
Appendix A – Msunduza Map



Appendix B – Mahwalala & Nkwalini map



Appendix C – Observation checklist

OBSERVATION CHECKLIST (HOUSES)

DATE:_____ **REFERENCE NUMBER:**_____

A. Site details		
Plot number	PLTNBR	.....
Plot size	PLTSZ	.....
Number of houses	NBRHS	.....
B. House Typology		
Type of house	b01	1 ☐ Free standing 2 ☐ Semi-detached 3 ☐ Row House
Number of storeys	b02	1 ☐ One storey 2 ☐ Two Storeys 3 ☐ Three Storeys
Size of the house	b031 b032 b033	Length _____m Breadth _____m Area _____m^2
C. Building Infrastructure		
Levels of perceived natural ventilation (Areas of openings area analysed)	c01	1 ☐ Very Good (above required area by the building standards) 2 ☐ Good Enough (required area) 3 ☐ Not Good (less than the required area) 4 ☐ Inadequate (no openings)
Levels of perceived natural light	c02	1 ☐ Very Good (proper building orientation, with enough lighting) 2 ☐ Good Enough 3 ☐ Not Good 4 ☐ Inadequate (no light received throughout the year)
Type of roofing used	c03	1 ☐ Flat roof 2 ☐ Gable roof 3 ☐ Hip roof Roof angle:_____^{0}
Roof overhang	c04	1 ☐ No overhang (0 -300 mm) 2 ☐ 300 – 1000 mm overhang 3 ☐ Overhang by way of verandas
Use of small-scale solar panels and/or collectors	c05	1 ☐ Available (Name) _____ 2 ☐ Not available
Materials used: Walls	c06	1 ☐ Concrete Blocks/cement
		2 ☐ Compressed earth blocks 3 ☐ Timber 4 ☐ Corrugated Iron 5 ☐ Stick and mud 6 ☐ Other (specify) _____

Roofing	c07	1 ☐ IBR roof sheets 2 ☐ Corrugated iron sheets 3 ☐ Thatch 4 ☐ Tiles/Asbestos 5 ☐ Other (specify) _____
Flooring	c08	1 ☐ Concrete slab/cement 2 ☐ Wood 3 ☐ Compressed earth 4 ☐ Other (specify) _____
Window frames	c09	1 ☐ Wooden 2 ☐ Steel 3 ☐ Vinyl 4 ☐ Other _____
Energy source	c10	1 ☐ Solar panels/passive 2 ☐ Coal 3 ☐ Petroleum/ gas 4 ☐ Water 5 ☐ Wood 6 ☐ Other (specify) _____
Condition of waste water drainage system	c11	1 ☐ Very good (good condition - drains to french drain or public sewer. Grey water re-use) 2 ☐ Good enough (septic tank) 3 ☐ Not good (available but faulty - leaking) 4 ☐ Not available If not available water is disposed _____
Signs of incremental growth	c12	1 ☐ Yes Space available _____m^2 3 ☐ No (Reason) _____

Physical condition of the house (including maintenance)	c13	1 ☐ Very good (Strong structure & proper maintenance) 2 ☐ Good 3 ☐ Moderate 4 ☐ Bad 5 ☐ Very bad (Failing structure, no maintenance)
Signs of demolition	c14	1 ☐ Yes (evidence) _____ 2 ☐ No
On-site waste	c15	1 ☐ Yes Type of waste _____ _____ 2 ☐ No

OBSERVATION CHECKLIST

(SETTLEMENT PLANNING & ENVIRONMENTAL CONDITION)

(Map & pictures attached to this checklist)

DATE:_____

D. Settlement planning		
Total area of neighbourhood Total built area Densification	TAN TBA DT	_____m^2 _____m^2 , _____% _____Houses/Ha
Availability of a public sewer	d01	1 ☐ Available 2 ☐ Not available
Availability of drainage channels along streets	d02	1 ☐ Available 2 ☐ Not available
Condition of roads	d03	1 ☐ Very Good (Tarred road) 2 ☐ Good Enough (Gravel road properly maintained) 3 ☐ Not good (Gravel or tarred road with signs of erosion) 4 ☐ Bad (gravel road with dongas on the sides)
Condition of movement	D04	1 ☐ Very good (Roadways, footways & cycle-ways) 2 ☐ Good enough (Roadways & footways) 3 ☐ Not good (Roadways only) 4 ☐ Bad (no official roadways & footpaths)
Movement network type	D05	1 ☐ Rectilinear multidirectional 2 ☐ Distorted rectilinear multidirectional 3 ☐ Radial multidirectional 4 ☐ Looped hierarchical 5 ☐ Branched hierarchical
Main water source	d06	1 ☐ Public water system – for every house (from Swaziland Water Services Co-operation) 2 ☐ Shared water supply from SWSC 3 ☐ Water from wells and river streams
Electricity supply (SEC)	d07	1 ☐ Available 2 ☐ Not available
Diversity of plots & movement routes	d08	1 ☐ Diversity exists Plot sizes range:_____ Average: _____m^2

		2 ☐ No diversity
Types of buildings in the neighbourhood	d09	1 ☐ Residential only 2 ☐ Mixed development (religious, cultural, educational, residential)
Soft open spaces (open or unbuilt spaces within the neighbourhood, with a predominantly vegetated or porous surfaces)	d10	1 ☐ Exist Total Area_____m^2 Location _____ 2 ☐ Do not exist
Type of transport observed	D11	1 ☐ Public transport 2 ☐ Private cars 3 ☐ Bicycles 4 ☐ Other _____
E. Environmental condition		
Land/soil condition	e-01	1 ☐ Gullies along roads
		2 ☐ Signs of loss of vegetation 3 ☐ Deposit of silt in low-lying areas 4 ☐ Potholes on roads 5 ☐ Other observations _____ 6 ☐ Land/soil in good condition (No signs of erosion)
Air Condition	e02	1 ☐ Polluted air (signs of smoke) Source:_____ 2 ☐ Clean air (no signs of smoke in or near the study area)
Water Condition	e03	1 ☐ Signs of dead fish in rivers 2 ☐ Visual discoloured water 3 ☐ Form in water 4 ☐ Visual litter on water surface 5 ☐ Unpleasant odour from lakes, rivers 6 ☐ Other observations _____ 7 ☐ No signs of water pollution
Wetlands	e04 e04a	1 ☐ Exist If they exist, answer the following: Total area_____m^2 Condition a. ☐ Preserved b. ☐ Not preserved 2 ☐ No signs of wetlands
Biodiversity & Wildlife	e05	1 ☐ Signs of dead fish and other water creatures 2 ☐ Signs of deforestation (cut trees, evidence of uncontrolled fire, other) _____

		3 ☐ No sign of birds (bird nests) 4 ☐ Signs of biodiversity observed Evidence _____ _____ _____ Other observations _____
Vegetation cover condition	e06	1 ☐ Signs of uncontrolled fire 2 ☐ Signs of Agriculture practice Area_____m^2 3 ☐ Availability of green area Area _____m^2 4 ☐ Other observations
Littering (land pollution) -landfills	e07	1 ☐ Floating litter on water surface 2 ☐ Litter on streets and around dumpsites 3 ☐ No litter observed 4 ☐ Other observations _____
Noise pollution	e08	1 ☐ Noise observed Source _____ 2 ☐ Non observed 3 ☐ Other observations _____
Disposal sites	e09	1 ☐ Available Condition _____ _____ 2 ☐ Not available
Signs of food production	e10	1 ☐ Agricultural practices Evidence _____ _____ Area _____m^2 2 ☐ No signs of food production

Appendix D – Results from observation study of construction practices

			Msunduza	Mahwalala	Nkwalini	Mean
A. General Information						
Total area	-	-	143 hectors	227.6 hectors	74.4 hectors	
Total built area	-	-	118 hectors (82%)	118.7 hectors (52.2%)	33.8 hectors (45.4%)	
Densification	-	-	12.6 houses/hector	7.9 houses/hector	10 houses/hector	
Number of plots	-	-	1828	1700	800	
Plot sizes		0 – 400 sqm 401 – 1000 sqm 1000 sqm & above	41.7% 56.6% 1.7%	28% 68% 4%	3.3% 90% 6.7%	24.3% 71.6% 4.1%
Type of houses		Free standing Semi detached Row houses	83.3% 1.7% 15%	68% 0% 32%	66.7% 0% 33.3%	72.7% 0.57% 26.8%
House areas		9 – 100 sqm 100 sqm & above	60% 40%	62% 38%	70% 30%	64% 36%
Number of storeys		1 storey 2 storeys	100% 0%	100% 0%	100% 0%	100% 0%
B. Building Infrastructure						
Energy	**Natural Ventilation**	Good Not good	45% 55%	68% 32%	60% 40%	58% 42%
	Natural Lighting	Good Not good	45% 55%	64% 36%	53.3% 46.7%	54.1% 45.9%
	Small scale solar panels	Available Not Available	3.3% 96.7%	2% 98%	3.3% 96.7%	2.9% 97.1%
	Energy source	Electricity Wood	75% 25%	74% 26%	86.7% 13.3%	78.6% 21.4%
	Roof overhang	No overhang Proper overhang	63.3% 36.7%	48% 52%	40% 60%	50.4% 49.6%

Materials	**Wall**	Concrete blocks Compressed earth Timber Corrugated iron Stick and mud	65% 10% 1.7% 1.7% 21.7%	54% 16% 0% 0% 30%	76.7% 10% 0% 0% 13.3%	65.2% 12% 0.6% 0.6% 21.7%
	Roof	IBR Corrugated iron Tiles (Harvey)	10% 85% 5%	26% 60% 14%	40% 53.3% 6.7%	25.3% 66.1% 8.6%
	Floor	Concrete slab Compressed earth	100% 0%	92% 8%	96.7% 3.3%	96.2% 3.8%
	Window frames	Wooden Steel Aluminium	1,7% 98.3% 0%	0% 94% 6%	3.3% 96.7% 3.3%	1.7% 96.3% 3.1%
Waste Management	**Waste water drainage**	Good Not good Not available	43.3% 15% 41.7%	58% 4% 38%	56.7% 0% 43.3%	52.7% 6.3% 41%
	On site waste	Yes No	51.7% 48.3%	50% 50%	36.7% 63.3%	46.1% 53.9%
	Waste type	Litter Building Material	83.3% 16.7%	36% 64%	27.3% 72.7%	48.9% 51.1%
C. Settlement Planning						
Waste Management	**Public sewer**	Available Not available	Available	Not available	Not available	
	Solid waste	Type	Waste bins Recycle centre	Waste bins	Waste bins	
	Drainage channels	Exist Not available	One sided only on tarred roads	One side only on tarred roads	One side only on tarred roads	
Land Use	**Function**	Residential only Mixed land use	Mixed land use	Mixed land use	Mixed land use	
	Soft open spaces	Available Not available	Available	Available	Available	

Diversity	**Plots**	Exist Don't exist	Less diversity 200 – 600 sqm	Less diversity 200 – 600 sqm	Less diversity 200 – 600 sqm
	Movement	Exist Don't exist	No diversity	No diversity	No diversity
Movement/Transportation	**Movement condition**	Good Not good	Not good	Not good	Not good
	Roads condition	Good Not good	Not good	Not good	Not good
	Network type	Rectilinear multidirectional Radial multi directional Looped hierarchical	Looped hierarchical	Looped hierarchical	Looped hierarchical
	Transport type	Public transport Private cars Bicycles	Public transport	Public transport Private cars	Public transport Private cars
Services	**Water source**	Public water system Shared water supply Wells and river streams	Public water system (not accessible to all)	Public water system and Public water supply (not accessible to all)	Public water system (not accessible to all)
	Electricity	Available Not available	Available but not accessible to all	Available but not accessible to all	Available but not accessible to all

Appendix E – Results for settlement planning and environmental condition

OBSERVATION CHECKLIST (MSUNDUZA)

(Map & pictures attached to this checklist)

DATE:_____

F. Settlement planning	
Total area of neighbourhood Total built area Densification	143 Ha 118 Ha , 82% 12.6 Houses/Ha
Availability of a public sewer	1 ☒ Available 2 ☐ Not available
Availability of drainage channels along streets	1 ☒ Available (single sided along tarred roads only) 2 ☐ Not available
Condition of roads	1 ☐ Very Good (Tarred road) 2 ☐ Good Enough (Gravel road properly maintained) 3 ☒ Not good (Gravel or tarred road with signs of erosion) 4 ☐ Bad (gravel road with dongas on the sides)
Condition of movement	1 ☐ Very good (Roadways, footways & cycle-ways) 2 ☐ Good enough (Roadways & footways) 3 ☒ Not good (Roadways only) 4 ☐ Bad (no official roadways & footpaths)
Movement network type	1 ☐ Rectilinear multidirectional 2 ☐ Distorted rectilinear multidirectional 3 ☐ Radial multidirectional 4 ☒ Looped hierarchical 5 ☐ Branched hierarchical
Main water source	1 ☒ Public water system (from Swaziland Water Services Co-operation) 2 ☐ Shared water supply from SWSC 3 ☐ Water from wells and river streams
Electricity supply (SEC)	1 ☒ Available (Worth noting that some houses are not connected to the system. Affordability?) 2 ☐ Not available
Diversity of plots & movement routes	1 ☒ Diversity exists Plot sizes range: 200 – 1000 m^2 Average: 500 m^2 2 ☐ No diversity
Types of buildings in the neighbourhood	1 ☐ Residential only 2 ☒ Mixed development (religious, cultural, educational, residential) (noted that about 95% of the area is for residential use)
Soft open spaces (open or unbuilt spaces within the neighbourhood, with a	1 ☒ Exist Total Area 25.7 Ha (18%)

predominantly vegetated or porous surfaces)	Location Escarpments 2 ☐ Do not exist
Type of transport observed	1 ☒ Public transport 2 ☐ Private cars 3 ☐ Bicycles 4 ☐ Other
G. Environmental condition	
Land/soil condition	1 ☒ Gullies along roads 2 ☒ Signs of loss of vegetation 3 ☐ Deposit of silt in low-lying areas 4 ☒ Potholes on roads 5 ☒ Other observations Saturated with lightweight litter 6 ☐ Land/soil in good condition (No signs of erosion)
Air Condition	1 ☒ Polluted air (signs of smoke) Source: Minor from welding processes within the settlement 2 ☐ Clean air (no signs of smoke in or near the study area)
Water Condition	1 ☐ Signs of dead fish in rivers 2 ☐ Visual discoloured water 3 ☐ Form in water 4 ☒ Visual litter on water surface 5 ☐ Unpleasant odour from lakes, rivers 6 ☐ Other observations 7 ☐ No signs of water pollution
Wetlands	1 ☐ Exist If they exist, answer the following: Total area_____m^2 Condition c. ☐ Preserved d. ☐ Not preserved 2 ☒ No signs of wetlands
Biodiversity & Wildlife	1 ☐ Signs of dead fish and other water creatures 2 ☒ Signs of deforestation (cut trees, evidence of uncontrolled fire, other) 3 ☐ No sign of birds (bird nests) 4 ☒ Signs of biodiversity observed Evidence Only assumed with the existence of soft spaces which are threatened Other observations
Vegetation cover condition	1 ☐ Signs of uncontrolled fire

	2 ☐ Signs of Agriculture practice Area_____m^2 3 ☒ Availability of green area Threatened! 4 ☐ Other observations
Littering (land pollution) -landfills	1 ☒ Floating litter on water surface 2 ☒ Litter on streets and around dumpsites 3 ☐ No litter observed 4 ☐ Other observations
Noise pollution	1 ☒ Noise observed Source Mbabane industrial site (minor) 2 ☐ Non observed 3 ☐ Other observations
Disposal sites	1 ☒ Available Condition Waste bins along roads in an acceptable condition 2 ☐ Not available
Signs of food production	1 ☐ Agricultural practices Evidence _____ Area _____m^2 2 ☒ No signs of food production

OBSERVATION CHECKLIST (MAHWALALA)

(Map & pictures attached to this checklist)

DATE:_____

H. Settlement planning	
Total area of neighbourhood Total built area Densification	227.6 Ha 118.7 Ha , 52% 7.9 Houses/Ha
Availability of a public sewer	1 ☐ Available 2 ☒ Not available
Availability of drainage channels along streets	1 ☒ Available (single sided along tarred roads only) 2 ☐ Not available
Condition of roads	1 ☐ Very Good (Tarred road) 2 ☐ Good Enough (Gravel road properly maintained) 3 ☒ Not good (Gravel or tarred road with signs of erosion) 4 ☒ Bad (gravel road with gullies on the sides)
Condition of movement	1 ☐ Very good (Roadways, footways & cycle-ways) 2 ☐ Good enough (Roadways & footways) 3 ☒ Not good (Roadways only) 4 ☐ Bad (no official roadways & footpaths)
Movement network type	1 ☐ Rectilinear multidirectional 2 ☐ Distorted rectilinear multidirectional 3 ☐ Radial multidirectional 4 ☒ Looped hierarchical 5 ☐ Branched hierarchical
Main water source	1 ☒ Public water system (from Swaziland Water Services Co-operation) (Some houses are not connected to the system) 2 ☒ Shared water supply from SWSC 3 ☐ Water from wells and river streams
Electricity supply (SEC)	1 ☒ Available (some houses are not connected to the system) 2 ☐ Not available
Diversity of plots & movement routes	1 ☒ Diversity exists Plot sizes range: 200 – 1000 m^2 Average: 500 m^2 2 ☐ No diversity
Types of buildings in the neighbourhood	1 ☐ Residential only 2 ☒ Mixed development (religious, cultural, educational, residential) (main function is residential)
Soft open spaces (open or unbuilt spaces within the neighbourhood, with a predominantly vegetated or porous surfaces)	1 ☒ Exist Total Area 108.9 Ha (48%) Location Escarpments 2 ☐ Do not exist

Type of transport observed	1 ☒ Public transport 2 ☒ Private cars 3 ☐ Bicycles 4 ☐ Other
I. Environmental condition	
Land/soil condition	1 ☒ Gullies along roads 2 ☒ Signs of loss of vegetation 3 ☐ Deposit of silt in low-lying areas 4 ☒ Potholes on roads 5 ☒ Other observations Litter along roads 6 ☐ Land/soil in good condition (No signs of erosion)
Air Condition	1 ☒ Polluted air (signs of smoke) Source: Uncontrolled grass fires 2 ☐ Clean air (no signs of smoke in or near the study area)
Water Condition	1 ☐ Signs of dead fish in rivers 2 ☐ Visual discoloured water 3 ☐ Form in water 4 ☒ Visual litter on water surface 5 ☐ Unpleasant odour from lakes, rivers 6 ☐ Other observations 7 ☐ No signs of water pollution
Wetlands	1 ☐ Exist If they exist, answer the following: Total area_____m^2 Condition e. ☐ Preserved f. ☐ Not preserved 2 ☒ No signs of wetlands
Biodiversity & Wildlife	1 ☐ Signs of dead fish and other water creatures 2 ☒ Signs of deforestation (cut trees, evidence of uncontrolled fire, other) 3 ☐ No sign of birds (bird nests) 4 ☒ Signs of biodiversity observed Evidence Only assumed with the existence of soft spaces which are threatened Other observations Construction occurring at a high rate which kills the habitats
Vegetation cover condition	1 ☒ Signs of uncontrolled fire 2 ☐ Signs of Agriculture practice Area_____m^2

	3 ☒ Availability of green area Threatened! 4 ☐ Other observations
Littering (land pollution) -landfills	1 ☒ Floating litter on water surface 2 ☒ Litter on streets and around dumpsites 3 ☐ No litter observed 4 ☐ Other observations
Noise pollution	1 ☐ Noise observed Source _____ 2 ☐ Non observed 3 ☒ Other observations
Disposal sites	1 ☒ Available Condition Waste bins along roads in an acceptable condition 2 ☐ Not available
Signs of food production	1 ☐ Agricultural practices Evidence _____ Area _____m^2 2 ☒ No signs of food production

OBSERVATION CHECKLIST (NKWALINI)

(Map & pictures attached to this checklist)

DATE:_____

J. Settlement planning	
Total area of neighbourhood Total built area Densification	74.4 Ha 33.8 Ha , 45% 10 Houses/Ha
Availability of a public sewer	1 ☐ Available 2 ☒ Not available
Availability of drainage channels along streets	1 ☒ Available (single sided along tarred roads only) 2 ☐ Not available
Condition of roads	1 ☐ Very Good (Tarred road) 2 ☐ Good Enough (Gravel road properly maintained) 3 ☒ Not good (Gravel or tarred road with signs of erosion) 4 ☐ Bad (gravel road with dongas on the sides)
Condition of movement	1 ☐ Very good (Roadways, footways & cycle-ways) 2 ☐ Good enough (Roadways & footways) 3 ☒ Not good (Roadways only) 4 ☐ Bad (no official roadways & footpaths)
Movement network type	1 ☐ Rectilinear multidirectional 2 ☐ Distorted rectilinear multidirectional 3 ☐ Radial multidirectional 4 ☒ Looped hierarchical 5 ☐ Branched hierarchical
Main water source	1 ☒ Public water system (from Swaziland Water Services Co-operation) 2 ☐ Shared water supply from SWSC 3 ☐ Water from wells and river streams
Electricity supply (SEC)	1 ☒ Available (some houses are not connected to the system) 2 ☐ Not available
Diversity of plots & movement routes	1 ☒ Diversity exists Plot sizes range: 200 – 1000 m^2 Average: 500 m^2 2 ☐ No diversity
Types of buildings in the neighbourhood	1 ☐ Residential only 2 ☒ Mixed development (religious, cultural, educational, residential) – Nkwalini primary school, Swaziland Christian University, shops (main function is residential use)
Soft open spaces (open or unbuilt spaces within the neighbourhood, with a predominantly vegetated or porous	1 ☒ Exist Total Area 40.6 Ha (54.6%) Location Escarpments

surfaces)	2 ☐ Do not exist
Type of transport observed	1 ☒ Public transport 2 ☒ Private cars 3 ☐ Bicycles 4 ☐ Other
K. Environmental condition	
Land/soil condition	1 ☒ Gullies along roads 2 ☒ Signs of loss of vegetation 3 ☐ Deposit of silt in low-lying areas 4 ☒ Potholes on roads 5 ☒ Other observations Lightweight litter along roads and around waste bins 6 ☐ Land/soil in good condition (No signs of erosion)
Air Condition	1 ☒ Polluted air (signs of smoke) Source: May only be from vehicles and uncontrolled fires 2 ☐ Clean air (no signs of smoke in or near the study area)
Water Condition	1 ☐ Signs of dead fish in rivers 2 ☐ Visual discoloured water 3 ☐ Form in water 4 ☒ Visual litter on water surface 5 ☐ Unpleasant odour from lakes, rivers 6 ☐ Other observations 7 ☐ No signs of water pollution
Wetlands	1 ☐ Exist If they exist, answer the following: Total area_____m^2 Condition g. ☐ Preserved h. ☐ Not preserved 2 ☒ No signs of wetlands
Biodiversity & Wildlife	1 ☐ Signs of dead fish and other water creatures 2 ☒ Signs of deforestation (cut trees, evidence of uncontrolled fire, other) 3 ☐ No sign of birds (bird nests) 4 ☒ Signs of biodiversity observed Evidence Asssumed with the existence of soft spaces (54.6%) Other observations
Vegetation cover condition	1 ☒ Signs of uncontrolled fire 2 ☐ Signs of Agriculture practice Area_____m^2 3 ☒ Availability of green area Threatened!

	4 ☐ Other observations
Littering (land pollution) -landfills	1 ☒ Floating litter on water surface 2 ☒ Litter on streets and around dumpsites 3 ☐ No litter observed 4 ☐ Other observations
Noise pollution	1 ☐ Noise observed Source _____ 2 ☒ Non observed 3 ☐ Other observations
Disposal sites	1 ☒ Available Condition Waste bins along roads in an acceptable condition 2 ☐ Not available
Signs of food production	1 ☐ Agricultural practices Evidence _____ Area _____m^2 2 ☒ No signs of food production