THESIS 2021

BUILDING A FRAMEWORK FOR THE SUSTAINABLE AFRICAN CITY OF THE FUTURE

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Abstract

The increase in rural to urban migration rates have resulted in the rapid urbanization and uncontrolled growth of modern day cities. This trend is expected to continue in the coming years, thereby increasing the demand for goods and services. Current operational methods in Africa involve old and outdated approaches, which have further exacerbated the challenges faced by cities. Continued operation in this manner will have negative long-term consequences such as climate change, environmental damage, and overconsumption of resources, ultimately decreasing the quality of life for citizens. These effects are particularly predominant in Africa, which despite being the least developed continent, is experiencing the highest rate of urbanization. This research looks at the implementation of the concept of sustainable cities in the African context, based on the main pillars of sustainability.

Currently, cities around the world are incorporating sustainable measures to design their frameworks, using different methods which are dependent on factors such as locality and available resources. In this research, these methods were generalised to two main approaches applicable in the developed and developing countries' contexts, namely the Smart and Symbio City concepts respectively. The use of Sustainability Indicators was applicable to both contexts, and was used to identify areas of concern with respect to the African context, specifically to the city of Durban. The indicators were derived from literature, case studies' assessment and field research. The comparison between the Smart and Symbio City concepts was complemented by the assessment of case studies of two cities through field analysis, namely Durban in South Africa and Trento in Italy. The Symbio City concept was found to be more applicable to the developing countries' context, therefore suitable for Durban. A method of evaluation was devised to guide in making informed decisions in defining short and long-term actions necessary for implementing a sustainable framework for African cities.

Preface

I, the undersigned, fully understand the concept of plagiarism, together with the implications thereafter.

I accept that:

I. All work presented in this report is that of my own;
II. All works obtained from external references have been correctly referenced;
III. The results obtained are that of my own work and have not been plagiarised from any source;
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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BEI – Baseline Emission Inventory

CBD – Central Business District

CCTV – Closed Circuit Television

CiM – Cities in Motion

CO_2 – Carbon Dioxide

CPI – City Prosperity Index

DUT – Durban University of Technology

EIA – Environmental impact Assessment

EU SDS – European Union Sustainable Development Strategy

GDP – Gross Domestic Product

GHG – Green House Gas

GPCI – Global Power City Index

ICC – International Convention Centre

ICT – Information and Communications Technology

IEEE – Institute of Electrical and Electronic Engineers

IDP – Integrated Development Plan

IRT – Integrated Rapid Transport

IRPTN – Integrated Rapid Public Transport Network

IoT – Internet of Things

IT – Information Technology

ITS – Intelligent Transport System

LBS – Location Based Services

LED – Light Emitting Diode

MCCP – Municipal Climate Protection Programme

MUT – Mangosuthu University of Technology

PV – Photo Voltaic

RDP – Reconstruction and Development Programme

SAPS – South African Police Service

SCI – Sustainable Cities Index

SDG – Sustainable Development Goals

SEA – Strategic Environmental Assessment

SEAP – Sustainable Energy Action Plan

SMART – Specific, Measurable, Achievable, Realistic and Timed

SMART – Strategy, Multidisciplinary, Appropriation, Roadmap, Technology

SWOT – Strengths, Weaknesses, Opportunities and Threats

UKZN – University of KwaZulu-Natal

UN – United Nations

UNCSD – United Nations' Commission on Sustainable Development

WDI – World Development Indicators

WHO – World Health Organisation

WFD – Water Framework Directive

WWTP – Waste Water Treatment Plant

1 Introduction

This research presents a study in the development and implementation of sustainable cities in an African context. It was motivated by the need for African cities to develop sustainable frameworks that can be used to guide decision making processes for municipalities. Current frameworks in use were devised by developed countries and are mostly applicable to their context. In order to solve urban challenges in Africa, it is imperative that a framework tailored towards an African environment is developed. This research analysed current urban challenges affecting modern day cities, together with solutions that are being implemented to resolve these challenges. Different approaches were considered in the context of a developed and developing country, namely the Smart and Symbio City approaches. A general framework was created using sustainability indicators as the main building blocks of a sustainable African city. The indicators were developed for the city of Durban, which is an example of an African city that has made great strides towards achieving sustainability. The following section presents the background of this research in order to give an insight based on challenges encountered by African cities.

1.1 Background

The migration of people in search of better jobs, education and opportunities for improved livelihood has increased population in cities. This has resulted in rapid urbanisation, which is expected to continue in the coming decades (Monfaredzadeh and Berardi, 2014). Cities in Africa are particularly experiencing the highest rates of urbanisation in the world due to the majority of the countries' populations still residing in rural areas. In 2007, the continent reached a tipping point when the urban population surpassed the rural population for the first time (Siemens, 2011). Wars and political conflicts are still common on some parts of the continent, forcing inhabitants to seek refuge in 'safer' urban areas. On average, 70 000 people migrate to cities on a daily basis in Africa (Ranhagen and Groth, 2012). This mass movement to cities has led to a rise in the demand for basic needs and services in cities. Most of the immigrants are usually unemployed and lack adequate shelter. They end up residing in slums, which have now conglomerated to create informal settlements (UN-Habitat, 2016k). These settlements are usually not part of cities' development plans; hence they lack basic services, experience overcrowding and are inhospitable. Local authorities in most African cities are struggling to devise and implement viable solutions as they have simply imported methods from developed countries, whose use is limited in Africa. The challenges faced in Africa are more complex and required a more holistic approach to resolving them efficiently (Bolis et al., 2017).

The increased worldwide consumption of natural resources by cities to meet the rising demands for services is now a global concern. Unsustainable resource consumption and waste generation is threatening ecosystems and biodiversity in cities. These conditions are particularly evident in

developing countries, where most municipalities do not have adequate environmental and waste management strategies in place. In most informal settlements, rubbish dumps are in the vicinity of houses. This poses health risks and leads to the pollution of soil, water sources and the surrounding environment (Emenda and Vilas, 2010). Rapid urbanisation has also raised the demand for transportation of goods and services essential for daily operation of cities and their citizens. More vehicles on the road result in congestion, increase the risk of traffic accidents and affect mobility within and around the city. The combustion of more fossil fuels due to vehicle increase pollutes the atmosphere through the emission of greenhouse gases and particulate matter. Particulate matter in the air has been known to cause respiratory diseases, while greenhouse gases cause climate change which has a negative impact the environment and ultimately the future of cities (Ranhagen and Groth, 2012). Prolonged dry spells and extreme weather events are occurring, threatening food security and destroying infrastructure. The recovery processes require intensive human and material resources, and most cities in developing countries are not fully equipped to deal with these sudden occurrences.

Infrastructural development to cater for the growing population and rapid urbanisation is not complementing the spatial growth of cities. Rather, some of these developments are destroying green areas and biodiversity as they are not carried out in accordance with environmental laws (UN-Habitat, 2016k). Most municipalities in developing countries lack the adequate resources to mitigate the uncontrolled growth of cities beyond serviceable boundaries. Despite the high rates of migration, urban infrastructure has not improved. This has resulted in inhospitable conditions in cities, coupled with minimal or no municipal service. In Africa, there are more profound social and economic disparities because of history, which resulted in an imbalance in service provision among different settlements. Service delivery protests are now frequent due to these imbalances, which have divided communities, causing social unrest. This is particular among the unemployed urban youth in informal settlements (UN-Habitat, 2009). South Africa is one of the countries being affected by such social disparities, and efforts to mitigate the effects of these differences have not been effective. There have been cases of foreign immigrants being attacked due to increased competition over limited resources, destabilising the social and economic strata. Failure to address these issues, particularly service delivery and environmental management, will have irreversible long-term consequences for municipalities and citizens. The implementation of sustainable developmental methods must become a priority for current governments, particularly in African countries where the challenges are more complex (UN-Habitat, 2014).

Various frameworks to curb the effects of urbanisation have been devised and implemented mainly by cities in developed countries. These frameworks have been developed in conjunction with organisations such as the European Union, United Nations, World Bank, private companies and Municipalities (EU, 2015). Most cities in developing countries also adopted these methods

upon attaining independence. These development models have not been effective as most African cities have not attained the goals they have set forth. There are, therefore, no defined frameworks and older methods of planning have persisted. These planning systems are exacerbating urban challenges rather than solving them. The systems are not adapting quickly enough to the rapid effects of population increase, infrastructural requirements and climate change. There is also a lack of proper systems to monitor and evaluate progress, therefore it is difficult to analyse current trends and gauge progress towards sustainability (UN-Habitat, 2009). Unless changes and transformations occur to the current methods, these challenges will become more complex and impossible to resolve. This will negatively affect the environment, economic, social and political aspects, and ultimately the quality of life for citizens.

Although there are common global challenges in cities such as climate change and environmental damage, cities employ different developmental models. These depend on various factors and they outline policies and strategies which are suited to a particular locality. Cities in Africa face a wider spectrum of challenges as compared to their European counterparts, hence the systems devised to address the challenges must cover a wider range of aspects. The level of development in Africa, however, presents a unique opportunity in the implementation of new urban paradigms (UN-Habitat, 2009). Cheaper alternative solutions must be sought due to the limited resources and inadequate funding, which can curtail efforts to improve cities. Solutions to African urban challenges must address more basic issues such as poverty, service provision, food security and social unrest (UN-Habitat, 2017). Cities are potential hubs of change which provide opportunities for prosperity and improved livelihoods through job creation and better services (Bolis et al., 2017). Africa is still and emerging continent commercially and politically, with vast potential to improve citizen welfare and generate wealth. The widespread of informality, from settlements to businesses, distinguishes the African environment as these aspects must be incorporated and regulated by the system. This can be achieved through efficient management systems focussed on human capital and available resources. Cooperation among stakeholders in the city ensures a multi-disciplinary approach to addressing challenges while enhancing knowledge sharing (UN-Habitat, 2016k). This creates balanced solutions which address all the potential issues in a balanced manner.

A framework that is unique to and accommodative of conditions in cities in developing countries must be devised and implemented (Ranhagen and Groth, 2012). This framework should be modelled around the main pillars of sustainability, consisting of the environmental, social and economic dimensions. It should be focussed on citizens, with particular attention towards the most vulnerable citizens which include women, children, the elderly and disabled (UN-Habitat, 2009). Synergy between different sectors is important as they usually have direct influence on each other. This also enables effective systems to be put in place to improve lives of citizens, the environment,

and in curbing climate change. This includes the use of green sources for energy production and transportation to reduce greenhouse gas emissions (Monfaredzadeh and Berardi, 2014). Most modern-day cities were designed around private motorised modes of transport. This has affected mobility within cities, particularly the urban poor who cannot afford private transport. Spatial growth of cities has also resulted in longer travel distances, increasing emissions. The location of poor settlements in Africa was largely due to colonial systems that were in place during the development of cities. A sustainable transport system must therefore be implemented to improve accessibility, ease traffic congestion and improve safety (UN-Habitat, 2013).

The above-mentioned issues are a general overview of the many challenges faced by cities, particularly those in developing countries. Their governments and municipal authorities have not devised effective solutions to deal with these challenges (UN-Habitat, 2016k). This research, therefore, seeks to develop the first stages in the development of a framework for a sustainable city in an African context. It also seeks to bridge the gap between research that has been carried out on sustainable cities in developed countries and that for developing countries. It will also outline different developmental methods applicable to the developed and developing countries' contexts, which will enable a direct comparison to find out what can be adapted to suit to African cities. Developed countries' models mainly focus on improving the efficiency of already existing services and infrastructure. Developing countries are starting from a lower level, which entails the provision of basic human needs and rights to their citizens. Aspects such as history and socio-cultural differences among communities must be considered, with comprehensive frameworks aimed at improving current living standards.

1.2 Problem Statement

Cities in developed countries have developed sustainable frameworks to deal with current urban challenges. Most frameworks for cities in developing countries, however, are not fully suited to solving the multi-dimensional challenges that come with rapid changes being experienced in the developing world. This is particularly evident in Africa, where lack of resources has hindered the improvement of living and operating conditions in cities. The African continent has the highest rate of urbanisation with the least resources, therefore frameworks developed must address these unique challenges. The existing frameworks devised by more developed countries can be used as a guide which must then be tailored to suit African cities, and not just replicated.

1.3 Research Question

How can African cities develop a sustainable framework suited to their context instead of just importing and replicating frameworks used in developed countries?

1.4 Aims and Objectives

1.4.1 Aims

To develop a methodological process for a sustainable city using a framework of indicators for a typical African city, based on the main pillars of sustainability.

1.4.2 Objectives

- To analyse the current situation and challenges faced by African cities
- To review the concept of sustainable cities from a developed and developing country's point of view and determine the suitable approach for a typical African city.
- To conduct case studies through field research in a developed and developing country in order to investigate the applicability of current approaches to sustainable cities.
- To obtain and evaluate sustainability indicators as methods of measuring the performance of cities to devise a framework for the city of Durban.

1.5 Methodology

The methodology for this research began with a critical analysis of the literature review. The first part of the review presented an in-depth overview of the current urban challenges. This enabled the identification of critical areas where urban challenges are more profound. These challenges were categorised in order to break them down into more specific and smaller sectors. Thereafter, mitigation measures that were proposed by authorities around the world, particularly at conferences focussed on the sustainable development of cities were reviewed. They focused on different aspects such as climate change, environmental sustainability and the development of infrastructure. These measures were reviewed in order to gain an understanding of the proposed developmental methods in a worldwide context. Most of these solutions to sustainable development were devised by international bodies such as the United Nations, European Union, and the World Bank, just to name a few. Agreements such as the Kyoto Protocol (1997), the Millennium Declaration (2000), and the Paris Agreement (2016), are a few of the many examples that were developed as global initiatives towards sustainable development.

From the mitigation measures, the concept of sustainable cities was introduced as the overall concept in addressing urban issues. This was in line with the proposed solutions to current urban challenges and could be used to guide cities in the measures they can implement to improve sustainability However, due to the differences in the way cities operate, the locality, and available

resources, different methods are implemented. This formed the next stage of the methodology, whereby the overall concept of sustainable cities was reviewed between two different standpoints, which were from the developing and developed countries' contexts. The concept of Smart Cities was tied to the developed countries, while the Symbio city concept was proposed for developing countries. A comparative analysis was done to identify the similarities and differences in the applicability of these concepts relative to the contexts of either a developed or developing country.

In order to develop the framework, Sustainability Indicators were used as the fundamental building blocks, influenced by the literature review. These indicators were chosen from a worldwide perspective, using literature developed by various world organisations. The rationale for each indicator was supported by reference of relevant literature.

From these indicators, data outlining conditions in the city of Durban was collected and statistically analysed to summarise these conditions. A comparative case study between a typical city in a developed country (Trento, Italy) and a city in a developing country (Durban, South Africa) was then conducted to compare the different contexts of sustainability. This resulted in the derivation of sustainability indicators for the city of Durban. An implementation plan was outlined, which showing how the indicators could be integrated in the development of the city, beginning with a pilot project. Figure 1-1 shows a flowchart for the methodology adopted in this research.

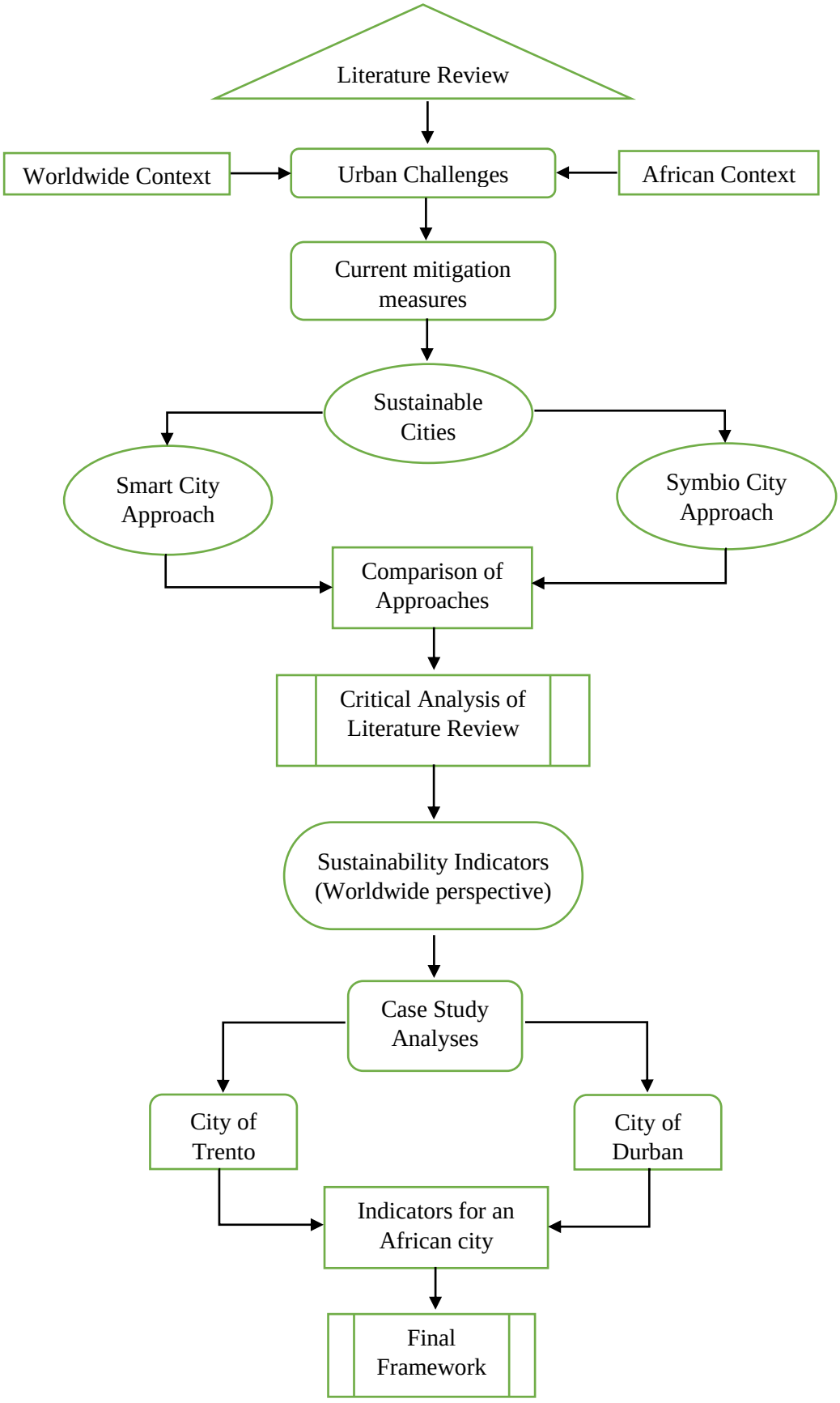

Figure 1-1. Methodological Framework

The need for sustainable frameworks for cities in Africa is of paramount importance as the continent faces more basic and urgent challenges. Since there has been no set development models for cities in developing countries, this research will help to identify challenges that are peculiar to Africa. Mitigation measures that have been proposed to curb these challenges are mostly tailored towards cities in developed countries, where comprehensive frameworks have been devised. This has left cities in developing countries without adequate frameworks that are suited to their context, considering differences in the environment and other factors such as resource availability and culture. This research will emphasize and identify issues affecting Africa and suggest methods in which these challenges can be effectively addressed, particularly in decision making processes in municipalities. The research will investigate the first stages in developing a sustainable city framework in the African context, considering the different aspects that make up the city ecosystem.

1.6 Limitations and Assumptions

The main challenge was the availability of consistent data due to the wide research spectrum in the thesis. Some indicators did not have reliable data and had to be excluded from the framework and they would mislead the outcome. Methods of evaluating indicators were either too simplified or too broad to be applicable to a specific context. Some of the methods were too complicated and required complex data computations. These methods would not be effective in portraying the reality of the situation on the ground. This research was also conducted using a top-down approach as there was minimal input from stakeholders such as public citizens.

1.7 Summary

Statistics have shown that an average of 70,000 people per day move into cities in Africa, with most of them staying under inhospitable conditions in slums. This rise in population has brought with it several challenges which, if not addressed urgently, will result in the collapse of the city ecosystem. This will make future cities uninhabitable, therefore municipalities need to come up with urgent and effective solutions to address urban problems. Since there is no set framework for African cities, the rapid rate of urbanisation and population increase are affecting these cities the most. African cities must resolve these challenges, considering factors such as locality and context, culture and availability of resources. Most African cities have resource constraints to ensure effective development.

Current frameworks have been devised and are currently being implemented in cities in developed countries. It is therefore imperative that a framework is devised for cities in developing countries. Cities must be seen as places which offer opportunities for better basic services, education and economic conditions. This dissertation seeks to develop a methodology for municipalities to aid in their decision-making processes in the development of a sustainable city. This will enable the

implementation of strategies that improve the sustainability and living conditions in cities in Africa, with Durban as an example. The structure of this dissertation entails the following:

Chapter 1 of this research outlines the background of challenges being faced by cities, as well as the research question, objectives, methodology and the significance of the research.

Chapter 2 contains an in-depth literature review of urban challenges. The literature review is a critical analysis of the current situation in cities, and proposed mitigation measures. It also shows how different approaches can be used to achieve sustainability, which is dependent on various conditions. Two different types of sustainable approaches, namely the smart and symbio city concept were reviewed, showing the differences in the approaches. Sustainability Indicators were introduced in this literature review as the building blocks in the derivation of a sustainable city framework. A list of Sustainable Indicators from a worldwide perspective was derived from journals and publications from organisations that have conducted extensive research in the field of Sustainable Development. The indicators were grouped into different sectors, which influenced the framework for the city of Durban.

Chapter 3 consists of the methodological approach used in this research. The rationale behind the choosing of the indicators and how they will be used to derive a sustainable framework were presented in this chapter. It also highlighted the need for a comparative case study between two cities which influenced the choosing of the indicators for Durban as a sustainable African city.

Chapter 4 introduces a comparative case study between two cities. The first one entails a field research conducted in the city of Trento in Italy, which represents a city in a developed country. The second case study analysis consisted of research conducted in the city of Durban in South Africa, representing a city in a developing country. The case study outlined the differences in the application of the concept of sustainability. Data pertaining to the prevailing conditions in Durban was presented to enable the final framework to be derived.

Chapter 5 outlines the framework of sustainability indicators for the city of Durban, derived from the indicators in Chapter 3 and backed by the Case Study in Chapter 4. It also contains a discussion pertaining to the applicability and implementation of such a framework.

Chapter 6 concludes the research, with a brief outline of implementing the framework. It will also highlight recommendations for future research to improve the framework devised in this research.

2 Literature Review

2.1 Introduction

Cities in developed countries are now in need of a defined framework due to population increase, rising rates of urbanisation and the demand for basic services. This literature review takes an in-depth look and critically outlines the challenges currently faced by modern day cities and the solutions that are being implemented. The challenges were categorised for clarity and to target specific sectors that make up a city's framework. Some of the challenges are interrelated and have a direct bearing on each other, which is briefly outlined in the synopsis of challenges later in the chapter. The synopsis was followed by examples of mitigation measures which emanated from worldwide conferences on sustainable development. This included the overall concept built around sustainable cities, which is the general solution to addressing current urban challenges. The concept further broke down a sustainable city into two approaches, namely the smart and symbio city. A comparison was carried out to highlight the similarities and differences between these two approaches. Sustainability Indicators were then introduced as the building blocks of the sustainable framework. The section on sustainability indicators concluded the literature review. The following section presents a detailed overview of challenges faced by cities, giving more attention to those that are more prevalent in Africa.

2.2 Current Urban Challenges

The aim for cities to be globally competent, coupled with the increasing urban population and inefficient development models, has resulted in the overexploitation of natural resources and environmental degradation (Vito et al., 2015). This has been further exacerbated by the increased consumption of fossil fuels and greenhouse gas emissions, which have resulted in climate change. This is now of major concern as it affects natural ecosystems and food production, which are essential for the survival of humanity. Most cities are still struggling to deal with the issue of rapid population increase from migration, resulting in unplanned expansion. It is estimated that by the year 2050, two thirds of the world's population will be residing in cities, with 580 million people currently residing in 34 megacities around the world (Cecilia, 2015). Megacities are defined as an area which harbours more than 10 million citizens. These cities have also been as a result of the conglomeration of informal settlements on the outskirts of cities to form a megalopolis (Mahsa et al., 2017). Such areas seldom fall under any municipal jurisdiction, hence they lack basic services such as water, sanitation and electricity. This is predominant in cities in developing countries, particularly in Sub-Saharan Africa (UN-Habitat, 2014).

With these trends likely to continue in future, cities must either adapt to the new conditions or put into place mitigation measures to curb the effects of rapid urbanisation. Current developmental methods have not been able to keep up with these changes, thereby contributing to urban problems rather than solving them. These challenges require integrated solutions as they do not occur in isolation. Poor countries are most affected by these challenges, particularly in Africa where the rate of urbanisation is higher than anywhere in the world (Ranhagen and Groth, 2012). Most cities in Africa do not have set frameworks to address these challenges, and lack of resources is hindering the implementation of effective solutions. Frameworks that have simply been adapted from developed countries have proved ineffective as the challenges faced by African cities are still predominant. Rapid changes have occurred in the civil society, with major issues such as unemployment and inequality, which have caused divisions among communities. This is common in informal settlements which have sprung up due to lack of housing and infrastructure for the urban poor and migrants (UN-Habitat, 2009).

Informal settlements are predominant in Sub-Saharan Africa, where 62% of the urban population reside in slums. There is little to no service provision in these settlements, and they are usually located on the outskirts of cities. High crime rate, poverty, social unrest, high disease spread rates, and general and unhygienic conditions are prevalent in these areas (Suzanne et al., 2017). Urban migration is expected to continue as economic opportunities, natural disasters and political conflicts are pushing residents from rural areas to cities, where it is safer and can provide decent livelihoods. Poor urban management and inefficient land usage have also led to uncontrolled expansion and the springing of informal settlements (Jürgens et al., 2013). Roles between municipalities and governments in African countries are not clearly defined, hindering effective decision-making processes. Lack of integration among municipal sectors has also resulted in uncoordinated operation and jurisdictional overlap, affecting the effective undertaking of projects and enforcement of urban regulations. Most municipalities in African countries do not have adequate financial resources to offer basic services to the citizens. Their budgets are spent on recurrent costs such as salaries, leaving little money for urban development. There are also high levels of corruption and mismanagement of the already limited funds (UN-Habitat, 2009).

Different cities experience different challenges, depending on factors such as the environment, locality, and availability of resources. Most challenges faced by cities in Africa are more inclined towards the provision of services, which are among the basic human rights (Ngobese et al., 2017). African cities must therefore develop models aimed at equipping authorities to deal with urban challenges, offering solutions tailored for their context. The continent needs to come up with development models for infrastructure and service provision for the growing population, with focus on the poor and vulnerable communities (UN-Habitat, 2009). The overarching challenge in Africa is massive population growth coupled with widespread poverty. This section of the

literature review outlines the challenges being experienced particularly by African cities. Classification provides for easy analysis of the problem so that solutions specific to that problem can be devised. Cities are complex systems which will require all the solutions to be consolidated into a coherent framework (Obeng-Odoom, 2013). This will prevent missed opportunities due to fragmentation which can result in the overlapping of authoritative jurisdictions among governments and municipalities. The following subsection outlines the challenges experienced due to current governance and legislative methods.

2.2.1 Governance and Legislation

Governments and municipalities are responsible for the crafting of policies and decision making processes in cities. These decisions have significant impact on the environment and the quality of life, as they are pivotal in the creation and enforcement of urban laws. Resource constraints have hindered the building and maintenance of infrastructure, let alone public services (eThekwini, 2017). Population growth beyond city boundaries has resulted in some areas falling outside the jurisdiction of a municipally. Sometimes these areas conjoin with other cities, requiring different authorities to coordinate in order to service these areas. This can result in contradictory laws that hinder effective governance and management of resources (Ranhagen and Groth, 2012). Outdated laws and operational methods have failed to keep up and reflect the reality of current conditions in cities. They have also failed to address the issue of inequality in infrastructural and service provision. The poor have little influence, hence they are often excluded in the decision making processes (Suzanne et al., 2017).

Most African cities are marred by public protests due to lack of service and maladministration. Corruption is also common, particularly in African municipalities which lack accountability. Lack of transparency in divulging information to the public makes it difficult to bring authorities to book in cases of maladministration and mismanagement of resources. Currently, there are four main types of governmental strategies used to run cities worldwide, and these consist of the following models:

a) The Fragmented Model – each government unit has authority over a particular territory
b) Mixed Model – local municipalities and government work together within a city
c) Centralised Model – central government controls metropolitan areas
d) Comprehensive Model – local authorities control the whole metropolitan area (Ranhagen and Groth, 2012)

If these approaches are not updated or improved, cities could become ungovernable in the future, impacting the environment and the quality of life for the citizens. Most African cities also lack adequate urban data to help assess current scenarios and determine future strategies which can

improve their conditions. Inefficient governance is the root cause of most of the current urban challenges faced today (UN-Habitat, 2016b).

2.2.2 Urban Infrastructure and Planning

The current scale of urbanisation has resulted in an imbalance between the demand and provision of infrastructure and services. The infrastructural aspect of the city is largely dependent on the surrounding natural environment. It is also influenced by other aspects such as transportation corridors, energy use, drainage systems and future spatial growth (Angelidou, 2015). The gap between older forms of urban planning and current conditions in cities has rapidly widened, resulting in strategies that do not correspond with the actual situation on the ground. Modern day cities have become more complex, with some cities still incorporating rigid urban planning strategies. Existing infrastructure is deteriorating due to lack of maintenance and increased vandalism. The dilapidation of infrastructure has a significant impact on the daily operation of cities, affecting other aspects such as housing, sanitation, provision of clean water, waste management, transportation, drainage systems, communication, health, emergency services, electricity and social welfare of citizens (Jürgens et al., 2013).

The term infrastructure in this context not only entails the physical aspects of a city, but rather a combination of assets, knowledge, policies, and institutions (Ranhagen and Groth, 2012). The knowledge aspect constitutes of the intellectual capacities of institutions that are responsible for the crafting and implementation of regulations. Institutions ensure the securing of financial resources in order to operate viably (UN-Habitat, 2016i). Current management approaches have inconsistent regulatory frameworks, which shows a lack of comprehension with regards to the looming crisis. At this point, current infrastructure in cities has been stretched to the limit, with the current global backlog being estimated at US$57 trillion. The revenue generated from providing services is lagging behind the costs involved in providing those services to the citizens. Countries that have managed to improve their economies have improved in providing adequate infrastructure in their cities (Kassim et al., 2015). This has not been the case in developing countries, particularly in Sub-Saharan Africa where lack of human resources, capital and technical expertise are curtailing development. This inadequacy has left most African cities vulnerable to elements such as floods, wind exposure, heat waves and soil erosion (Todes, 2017). Figure 2-1 shows dilapidated infrastructure in a typical informal settlement in Equatorial Guinea, Central Africa. It shows the neglect of roads, houses, and drainage systems in an overcrowded and inhospitable area.

Figure 2-1. Infrastructural dilapidation in Equatorial Guinea (UN-Habitat, 2014)

Cities have also become so obsessed with improving physical appearance that they have neglected the building of social capital, particularly in developing countries. Most of the infrastructure is being developed in economically active areas, neglecting the poor communities in informal settlements (Harrison and Yang). Durban and Nairobi are examples of African cities that have made progress in providing housing for the urban poor. In some countries, however, rigid urban laws have resulted in insecure land tenure, driving residents away to live in areas which are not governed. This will be further outlined in Section 2.2.2 under the issue of housing. Planning systems are not fully integrated with governments and budgets, resulting in unequal distribution of resources. In some instances, there is no synergy between planning and regulatory bodies, resulting in poor spatial planning. The top-down approach to planning has not been viable, as citizens want to participate in the decision-making processes. Poor planning has also resulted in developing countries experiencing a reduction in urban density while increasing spatially. This spatial expansion has gone beyond the administrative and physical boundaries of most African cities, resulting in the springing of informal settlements (IDB, 2017).

2.2.3 Housing and Informal Settlements

Informal settlements are areas where residents do not have secure tenure rights to the land they occupy. The neighbourhoods do not have basic services or adequate infrastructure, and most of the houses do not comply with building regulations. They are located on unserviced land, with residents living with constant threat of diseases, violence and forced evictions. People who reside in these settlements encounter social and spatial segregation because of where they live and the facilities they use. Informal settlements are usually located on steep and marginal land, exposing residents to disasters such as floods, landslides and devastating fires that can damage property

and lead to loss of lives (Ranhagen and Groth, 2012). The current housing system has resulted in an oversupply of houses for the middle-income groups, which the poor cannot afford. They end up either living in streets or informal settlements. Due to the poor communities' dependency on natural resources, environmental damage is usually detrimental to their livelihoods and well-being. The exclusion of slum dwellers from formal urban planning makes them more vulnerable to natural disasters and environmental degradation as they do not have the infrastructure or resources to combat these situations. Slums are more common in sub-Saharan Africa, but can also be found in developed countries. This is a persistent worldwide problem that has been part of the Sustainable Development Goals for at least two decades (UN-Habitat, 2016g).

Land tenure still remains an issue due to rigid urban laws and often conflicting interests, mainly affecting those who migrate to cities. Most of the land in cities is now privately owned, causing more challenges in the regulation of urban development (Suzanne et al., 2017). The private sector has also taken the approach to build and develop urban areas in which an elite few have benefited from this endeavour. Regular and poorer citizens need secure tenure rights to housing for them to have access to services, which provide them with an opportunity for improved livelihood. Governments have not fully addressed the housing issue, hence the uncontrolled spreading of cities. In recent years, most governments have taken an enabling approach to the provision of housing by just being the regulators of land acquisition processes.

Insecure tenure and land rights to the poor are as a result of inadequate measures to regulate the private sector. Figure 2-2 shows a continuum of tenure rights currently in use in modern day cities. This shows the different levels of ownership available in cities, with informal and formal land rights as the extremes. Most inhabitants in modern day cities are renting houses under a temporary tenure as purchasing a house in now out of reach for most citizens (UN-Habitat, 2016g). Current urban laws are designed for wealthy countries, hence they become exclusionary when implemented in poorer countries in the developing world. Most of the time, the urban poor are not the primary beneficiaries of subsidised housing, and most of them end up living informal settlements where they do not have to pay for land and services. Informal settlements are costly to plan and to provide basic services for, as most of the inhabitants cannot afford to pay for them (Ranhagen and Groth, 2012).

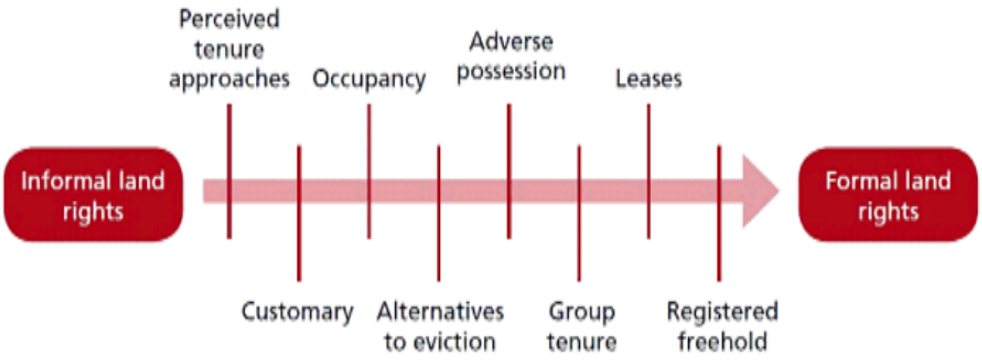

Figure 2-2. Land Tenure Continuum in modern day cities (Whittal, 2014)

Sub-Saharan Africa and Asia are the two poorest regions in the world, and with the population of residents in urban areas expected to double, informal settlements are expected to grow. Africa has the highest percentage of the urban population residing in slums, peaking at 62 percent as compared Asia's 30 percent. Sub-Saharan Africa accounted for 56 percent of the total increase in slum population from 1990 to 1994 (UN-Habitat, 2016k). Women, children, and the elderly are at risk as the prevailing conditions make them easy targets for crime and are more susceptible to inhospitable conditions. Most governments consider the existence of slums as undesirable, and slum dwellers are forcefully evicted with no alternatives for accommodation. Slums are not usually included in mainstream economic activities, aggravating poverty. Lack of funding has made the provision of affordable urban housing more difficult. Inadequate data on these settlements has led to a misinterpretation of the actual conditions that exist in these areas. Attempts to upgrade slums have been done in some cities, but most of them have implemented the process without adaptation to the local context (Ranhagen and Groth, 2012). Figure 2-3 shows a typical environment in an informal settlement in Mayville and Sherwood, Durban. This area has 4,355 informal and 293 traditional dwellings, which constitutes of more than 40% of the total dwellings in the area. Such settlements are usually located far from economically active areas, and residents who stay in slums have to travel long distances to get to work (eThekwini, 2017).

Figure 2-3. Informal Settlement in Durban, South Africa

2.2.4 Transportation

An upgraded transportation system, which allows citizens to access services, areas of interest and activities must compliment urban growth. The current growth has increased distances between residences and workplaces, markets, health facilities and education institutions. Most urban households now spend a significant amount of their incomes on travelling. Increased travelling distances have also made private vehicles a dominant use of transport, resulting in increased greenhouse gas emissions, energy usage, and noise pollution. Cities are now more congested and gridlocked, with higher space consumption due to a large number of vehicles. Congestion increases travel time for residents, and with private vehicle ownership on the rise, this trend is expected to continue as demand increases (UN-Habitat, 2013).

Most informal settlements are located along major transport routes such as highways. Increased interaction between pedestrians and vehicles, coupled with the use of unsafe crossing areas, compromises the safety of both drivers and pedestrians. With the number of people living in these settlements rising, fatalities are expected to increase, especially among children who play near these areas and also have to cross busy roadways to get to school (Ranhagen and Groth, 2012). Developing countries account for 90 percent of traffic related deaths even though they have only 33 percent of the world's motor vehicles. They also have informal modes of transport, which are dominant as they are more affordable to the urban poor. Even though this fills in service gaps by the current public transport system, it has worsened traffic jams and increased pollution. At most times, the informal industry is difficult to regulate, resulting in unsafe and obsolete vehicles transporting passengers. Sometimes, informal transport operators have been seen to charge more

expensive prices than buses. This affects the economic status of the urban poor, and increases expenditure on transport, further depleting their already low incomes (Kassim et al., 2015).

Citizens that live close to busy roads are at a higher risk of contracting respiratory diseases from toxic vehicular emissions. Inefficient, poorly serviced and obsolete engines emit smoke which contains harmful substances such as Nitrogen Oxides, Sulphur Dioxide and particulate matter, which causes respiratory problems particularly among children and elderly people (Ranhagen and Groth, 2012). Transport also accounts for 13% of the global greenhouse gas emissions, with almost 80% coming from road transport. Figure 2-4 shows a comparison of global oil usage for various sectors between 1973 and 2010, highlighting the increased use of fossil fuels from 45,4% up to 61,5% in transport.

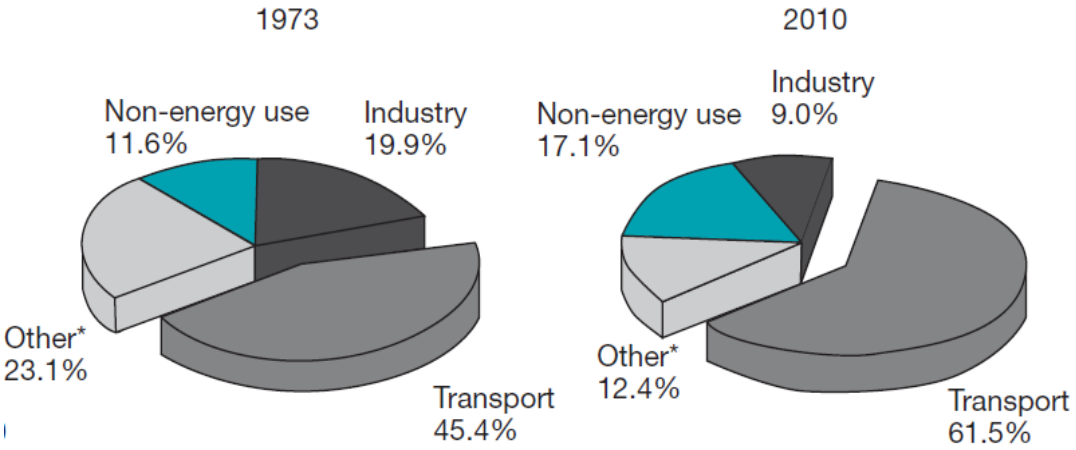

Figure 2-4. Comparison of Oil Usage between 1973 and 2010 (Stefano et al., 2014)

To address some of the challenges pertaining to the effects of congestion and general mobility, most cities have adopted the approach of building more infrastructure, which has not resolved the problem. Weak multi-sectoral and uncoordinated planning between transport authorities and city planners is hindering the implementation of an effective public transport system, especially in African countries. Bangui, a city in the Central African Republic, has only 6% of urban land allocated to streets, and with the rapid rate of urbanisation, mobility within the city will be impaired. In order to improve transportation and enhance mobility in cities, a more holistic approach must be devised, which focusses on bringing people and places closer to each other through mixed land use developments. Transportation in cities should not only cover roads, but should also link them to other modes such as rail, aviation and marine transport (UN-Habitat, 2013). The use of fossil fuels has become prevalent in the modern-day world and is not only limited to transportation, but also in the production of energy for industrial and domestic use.

2.2.5 Energy Production and Consumption

Current energy production methods predominantly involve the combustion of fossil fuels, which has increased greenhouse gas emissions. The increase in greenhouse gas emissions has majorly contributed towards global warming. Cities consume approximately 75% of the total energy worldwide and are responsible for 80% of greenhouse gas emissions (Lauren, 2016). Most of the energy is used for commercial purposes which include food manufacture, heating, cooling, and lighting of office buildings. Domestic energy use constitutes of household activities such as cooking and powering appliances. Developing countries are struggling to consistently provide power to their residents, with only 32% of the African urban population having access to electricity in 2011. Figure 2-5 shows a comparison of electricity production between countries in different continents in 2014. South Africa is one of the more developed countries on the continent, yet the electricity production is relatively low compared to other countries around the world. At least 30 countries on the African continent experienced acute power shortages in 2011 (UN-Habitat, 2016k). This has affected economies as it disrupts industrial production and office work. It also has social and educational implications as electricity is essential for proper functioning of households and schools. Residents without power or access to electricity rely on other sources of energy such as wood, charcoal, and biomass. This has a negative impact on the environment as these materials do not combust effectively. Fire stoves can also cause indoor pollution, which has resulted in casualties as a result of smoke inhalation and fires (Yamegueu et al., 2011). Lack of electricity also impacts factors like safety and crime in cities due to dark areas as a result of inadequate lighting.

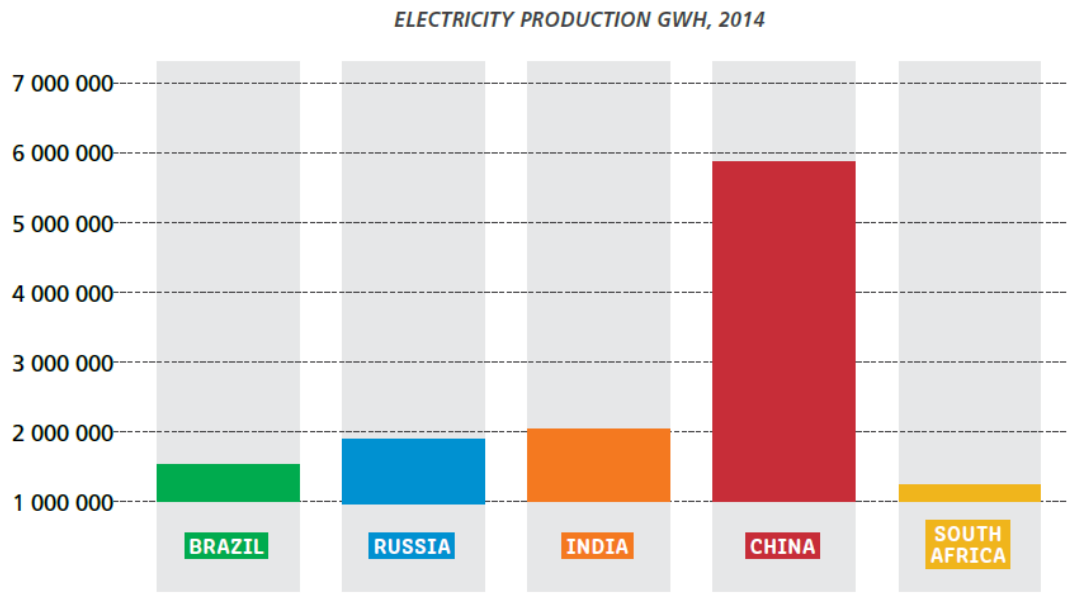

Figure 2-5. Electricity Production Comparison (BP)

Measures to eradicate the lack of power supply and to supplement the grid have been devised, using alternative and greener sources of energy (Nel et al., 2016). Cities in African countries lack resources and political will to implement regulatory frameworks which involve modern and more sustainable ways of producing electricity. Those areas of sustainable energy which governments are investing in still suffer from erratic production and supply of electricity. If governments fail to find effective solutions, it will hinder economic development and lead to a decline in the quality of life for citizens (Mohammed et al., 2013). In spite of this, African residents pay almost twice in tariffs as compared to their European counterparts. Energy development frameworks in sub Saharan Africa are being affected by factors such as corruption, ineffective implementation measures, lack of financial backing and skilled manpower. Most African countries rely on coal and hydroelectric power for electricity, and current droughts have threatened power supply as a result of low dam levels (Stefano et al., 2014).

2.2.6 Water and Sanitation

Competition between industries, agricultural entities and cities has had a significant impact on the availability of ground water. Efforts to conserve water sources have not been fully effective, as uncontrolled consumption, coupled with climate change, have caused underground water levels to drop. Climate change has contributed to worldwide water shortages due to longer drought spells and sporadic rainfall (De Paola et al., 2015). A prime example is found in North African cities, where climate change has depleted water sources in the Sahara Desert and the Nile River. Currently, a fifth of the world's population resides in water scarce areas, with little or no access to safe and potable water. In most African cities, residents do not have access to municipal water and have to rely on unsafe sources or buy from private vendors at exorbitant prices (Ranhagen and Groth, 2012). Some of these scarce water sources have been polluted by industrial effluents, further contributing to water shortage, and increasing the risk of water borne diseases. Vandalism of infrastructure has caused leaks in pipes, resulting in massive water loses. Most of the projects undertaken to upgrade water and sanitation systems are not being fully implemented, particularly in African cities. Involving other stakeholders, such as small businesses to assist with service delivery has not been successful as most of them do not have the capacity to fully implement these projects (UN-Habitat, 2016j).

Most cities in developing countries have poor sanitation systems, and residents are forced to use nearby rivers as sewers. The excrement pollutes rivers and is one of the leading causes of water borne diseases in informal settlements. The effluent also affects ecosystems and biodiversity by overfertilizing flora, contaminating water and fauna in the process. Effluents also clog waterways, cutting off water supply to communities downstream of water bodies (Ranhagen and Groth, 2012). Lack of sanitary infrastructure has also forced communities to build and share makeshift latrines that have unsanitary conditions. Absence of drainage systems and the culmination of

garbage has led to blocked drainage and cisterns, creating a breeding medium for disease carrying bacteria (Sarkar and Webster, 2017). Figure 2-6 shows the effects of lack of proper sanitation systems in informal settlements. Some of these settlements are actually built on top of sewer and drainage systems, but the complications and high costs involved make it difficult to connect these areas to the systems. In 2002, inadequate water and sanitation was responsible for 4% of deaths and 6% of all illnesses in developing countries. In 2010, Africa had only 54% average sanitation in urban areas. This was also coupled with lack of adequate waste management strategies to dispose waste using proper measures (Ranhagen and Groth, 2012).

Figure 2-6. Lack of sanitary systems in informal settlements (Ranhagen and Groth, 2012)

2.2.7 Waste Management

The metabolism of cities involves the ingestion of resources, which are then processed to make useful products (Bibri and Krogstie, 2017). The by-product of these processes is waste which must be disposed using the correct tools and methods. In developing countries, municipalities collect less than 50% of waste produced on average. There is a significant imbalance between waste generation and disposal, with waste management projects accounting for large portions of municipal budgets. With urban population on the rise, the amount of waste generated in cities is expected to increase (Scarlat et al., 2015). Industrial and hospital waste is of particular concern, as it contains hazardous substances. If not properly disposed, it can inflict damage to the environment and citizens alike. Lack of sanitary and properly managed landfills produce leachates that infiltrate and pollute the soil, ground, and surface water, thereby affecting soil fertility (Loukil and Rouached, 2020). The accumulation of landfill gas increases the risk of inextinguishable fires.

The smoke from these fires pollutes the air, affecting nearby residents. Uncollected garbage in the streets can mix with standing water, fuelling bacterial growth and creating bad odours. Waste dumps near informal settlements have become breeding grounds for bacteria and disease carrying animals (Ranhagen and Groth, 2012). Many people in poor countries depend on salvaging waste and selling it to recycling centres for a living. They must be educated about proper methods of waste collection, otherwise it may present a major health hazard. However, if waste is managed properly, it can offer opportunities for economic development through the creation of jobs for informal collectors (UN-Habitat, 2016k). Figure 2-7 shows waste traders scavenging for recyclable waste at a rubbish dump.

Figure 2-7. Waste scavengers at a waste dump (Ranhagen and Groth, 2012)

2.2.8 Disaster Management

Most cities in the world are located in areas where they are vulnerable to disasters such as storms, cyclones, and volcanic eruptions. Coastal cities are increasing in numbers due to the economic and unique lifestyle opportunities they offer. These cities are more vulnerable to flooding, and the worst effects have been seen in developing countries (Ranhagen and Groth, 2012). Most cities in developing countries do not have the resources of ability to manage pre and post disaster effects. This results in more casualties as compared to cities in developed countries (eThekwini, 2017). Marginalised groups have been forced to live in locations that are vulnerable to natural and man-made disasters, where 40% of these dwellings are under constant threat. Municipalities in developing countries struggle to prioritise measures to mitigate climate change as the limited

resources they have are in direct competition with other pressing issues (Sawada and Takasaki, 2017).

2.2.9 Health and Safety

Air and water pollution in cities have increased the risk of contracting diseases. Industrial and vehicle emissions affect the respiratory system and have been responsible for the majority of non-communicable diseases among cities in the world. In 2012, these non-communicable diseases accounted for 68% of the world's deaths. Lack of potable water supply and adequate sanitation, particularly in slums in developing countries, has amplified the spread of diseases, and contributed to the death of millions of people (Sarkar and Webster, 2017). Standing water in streets due to inadequate drainage creates breeding grounds for mosquitoes which spread malaria. Lack of sanitary waste disposal methods has created rubbish dumps near settlements, and these have become breeding grounds for flies and other disease carrying vectors. Contaminated water from domestic and industrial effluent is also adding to the tally of diseases among city residents (Ranhagen and Groth, 2012). The increasingly busy lifestyles of cities, coupled with less manual work and modernised services, has resulted in less physical activity. This increases the risk of cardiovascular diseases, strokes, and diabetes. This is also exacerbated by the consumption of high cholesterol diets, particularly in developed countries where obesity is a challenge among most of the citizens (Ngobese et al., 2017).

Studies have also shown that vehicular noise affects residents' sleep patterns, which can have adverse effects on their health. In developing countries, the main challenge with the health system is the availability of medical facilities and medicines. Most public hospitals in developing countries do not have the infrastructure, skill, or equipment to cater for a large patient influx. In some areas, residents travel long distances in search of medical attention (Sawada and Takasaki, 2017). The health system is poorly managed, with people having to wait in queues for long hours, and some dying in the process. There are high mortality rates among infants and new born babies due to deficits in the health system. These conditions are particularly predominant on the African continent, which has also been ravaged by AIDS, tuberculosis, malaria, cholera and typhoid amongst other life threatening epidemics (Ranhagen and Groth, 2012).

Cities generally have areas that are unsafe to the public, particularly the downtown areas. Informal settlements and poor townships harbour most of the criminal activities as a result of socio-economic challenges, with drugs and poverty as the main drivers. Victims suffer bodily harm and sometimes perish as a result of these crimes. Safety measures to reduce crime have not been fully effective as not all crimes are reported by the public (Lacinák and Ristvej, 2017). This is largely dependent on the communities' motivation to report crimes, as well as the lack of trust in law enforcing agents. People living in different neighbourhoods and social spaces experience different

types of crime risk. In South Africa, crime rate is high particularly in high density, low income areas which have hostels that were created for labourers during the apartheid period. Most of the criminal hotspots in cities constitute of high poverty levels, dilapidated buildings, transient populations with mixed residential and commercial environments. Figure 2-8 shows a comparison of crime rates in a South African urban safety publication between the periods 1994-2015 and 2015-2016. The figure depicts the different crimes committed and how they have evolved over the years. South African Police Service (SAPS) updates crime data on their websites to keep up with the hotspots and evolution of different crimes. Combating crime and provision of adequate data will improve the socio-economic status of cities. Authorities can use this data to implement effective measures to combat crime and ensure that cities are safe for both residents and visitors (Ngobese et al., 2017).

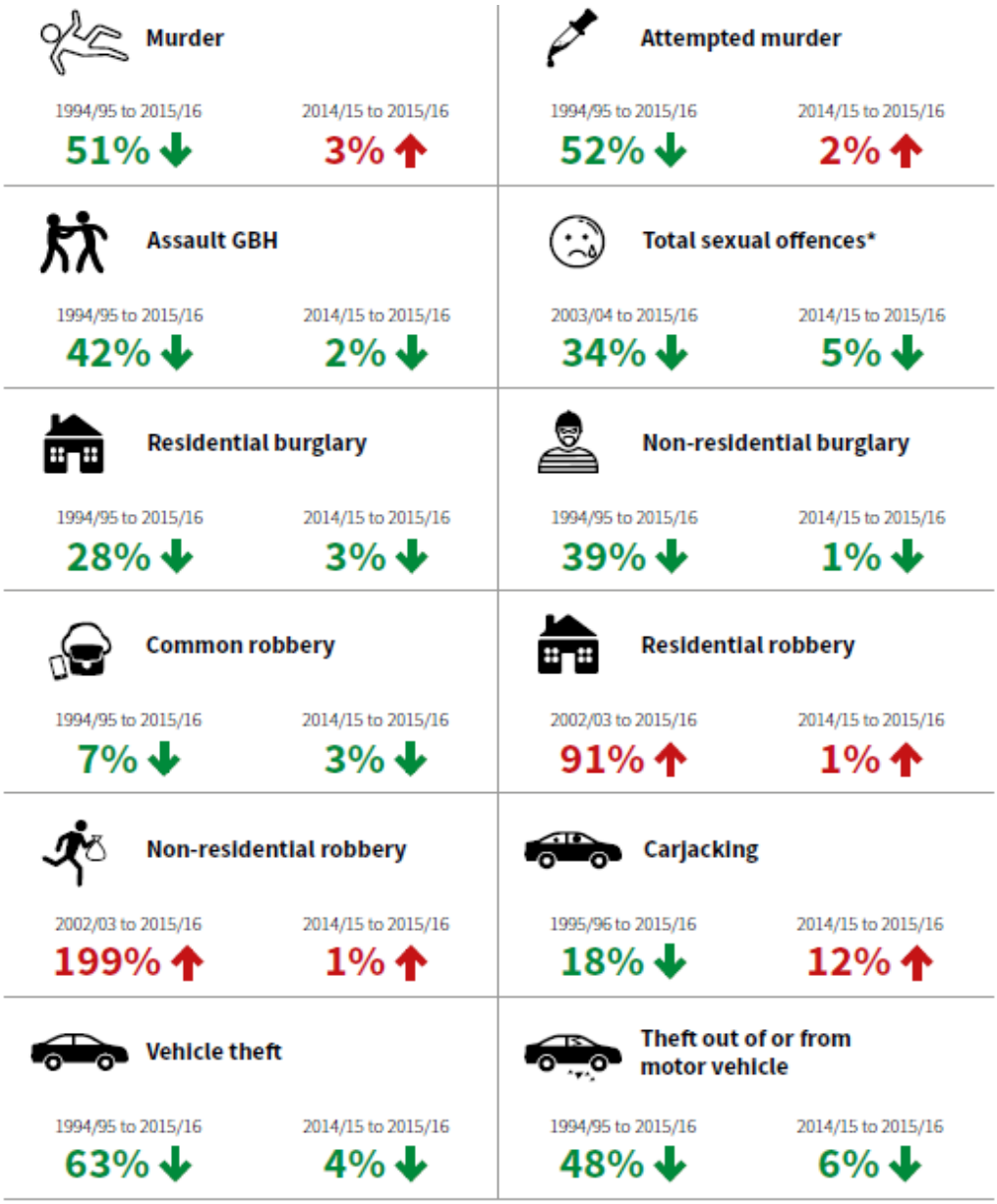

Figure 2-8 Comparison of crime rates for South Africa (Ngobese et al., 2017)

2.2.10 Education, Science and Technology

Most African countries are struggling to provide education for children, particularly at high school and primary school levels. In some instances, children walk long distances to their schools, where they have to negotiate flooded waters and busy highways. Most of the schools in villages do not have enough desks, textbooks, and sanitary toilets (UN-Habitat, 2016e). The student-teacher ratio is inadequate, affecting the quality of education. The current education system has not been able to keep up with the rapidly changing technological world. In developing countries, there is little coordination between industry and academic institutions, hindering the implementation on effective, inclusive and well researched solutions (Ranhagen and Groth, 2012). One of the main challenges prevalent in developing countries is lack of gender equality as culture historically discouraged women to attend school. Technology is not being fully harnessed to improve services due to lack of infrastructure and resources. Internet is now a major portal for learning and obtaining information, therefore it is imperative that cities provide as much coverage as possible (Anna et al., 2014). Lack of information and real time data renders poor citizens vulnerable as they do not have up to date information, particularly of impending disasters, which affect the economic and social lives of people. It is also imperative that cities have high literacy rates, as this provides for effective communication and offers educational opportunities for improving lives (Sawada and Takasaki, 2017).

2.2.11 Socio-Cultural and Economic Challenges

The issue of inequality among communities has existed for a long time, with most cities having to deal with inequality from economic and social standpoints. 75% of modern day cities have experienced an increase in urban inequality as compared to 20 years ago (UN-Habitat, 2016k). Cities are now divided by differences in access to opportunities, consumption, basic services, education, technology, wealth, income, and race. In Africa, this divide is hindering development and stalling progress. Poverty is prevalent in ‘poor’ areas, where the majority of the population live below the poverty datum line (Todes, 2017). Labour markets are taking advantage of the informal sectors whereby unskilled and unemployed workers are hired for minimum wage. In some areas, the workforce constitutes of undocumented immigrants who cannot seek legal help when exploited (Jürgens et al., 2013). However, some informal sectors in developing countries are contributing to the countries’ GDP, becoming a source of employment for the urban poor. In most African countries, the formal economy is growing in parallel with the informal economy, resulting in unequal growth in cities. This is evident in the transport and retail sectors, which consist of a lot of informal operators. This reduces revenue collected by authorities in the form of tax. There is also a divide between genders, whereby males have more access to economic opportunities as compared to females, causing gender related income gaps (Ranhagen and Groth, 2012).

Urban divide is further reinforced by the emergence of gated communities, where wealthier people reside and have created a system consisting of privatised services and infrastructure. Slums, on the other hand, are ravaged by unemployment and poverty. Residents resort to unorthodox means of survival, ranging from informal trading to criminal activities (Ngobese et al., 2017). The urban divide has also fuelled the increase in crime rates due to disparities. Most of these crimes are committed by residents from the poor and marginalised communities, who are most affected by these disparities. Women are concentrated in the informal trading industry, with their endeavours yielding very low profits. There is limited support for these women and children, who are the most significant in the social sector (UN-Habitat, 2014). While some groups enjoy development of new and modern infrastructure, the marginalised are being neglected. There is polarisation between economic active areas and those with lower economic activity due to global competition. Urban disparities are not only limited to the rich and poor communities. There are also socio-cultural divides such as race, gender, ethnicity, and religion. The provision of educational and health facilities is also of particular concern, as the poor sometimes have to walk long distances to access these services. These challenges must be addressed, particularly in developing countries where there is a high risk of economic instability and social unrest (Ranhagen and Groth, 2012).

Maintenance and improvement of public infrastructure requires a lot of financial investment. Most municipalities do not generate enough revenue to cater for the maintenance and upkeep of infrastructure (eThekwini, 2017). The allocation of tariffs among different income groups has always proved inefficient. The poor would favour the charging of tariffs based on income, but this would not generate profits for the municipalities as their contribution will be marginal. Large consumers such as industries can choose to opt out by providing their own facilities for purifying and providing water, reducing possible revenue to municipalities. Municipalities, however, should engage with stakeholders and make the consequences of the decisions transparent (UN-Habitat, 2016i).

2.2.12 Environmental Degradation and Climate Change

Cities have a large environmental footprint due to the concentration of activities, infrastructure and industries within a small area that is largely dependent on external natural resources. While the current operation of cities poses a threat to the environment, the environment can also become a threat to cities if a balance between resource consumption and replenishment is not attained. This can occur through natural and man-made disasters which damage infrastructure and lead to loss of lives (UN-Habitat, 2016k). Various needs and necessities like transportation, production of food and manufacturing of goods and services require vast amounts of energy and resources. Meeting these demands increases the unsustainable use of fossil fuels, which in turn leads to a rise in the emission of greenhouse gases which cause climate change (Ranhagen and Groth, 2012).

The creation of new infrastructure as cities expand to accommodate an increasing population has resulted in the destruction of natural ecosystems such as forests and wetlands. The destruction of vegetation will impact the health of the city as plants and wetlands are natural toxin filters. Wetlands also help to regulate the microclimate by acting as heat sinks. Improper waste disposal by residents and industries have also contributed to environmental pollution. Environmental degradation will negatively impact the quality of life as soils become less productive, threatening food security (UN-Habitat, 2016k).

Climate change has been a global concern and is seen a threat to the sustainability of cities. The occurrence of extreme weather events such as droughts, storms, cyclones, and landslides has been attributed to climate change, with cities in developing countries being the most affected. Sea levels are on the rise, and even moderate scenarios can render social and economic infrastructure vulnerable to damage. The rising sea levels have caused the intrusion of fresh water sources by sea water, making it unsuitable for consumption. Storm surges have caused flooding, resulting in the destruction of property and loss of lives. The impact of developing countries on climate change is, however, considerably less than in the developed world. This does not mean that cities in developing countries should be negligent, but should advocate more for climate change as the negative environmental effects have more impact on them (Ranhagen and Groth, 2012).

Several factors contribute to these problems, which are uncontrolled urban growth, increase in population, outdated technology, poor transport systems, and inadequate water and sewer systems. The fragmentation between governing bodies has resulted in the ineffective use of natural resources and implementation of environmental protection measures (Kassim et al., 2015). There is little collaboration between authorities responsible for sectors such as planning, transport, energy, environmental and waste management. This, coupled with the heavy reliance on non-renewable energy sources, has negatively impacted the health of citizens and the environment at large. In light of this, cities have two options with regards to climate change. The first one involves putting into place measures to reduce the causes, such as greenhouse gas emissions. The second option would be to adapt and learn to live with the effects of climate change. Whichever approach is chosen, it should ensure that it does not threaten the effective functioning of a city (UN-Habitat, 2016k).

2.2.13 Synopsis of Urban Challenges

The problems outlined in this section show how the current operation of cities has led to the deterioration of the environment, climate, and quality of life for citizens. Production and consumption patterns of cities are unsustainable, and if not addressed, will aggravate poverty, social disparities, and climate change. Cities offer opportunities to effect change, generate new ideas and implement concepts and frameworks to ensure that citizens lead comfortable lives

without inflicting damage on the environment. Most of these problems being faced are influenced by the following factors:

a) Rapid urban growth that is not coordinated and planned for
b) Increase in population and spatial demand
c) Insufficient investment in services
d) Inadequate industrial technology
e) Increasing and environmentally inefficient transport
f) Sewer systems disposing untreated wastewater from industries and households into the environment
g) Improper management of waste
h) Lack of citizens' knowledge with regards to how they can participate in bettering their cities
i) Lack of resources and political will to effect sustainable changes
j) Inadequate urban governance policies and low urban institutional capacities
k) High levels of inequality among different socio-economic population strata
l) Limited options for the African urban poor to access land
m) Climate and environmental change that have exacerbated the effects of urban problems

2.3 Current Mitigation Measures

Cities around the world have been implementing mitigation measures to improve operations and combat climate change. Countries have come together through global initiatives to devise solutions to urban challenges. A few of these examples will be mentioned, in which some frameworks were derived and are currently being used to improve sustainability worldwide. Some of the indicators used to create the framework for this research were derived from information from the following conferences on sustainable development.

Conference on the Environment (Stockholm, 1972) – This conference was the first of its kind, addressing issues with regards to climate change. It was agreed that man depends on the natural environment for his wellbeing and overall growth. It encouraged citizens to take responsibility of their actions and their contribution to environmental damage. International corporation was encouraged to provide resources to ensure that governments and people actively participated in the preservation of the environment.

Conference on the Environment (Rio, 1992) – Rio Declaration Agenda 21 – The 1992 Rio conference reaffirmed the Stockholm congress in 1972. It also aimed to improve communication

between member states, which was key in improving the lives of communities and individual citizens.

Kyoto Protocol (1997) – The Kyoto Protocol looked at reducing the emission of greenhouse gases on a worldwide scale, while promoting sustainable forms of operation and agriculture to reduce the effects of climate change. It provided incentives for countries to cut down on emissions, reduce pollution and manage waste using proper measures.

World Summit on Sustainable Development (Johannesburg, 2002) – The World summit further reinforced what had been agreed in the Stockholm and Rio Declaration. It emphasized how development frameworks had been elusive to African countries, thereby prompting other countries to commit to address these unique challenges such as poverty and conflict.

United Nations Conference on Sustainable Development (Rio, 2012) – The Rio conference marked a 20-year anniversary since the Rio 1992 conference. It emphasized the need for cities to monitor and evaluate performance using targets and indicators. It was meant to be a renewal of the 1992 conference, as well as addressing new and upcoming challenges. The conference analysed past developments towards sustainability with the integration of institutional governance.

Millennium Development Goals – Millennium Development Goals are broad goals for the entire world, which were devised to combat extreme poverty, improve health, education, gender equality and the environment. They consist of a framework of eight goals that are aimed at improving the lives of citizens by offering a range of practical steps. These goals also helped instil gender equality and enhance social capital by educating women. They also encouraged political involvement in order to integrate the environmental, economic, and social dimensions, thereby improving sustainability. These congresses have been influential in the creation of sustainable cities worldwide, where governments and individual citizens are now committing to preserving the environment (UN-Habitat, 2014).

Sustainable Development Goals (2021) – The Sustainable Development Goals (SDGs) were developed in 2015, with the aim to alleviate poverty from humanity, reduce mortality, improve the planet for future generations, invest in sustainable infrastructure, energy, and foster peace among societies (UN-Habitat, 2016k). They ensured that women's rights were also uplifted for social and economic equality. Sustainable development also entails the inclusion of poor countries where poverty and civil wars are predominant. They also sought to bring education to the poor and low-income communities to improve human capital among the younger generations. The SDGs are based on the Millennium Development Goals which aimed to ensure that every country was included with the responsibility of delivering a shared world vision (eThekwini, 2020). To date, 17 goals were drafted which are still being used by countries worldwide to improve on

sustainability. They have superseded the Millennium Development Goals and will be the basis of choosing sustainability indicators in this research. Most countries, particularly in the developing world, are developing at a slower rate than is needed in order to fulfil the intended targets by the year 2030. These regions need to be effectively governed through coordination of different decision-making bodies such as municipalities and provincial governments (Kassim et al., 2015).

World congresses on the issue of sustainability have shaped the way cities devise and implement policies. With the Sustainable Development goals in place, most cities around the world have changed the way they operate and started working towards the 2030 targets. The following Section 2.4 illustrates how the concept of sustainable cities was adopted, though there are different ways of implementing the concept.

2.4 Sustainable Cities

Current levels of global transformation have put cities as the main focal point of development. Worldwide growth is expected to occur predominantly in cities, and the need to implement sustainable methods of operation is of paramount importance. It should be understood that cities are complex urban ecosystems which entail social, biological, physical and economic aspects (Hannele et al., 2017). A sustainable city, therefore, is "a city that seeks to achieve a dynamic balance between the environmental, institutional, social and economic endeavours which are overseen by effective governing procedures characterised by deep citizen involvement" (UN-Habitat, 2016k). This city conducts activities that have minimal environmental damage and does not overexploit natural resources. This is done while boosting the economy and improving the quality of life for the citizens without compromising the needs of future generations (Aschkenazi et al., 2012). Stakeholder participation is important in the development and implementation of sustainable operation measures. Sustainable cities seek to address the challenges outlined in Section 2.1 and try to create a balance between the consumption and the replenishment of available resources. Some factors that are highly influential to the sustainability of urban areas include compactness, efficient transport, urban density, supporting of green initiatives, diversity, and mixed land use. The sustainable city model is developed in line with the main pillars of sustainability, which consist of the Environmental, Social and Economic dimensions (Ranhagen and Groth, 2012).

The environmental dimension focusses on the long-term preservation of biodiversity and ecosystems. It also encourages environmentally friendly processes to guarantee the sustainability of turning resources into essential products. Climate change resilience is a long-term plan which encourages the adaptation or mitigation of actions that increase the impact of unsustainable activities (Kassim et al., 2015). It also enables the environment to withstand the effects of sudden

climate change, particularly in vulnerable cities. There is need for cities to reduce greenhouse gas emissions through efficient energy usage. The social dimension entails the ability to provide basic needs and services through integrated and citizen inclusive approaches. It promotes easy access to facilities such as health centres and clinics, schools, day-care centres and parks. Social sustainability entails the inclusion of women in decision making processes, taking into consideration the needs of the poor and vulnerable. This involves the upgrading of informal settlements to address social injustices, while promoting urban diversity which includes mixed land use and cultural diversity (Ranhagen and Groth, 2012).

The economic dimension identifies urban areas as centres for growth, which should be in balance with available resources. Economic sustainability entails investing in green infrastructure and efficient energy systems which mitigate climate change and offer new jobs and business opportunities. There is coordination between the public, private and academic sectors to boost the image of a city in order to attract investment opportunities. These investments are targeted towards the most important sectors in the city's economy, such as labour intensive public works and private construction projects (Bibri, 2018). Investment in the maintenance of public infrastructure and agriculture provides opportunities for the urban poor to make a living, while producing local quality products. This requires large financial investments and provision of resources by central governments and municipalities. This ensures that there are enough resources to implement developmental projects. Sustainable cities must ensure that they operate in a transparent manner, where they inform the public on aspects such as municipal expenditures for accountability purposes. This also reduces corruption and mismanagement of resources (UN-Habitat, 2016k).

2.4.1 Strategies and Vision

A sustainable city must have clear development strategies of urban areas and environmental preservation, taking into consideration income equity, employment, shelter, basic services, social infrastructure and transportation (Hannele et al., 2017). The general public must be central to its development, embracing all social differences amongst inhabitants which include race, culture, age, gender and religion. The quality of life, comfort, health and financial stability of the citizens must be among the top priorities in deriving strategies and visions for cities. Citizen participation must be encouraged, which includes the youth, refugees and migrants, providing them with a platform to contribute to the crafting of policies (Ahvenniemi et al., 2017). Governments and local authorities are the main visionaries and drivers of change. Clear goals and plans ensure that the implementation of a sustainable city framework will create a resilient, comfortable and liveable city in line with the main pillars of sustainability. The allocation of adequate resources by governments will also help authorities with the effective implementation of plans. Solutions to

urban challenges must be developed through local skills and materials (Ranhagen and Groth, 2012).

Full coordination between different sectors and policy makers of the city allows for a coherent framework that offers equal opportunities to all citizens. Resources for the citizens must also be equally distributed, with services more focussed on accommodating women, children, the poor, the elderly and disabled (Ishkineeva et al., 2015). The city should be able to curb urban sprawl, controlling its population and providing safe and adequate housing to all citizens, including migrants. It should be resilient enough to recover from or absorb the effects of natural and man-made disasters. Where feasible, preventive measures must be taken to avoid impending disasters, with special consideration towards the vulnerable (Ranhagen and Groth, 2012). The integration of informal settlements in planning and development improves the resilience of the urban poor. Cities must realize that they are only as strong as their weakest inhabitants, therefore survival is depends on the level of protection offered to these citizens (UN-Habitat, 2016k).

According to the UN-Habitat, the following five issues should be addressed in order to promote an all-inclusive city:

- Assessment of the past, with a measure of progress
- Establishing new institutions or upgrading and strengthening new ones
- Promoting collaboration and resource sharing among different sectors of government
- A long-term clear vision to guide long term planning and promote participation
- Equal distribution of resources and ensuring freedom to mould a desired lifestyle (UN-Habitat, 2009)

2.4.2 Governance

Effective governance entails the decentralisation of responsibilities from governments to local authorities. This encourages public participation and uses partnerships to achieve common objectives. Small and large-scale cooperation involves political will, professional capacity and leadership. Institutional factors play a crucial role in ensuring the sustainability of a city through effective management and administration of financial, technical and human resources (Obeng-Odoom, 2013). Three factors guarantee the effectiveness of sustainable governance; and these comprise of leadership, efficient financing and public participation. Governance includes decision making structures and implementation of policies which are guided by informed strategies and vision (UN-Habitat, 2016b). The involvement of different institutions encourages multi and transdisciplinary decision making which improves synergy within a city's framework, enabling perspectives from various professionals. Decentralisation of local authorities in developing countries ensures rapid response to each area's developmental needs and environmental conditions. Planning and building codes are established in line with local conditions and

environmental standards which regulate development in line with the national framework (Fioroni et al., 2014).

Sometimes legislation and policies might be valid, but contradictory. An example could be densification to improve sustainability. This, however, can be detrimental to the environment and can clash with environmental policies. A sustainable city seeks to find a balance which can be achieved by involving all stakeholders in the early stages of the developmental process (eThekwini, 2020). Public participation is also vital to the sustainable development of a city, involving different stakeholders such as organisations, citizens and academia. Stakeholder participation is facilitated through forums, workshops, seminars and public meetings. Surveys can also be used to get input and feedback from citizens, which can be communicated through various forms of media. The internet is now the largest medium for sending, receiving and obtaining information, therefore cities can create websites to open communication channels (UN-Habitat, 2016k). Although full public participation is difficult to achieve, representatives can be appointed to advocate for their respective areas, including those in informal settlements. Public participation can also be difficult due to current levels of international migration, which makes communities more diverse and less likely to agree on common solutions. A communications centre could be established in every community, which can host dialogues and events. These centres can also be used to provide services such as payment facilities and general information to citizens and visitors. They must be located centrally and along public transport routes, allowing easy access for the citizens (Suzanne et al., 2017).

2.4.3 Infrastructure Provision

The provision of infrastructure ensures adequate services, as well as protecting vulnerable citizens from disasters. Infrastructural design should organise and connect the physical and institutional aspects of a city (Tzoulas et al., 2007). One of the most important aspects of physical infrastructure in a city should include the provision adequate housing, which generally accounts for more than 70% of cities' land use. The provision of housing provides employment opportunities to the local public through construction projects. These people can be trained through cooperation between relevant companies and government institutions. Governments can provide subsidies to the poor, so they can afford to own, or at least rent a decent, standard house (UN-Habitat, 2016k).

Other infrastructural aspects which determine the sustainability of a city include roads for easy mobility, pipelines for water and sewerage, landfills for storing waste, sports facilities and public spaces for relaxation and entertainment. Public spaces provide facilities where residents and visitors can meet and interact. They can be in the form of parks, green areas, public squares, libraries, bus and train stations (Kassim et al., 2015). Accessibility and safety of public spaces is

one of the main deciding factors on whether a city is attractive, particularly for visitors. These spaces must be compact and can be combined with commercial services to create a stimulating, varied and income generating environment (Singh, 2016). Facilities like benches and lighting should also be provided to allow for relaxation and improved safety respectively. Presence of vegetation in outdoor open areas creates comfortable microclimates, diffuse air pollution and reduces exposure to the sun and wind. Rainwater harvesting can be useful in helping reduce heat islands (Ranhagen and Groth, 2012). The provision of infrastructure requires careful planning and design of spaces to create a coherent system between different aspects within a city.

2.4.4 Spatial Design and Mobility

Spatial design involves the management of land use and its interaction with the built environment. It integrates different systems such as infrastructure, green areas and transport corridors. Spatial planning helps to curb rural-urban migration by developing sub centres in rural areas. Compact city design is seen as spatially efficient, allowing for less energy usage and shorter transportation routes for the delivery of goods, people and services (UN-Habitat, 2016c). It also promotes mixed land use design which provides green and open areas for recreational purposes within the precinct of businesses, housing complexes and shopping centres. This creates a well-connected public space where citizens from different backgrounds, ethnicities and beliefs can meet, fostering a culture of diverse social and cultural interaction. Public safety can be enhanced by providing lighting and constant monitoring, either by cameras or the police force(Ranhagen and Groth, 2012). Spatial planning ensures effective land use and balanced development that can help to curb segregation between communities. Different communities can be connected by enhancing mobility systems within the city through efficient and affordable transportation modes with minimal environmental impact (Margarita, 2014).

Transportation is also central to the economic development of cities, and effective management ensures that it plays a major role in the improvement of lives and businesses around cities (Chiara et al., 2016). Appropriate street patterns and space allocation improves accessibility to residences, workplaces, shops, cultural and recreational facilities. These facilities should be accessible at any time of the day and any place without restrictions and fear of crime. This can be achieved by engaging all citizens in the design, planning and implementation of a sustainable city framework, considering different requirements (Macedoa et al., 2017). Citizen engagement will also promote peace between different communities by facilitating dialogue that encourages understanding and tolerance towards one other. Urban typology and density have considerable influence on the efficiency of land use. Various designs may incorporate multi-functional housing in which part of a building can have space for commercial use at ground level. This generates income and creates job opportunities, while providing services in surrounding neighbourhoods. Different configurations can be implemented in spatial planning, each one having its own merits and

demerits (Garau et al., 2016). Figure 2-9 shows two examples of these configurations and their effect on land usage.

The low-rise, high coverage configuration provides living space that is in close relation to the surroundings but limits the potential for a variable urban landscape and common space. The high-rise, low coverage configuration does not offer gardens or open spaces to occupants, with little interaction between the building and surrounding streets. The large open spaces that result can also be expensive to maintain and manage. The configuration, however, does offer the possibility of mixed usage and increased urban density. A third configuration is shown in Figure 2-10. The medium rise and medium coverage create a balance between the high rise low coverage and the low rise high coverage configurations. It offers opportunities for mixed usage while availing communal areas and public parks (Ranhagen and Groth, 2012).

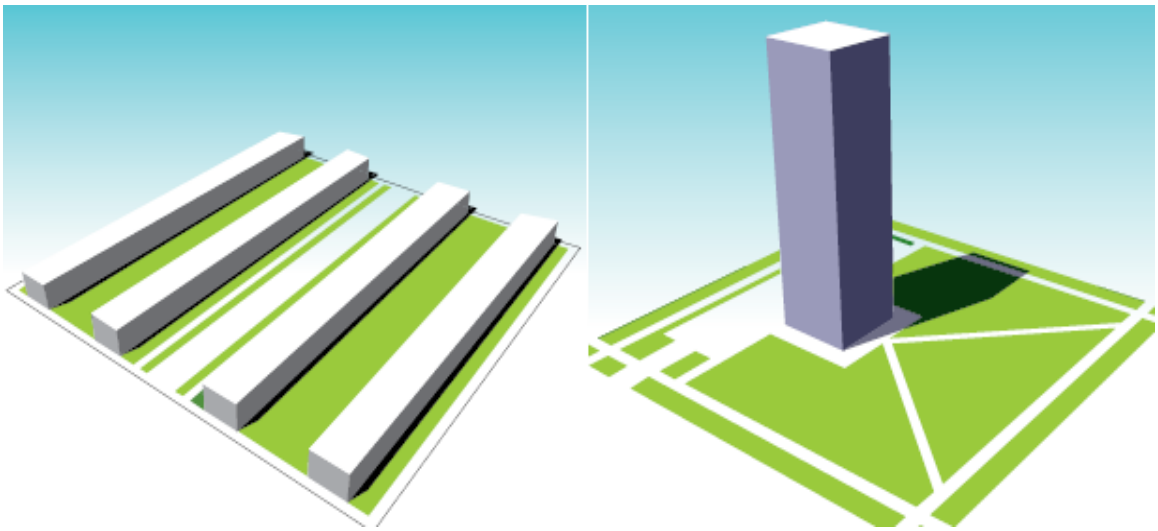

Figure 2-9. Comparison of Low-Rise High Coverage and High-Rise Low Coverage (Ranhagen and Groth, 2012)

Figure 2-10. Medium rise medium coverage configuration (Ranhagen and Groth, 2012)

Spatial plans should be regularly updated and must be designed to adjust to local changes. This can be achieved by involving all stakeholders within a city, whereby current issues are discussed, and conflicts addressed (Harrison and Yang). The UN-Habitat outlined the future roles of spatial planning in cities as below:

- Planning based on values and not just technical aspects
- Promoting a more flexible and proactive approach to urban development
- Planning by communities, stakeholders and professionals for mediation of inevitable conflicts over resources
- An integrated system that prevents urban sprawl
- To create systems in support of informality and to find ways of retrofitting services in informal areas, and preparing some land for informal settlement
- Integrated planning and management across all sectors in the city framework
- Implementation of cost effective, efficient energy and mass public transport system (UN-Habitat, 2009)

2.4.5 Environmental and Citizen Welfare

Citizen welfare is a significant aspect, and health is one of the main factors that has a profound effect on human productivity. Measures must therefore be taken to alleviate spreading of diseases, nutritional deficiencies, unsafe childbirths, as well as promoting healthy lifestyles (Nollo et al., 2014). Provision of sporting facilities and jogging paths will encourage exercise, as well as provide entertainment and foster social interaction. This can reduce the risk of substance abuse, particularly among young adults. Quality food, including home grown and organic products provide healthy diets, which curbs the risk of non-communicable diseases such as obesity and diabetes. Urban agriculture will ensure that cities grow their own food and not rely on external sources that incur transportation and delivery costs (eThekwini, 2020). A sustainable city also enhances the health of its citizens by implementing measures to reduce air and water pollution, while providing access to clean water and efficient services. Some of these services entail the implementation of cleaner forms of energy production and transportation, thereby cutting down greenhouse gas emissions (Gionanni et al., 2014).

A sustainable city recognises the carrying capacity of the environment in relation to infrastructure. Preservation and restoration of ecosystems must be prioritised, ensuring adequate environmental protection by the law. Stiff penalties should be enforced on industries, companies and individuals who breach environmental laws and pollute the environment (UN-Habitat, 2016d). Preservation of ecosystems and biodiversity also helps to curb the effects of climate change, while adding to the aesthetics of the city. Preservation measures also apply to residents, and it is imperative that they are educated and informed well enough to respect the environment and practice sustainability

at a micro level. An example is in waste recycling, where they can separate waste before collection. Stormwater harvesting allows for extra water to cater for the green areas, which can improve ecosystems (De Paola et al., 2015). Sustainability can be implemented on an individual level, which is then scaled up to households and organisations. From this, it can finally be applied to the overall city framework. Energy efficiency can also be implemented on an individual level. This will reduce the effects of climate change, thus improving conditions in cities (Weisz and Steinberger, 2010).

2.4.6 Water, Solid Waste and Wastewater

Efficient use of water must be encouraged for both domestic and commercial consumption. Industries and households should implement different ways to find efficient methods to conserve water usage. Fresh water sources can be complemented by stormwater harvesting mechanisms, recycling of wastewater, and the implementation of sustainable urban drainage systems. This must also be supported by proper waste management methods to avoid polluting the environment and littering the city (Emenda and Vilas, 2010). Waste can also be treated as a resource, particularly organic waste which can be used in the production of biogas and electricity. It can also be used as compost material for agricultural purposes. This, however, is largely dependent on operational, technical and financial capabilities of an organisation (Ranhagen and Groth, 2012). The Waste Hierarchy is a powerful tool that has been adopted to categorise and handle waste, and it entails the following steps:

1) To minimise the amount of waste and hazardous substances
2) To reuse waste by selling second-hand products
3) Recycling by using old material as a source of production for new products
4) Recovery of energy from waste
5) Deposit and treatment of waste in sanitary landfills as the last option

With adequate expertise, wastewater can be separated and reused for different purposes. Grey water that does not contain harmful substances can be used for energy production, since it may contain organic material (UN-Habitat, 2016k). Storm water and grey water can be collected in tanks and ponds, which can be used to water gardens. Green areas streets and parks can be designed to retain water which has a cooling effect in hot climates. The successful implementation of the design will depend on the inclusion of various stakeholders in the design (De Paola et al., 2015).

2.4.7 Education and Socio-Economics

Measures to improve the standard of living for residents involve sustainable strategies targeted towards the poor, the disabled, the elderly and minority groups. One of the main socio-economic challenges is to strive for equal social and economic development in communities, particularly in

developing countries (Ranhagen and Groth, 2012). Social and economic equality will improve lives and enhance safety, particularly among the urban poor. To improve productivity and service delivery, infrastructure must be upgraded and constantly maintained. Proper urban planning contributes to a favourable geographic and physical environment for sustainable development, but this should involve various stakeholders and different government tiers (UN-Habitat, 2016k).

The city must be aesthetically pleasing and trigger a sense of wellbeing, belonging and comfort for its citizens and visitors. Areas with historical significance should be preserved and used as a means for bringing together people from different cultures, races and ethnical backgrounds. A sustainable city must offer employment, education opportunities and training for its citizens, and measures for raising families such as day care facilities for children (Siemens, 2011). Children should be educated about environmental issues and the need to preserve resources by limiting consumption. The education of citizens ensures that they have adequate knowledge to make informed decisions that impact their lives (eThekwini, 2017). The role of citizens, particularly women, young people, migrants and businesses is essential in the city's development. Constant monitoring and feedback ensure that progress towards achieving sustainability is measured and relevant authorities are held accountable. The institutionalisation of sustainability measures ensures that there is coordination among different sectors in the cities, including municipal departments (Ranhagen and Groth, 2012).

2.4.8 Energy

A sustainable city harnesses clean forms of energy such as solar, wind, hydroelectric power and waste. In Africa, solar energy is becoming more favourable as droughts and sporadic rainfall patterns are affecting the water cycle which is essential for hydroelectric power for production of electricity (Azoumah et al., 2011). The implementation of renewable energy production methods can maximise conservation and reduce dependence on burning fossil fuels. Green energy sources also reduce emissions and alleviate climate change. Domestic houses and commercial buildings can be retrofitted to become more energy efficient and have standalone electricity generating mechanisms. These are generally referred to as smart buildings, with reduced water and energy consumption (Kylili and Fokaides, 2015). This reduces resource demand and is beneficial to the environment. Renewable energy is expected to reduce the costs of producing electricity, thereby contributing to economic development. Decentralised energy production is a viable option which can cater for remote areas, particularly in African villages (Gionanni et al., 2014). The first step in energy efficiency would be to reduce demand by using more efficient systems for buildings and vehicles, coupled with consistent monitoring. This will enable cities to play a significant role in the fight against climate change by lowering the usage of fossil fuels, curbing deforestation and rapid changes in land usage (Mahsa et al., 2017).

2.4.9 Adaptive City

Dynamism is important to ensure that the city evolves and adapts to changes, experimenting with different strategies and scenarios. Cities must be adaptive to changes in different aspects without affecting their operation methods or the citizens' quality of life. They must also offer facilities to accommodate and cater for migrants who move to cities for various reasons. Continuous learning encourages innovation in the formulation of problem solving strategies (UN-Habitat, 2016k). Technology is a crucial tool that can be used to improve sustainability through the enhancement of services. It can be applied to machinery and electrical appliances for efficiency, reducing the dependence on fossil fuels. Technology also provides an open platform for sharing ideas and knowledge without the need for physically meeting. It allows the public to access information relevant to them at their own convenience. Crowdsourcing allows authorities and municipalities to collect information about the effect of improved services on citizens. It also allows different stakeholders to access accurate and realistic data sets. However, the citizens should be consulted with regards to data collection methods in order to protect their privacy (Molinari et al., 2014).

2.4.10 Retrofitting or Ground Up Approach

The design of a sustainable city can be done by either retrofitting old infrastructure or building a new city from the ground up. This is dependent on the locality, resources and the availability of land. Both methods have their own benefits and demerits, and these have to be assessed by local authorities, governments and citizens (UN-Habitat, 2016k). The following Table 2-1 shows some of the advantages and disadvantages of building a new city.

Table 2-1. Advantages and disadvantages of building a new city

New City	
Advantages	**Disadvantages**
• There is freedom to experiment and apply new and clearly defined concepts • It allows planners to explore new business models and funding options • ICT can be easily introduced to new infrastructure • New sample cities can help with analytical work in policy and framework implementation	• Attracting new residents is a major challenge, and that can affect planning and budgets • Projects with a lot of environmental and sustainability concepts entail higher costs than conventional ones, for example, the use of green concrete

Building a city from the ground up enables the inception and application of new concepts. This can be beneficial particularly in developing countries where there a large land reserves for new developments. These cities can be created already in line with world standards of sustainable development without the need for alterations. However, development costs can run high, resulting in the projects not being finished or being abandoned entirely. Table 2-2 below shows an alternate option which involves retrofitting existing cities.

Table 2-2. Advantages and disadvantages of retrofitting

Retrofitting	
Advantages	**Disadvantages**
• Same existing techniques being used to create cities may be replicated, with innovative measures being introduced • Presence of stakeholders makes it easier to secure funding • Provision of new services might not require large infrastructural investments and systems	• Existing cities are already too complex, making it difficult to organise and rearrange • Outdated infrastructure could hinder the introduction of new systems

Authorities have a choice of implementing two methods of approach in creating a sustainable city. A top-down or a bottom up approach can be used. The following section elaborates on the top-down approach and how it can be implemented, together with the merits and demerits of such a framework.

2.4.11 Top-Down Approach

This approach entails a design by experts, based on their skills and information collected. There is minimal public participation, and decisions are made centrally. This has, however, drawn criticism as experts argue that cities designed using a top-down approach may be overdesigned, expensive and might not attract new residents. Some of the new cities are designed with commercial interest, therefore they might not meet the functional needs of a sustainable city. Masdar city in Abu Dhabi is an example of a city that entails sustainability and has been designed using a top-down approach (Iman, 2016). This approach has some merits and demerits as depicted in Table 2-3.

Table 2-3. Advantages and disadvantages of the Top-Down Approach

Top-Down Approach	
Advantages	**Disadvantages**
• The city can be controlled from a central hub, making it easy to monitor activities	• Risk of over planning • It might not attract new residents • It amplifies social divisions which hinders decision making, particularly in developing countries • It can leave the city at odds with different communities

2.4.12 Bottom-Up Approach

The bottom-up approach consists of a design by the citizens and for the citizens. Their input is the basis on which infrastructure and services are modelled around. The merits and demerits are shown in Table 2-4. These two approaches are alternatives in creating a city's framework.

Table 2-4. Advantages and disadvantages of a Bottom-Up Approach

Bottom-Up Approach	
Advantages	**Disadvantages**
• Citizen input instils a sense of belonging among residents • There is coordination among different ethnic groups which promotes peace • Solutions developed by the people are generally met with little resistance	• Organisations that fund projects may feel left out of decision-making processes • Citizen goals may clash with the long-term goals of the city

2.5 Current Sustainable City Models

With the Sustainable Development Goals in place, cities are now striving to meet the targets set out in order to improve living and operating conditions in cities (eThekwini, 2020). Cities in developed countries are employing high-tech methods to improve the environment and services, while less developed countries generally lack the resources to fully incorporate technology in their development. They use different and more physical approaches to improve sustainability. The challenges faced are more basic and entail the provision of needs and services such as water, sanitation, infrastructure and food. The approach taken, therefore, is more basic and different compared to developed countries, as it seeks to address the fundamental needs of the people (Ahvenniemi et al., 2017). The African continent faces unique challenges which cannot be easily solved by approaches used in the developed world. The two common approaches considered in this research consist of the Smart City and Symbio City models. They generally have the same underlying goal and seek to provide services, improve the environment, incorporate sustainable infrastructure and increase the quality of life for the citizens. As mentioned, they use different approaches and methods in the development of their models. The following section outlines the Symbio City Approach, which is more flexible towards being applied to a developing country (Ranhagen and Groth, 2012).

2.6 The Symbio City Approach

The symbio city concept focusses on maximising synergies between different systems in a city, creating a holistic approach to improving sustainability particularly in low and middle income countries. It is important to establish relationships between different systems and how they can be harnessed to improve living conditions in cities, in line with the main pillars of sustainability. The approach seeks to combine different faucets of knowledge bases on an interdisciplinary basis, with focus on science and policy making (Ranhagen and Groth, 2012). The emphasis on maximising synergies helps to identify potential conflict areas in the early development phases, ensuring the efficient use of resources. The Symbio City approach is a category of the overarching concept of Sustainable Cities presented in the previous Section 2.4. There are various ways in which sustainability can be achieved, and the Symbio City concept focuses on maximising the resources in lower income countries to achieve sustainability (UN-Habitat, 2016i).

The main concerns are social and economic aspects that are plaguing less developed continents such as Africa and Asia. These are areas which lack basic service provision, and their issues need to be addressed from a more basic and physical perspective, aimed at the poor and disadvantaged communities. Governments in less developed countries have higher cases of conflicting strategies that have resulted in poor service delivery, particularly in the urban slums. Synergies between the

various sectors and stakeholders will ensure that the city develops in a homogenous manner, with the inclusion of the marginalised communities (Suzanne et al., 2017). Effective management strategies across all sectors ensure the provision of infrastructure, basic needs and services. This helps in developing visions, strategies and solutions while optimising available resources (Ranhagen and Groth, 2012).

The Symbio City concept is not the only approach considered in the development of a sustainable city. The Smart City approach in Section 2.7 involves a sustainable city with technology at its centre of development. This differs from the Symbio City approach introduced in this section since in developing countries, development begins with the provision of basic needs and services. The Symbio City has the ability to evolve into a Smart City by incorporating technology only after the basics have been addressed (UN-Habitat, 2016k).

2.6.1 The Symbio City conceptual model and its applications

The Symbio City model is an integrated multi-disciplinary approach to sustainability, which can be adjusted to suit any local context. Cities are encouraged to reduce their ecological footprint while improving the quality of life for their residents and visitors. However, concepts alone do not have much of an effect if they are not physically implemented. Various dimensions at the core of this model guide the physical application of this concept, and these entail the following:

a) Environmental, Economic and Socio-Cultural dimensions.
b) Urban systems comprising of everyday structures and services functional to humans.
c) Institutional systems which entail governance and stakeholder participation, including planning and decision making.
d) The physical components which deal with the organisation and layout of infrastructure in relation to the surrounding natural environment.
e) The analysis of past and future stages in development (Ranhagen and Groth, 2012).

An understanding between local stakeholders and residents will ensure that everyone is active in the planning and decision making (Ahvenniemi et al., 2017). This will enable the crafting of tools to develop and implement policies which are aligned with the vision of the city and adapted to the prevailing conditions. Implementing the Symbio City approach is best done in stages, from planning and perception, through to detailed activities and alternative methods, and finally the implementation and follow up. Figure 2-11 shows a Symbio City concept that can be used mainly in developing countries, adapted from Ranhagen and Groth, 2012.

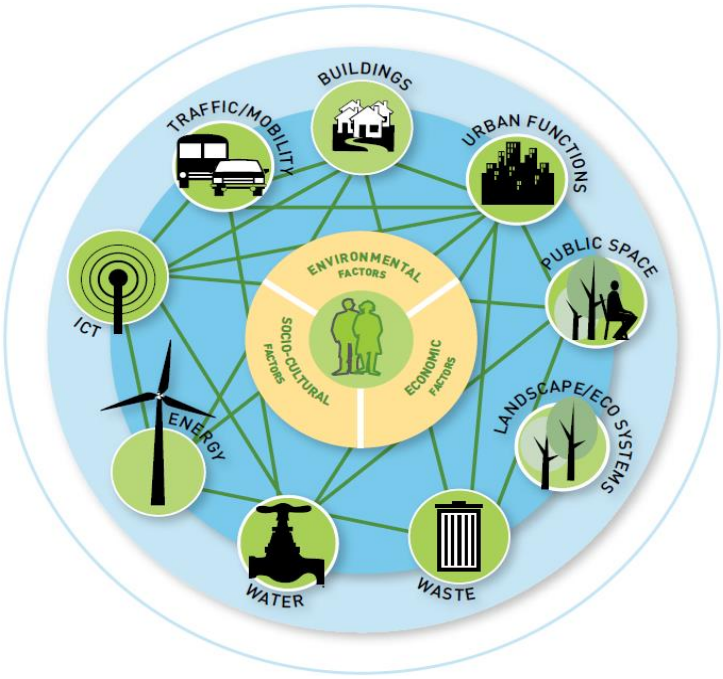

Figure 2-11. The Symbio City concept (Ranhagen and Groth, 2012)

2.6.2 Mixed Land Use Development

Mixed land use involves the utilisation of a specific piece of land for different purposes. It allows for different activities and functions within a precinct. This promotes better use of public spaces and services, while cutting down on travel distances and travel times due to the proximity of different services (Salazar Ferro et al., 2013). This enables synergy and stimulates integrated and effective land use through the interaction of mixed-use structures, green areas, public spaces and mobility systems. Mixed land use development fosters a sense of security and economic viability due to the increased number of people on the streets. It reduces the dependency on cars as a mode of transport, which in turn reduces greenhouse gas emissions and provides a healthier environment for the citizens. These areas must be developed so that major services such as public transport stations, shops, gyms are within walking distances from residences. Figure 2-12 shows a typical example of a mixed land use model, adapted from Ranhagen and Groth, 2012.

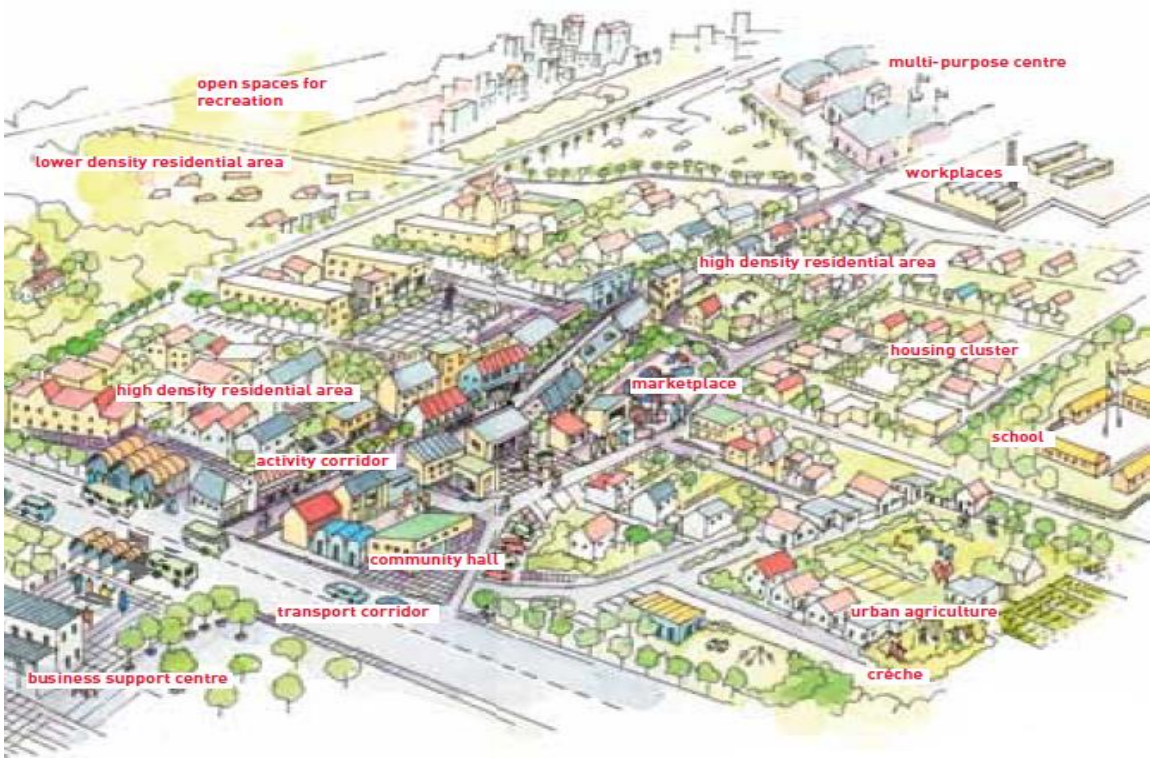

Figure 2-12. Mixed land use development model (Ranhagen and Groth, 2012)

They layout of public space influences the spatial, economical, and socio-cultural aspects with regards to sustainability (Mateos et al., 2018). The planting of vegetation in public spaces enhances biodiversity, improves aesthetics and also provides educational opportunities for residents and visitors to learn about local plant and animal species. The encouragement of diverse use of public spaces creates a comfortable and social stimulating environment. Overall, public spaces should encourage citizens to meet and interact to improve the socio-cultural environment in a city (UN-Habitat, 2016c).

2.6.3 Building Design and Mixed-use Structures

The design of buildings must incorporate sustainability throughout their life cycles. This also includes the construction and general use phases. The buildings must be able to adapt to ground conditions, microclimates and the effect of other surrounding structures, traffic systems and public spaces. They must also be designed to actively interact with both the indoor and outdoor environments. Using green materials, allowing the filtering of natural light into the building, efficient energy and water recycling systems can reduce the ecological footprint. The buildings must be able to provide an indoor climate that ensures comfort for occupants (Ranhagen and Groth, 2012). Proper design guarantees that the buildings require less cooling in summer and retain heat in cold weather. They can also be made to generate and distribute energy through renewable sources such as solar power, whereby excess energy can be sold by feeding directly

into the grid. This creates potential for new markets that can have positive effects on the economy. Water harvesting techniques which include the collection and sustainable drainage of storm water, recycling grey water for use, waste recycling and general management contribute to the overall sustainability through efficient resource usage. These buildings must be accessible from walking paths, parking areas and bicycle lanes (UN-Habitat, 2009).

2.6.4 Urban Landscape Planning and Ecosystems

Urban landscape planning considers how the environment relates to various urban functions. This includes the provision of public spaces for social activities and the mitigation of climate change. For entertainment and relaxation purposes, smaller parks near working areas and neighbourhoods must be provided, as these are most utilised as compared to larger and more distant parks (Rafiemanzelata et al., 2017). Walking and cycling paths are environmentally friendly ways of accessing these parks, hence there must be enough coverage to ensure the parks are fully utilised. Proper planning also ensures that the natural and built environments are optimally integrated while taking informal settlements into consideration (UN-Habitat, 2009).

2.6.5 Mobility

This is a major aspect in a city's design as it allows easy access to services, systems and functions. It also dictates how citizens use their city, including the use of vehicles and parking facilities, bicycles and sidewalks. An integrated transport system enables seamless transit at neighbourhood, city and regional levels. It ensures effective management and operation for all forms of mobility (UN-Habitat, 2013). A coherent, integrated system can be created through combining technical capacities, innovative measures, institutional arrangements, legislation, policies, monitoring and evaluation. Mode hierarchy can be implemented to identify priorities pertaining to different transport uses in a particular situation and environment. For example, bicycles and pedestrians can be given preference at a neighbourhood level, while buses and taxis can be prioritised in the city centre. Figure 2-13 shows the hierarchy for different modes of transport in a sustainable city. Planning must prioritise more vulnerable commuters such as cyclists and pedestrians. The city of Cape Town in South Africa introduced narrow streets where vehicle access is limited, making them pedestrian and cyclist friendly and enhancing the social ambience in the city (Ranhagen and Groth, 2012). The transportation of hazardous material must be coordinated and restricted to certain routes to improve citizen safety and reduce the risk of environmental damage. The use of ICT improves transport services such as integrated ticket systems and surveillance, such as those implemented in Brazil. It has also allowed some developing countries to leapfrog some older methods that were implemented in developing countries. Mobility systems have social, cultural, health and environmental implications (Bedini et al., 2014). The use of greener forms of fuel such as ethanol and biogas will reduce carbon dioxide and toxic emissions.

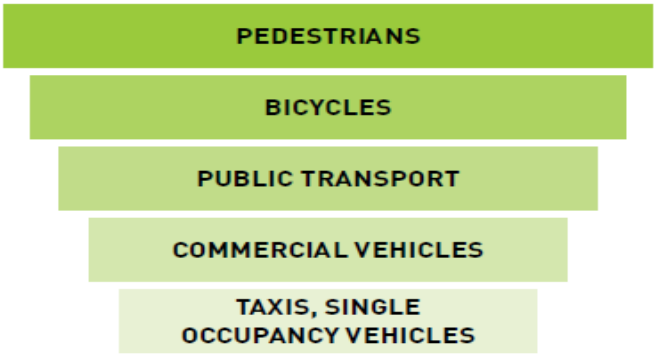

Figure 2-13. Transport Mode Hierarchy (Ranhagen and Groth, 2012)

2.6.6 Energy Systems and Waste Management

Energy systems cater for the generation, transmission and use of electricity for different purposes. In African countries, solar energy is a reliable source due to prevailing sunny weather conditions. However, key constraints include lack of public awareness and household finances. Using clean and renewable energy sources creates efficient and resilient systems which can reduce the effects of climate change and environmental depletion (Scarlat et al., 2015). The development of a waste hierarchy model will help to categorise and handle waste to ensure safe deposition into landfills. Waste separation is the first step to efficient waste disposal at a household and organisational level. Citizens must be educated to identify different types of waste and the most efficient ways of disposing off. Illegal dumping is attracting waste scavengers in developing countries, posing health hazards to the pickers and the general public (Ranhagen and Groth, 2012). The waste scavenging process must be formalised as this offers employment opportunities. Small contractors can also be included in the collection of waste in areas that are inaccessible to municipalities. Proper waste collection and disposal methods benefit cities in that landfills can be used to generate gas that can be used in producing electricity. Old, disused landfills can be rehabilitated into green areas that can support different forms of plant and animal life (Oteng-Ababio et al., 2013).

2.6.7 Water Management and Sanitation

Provision of clean, safe drinking water and sanitation are fundamental towards sustainability. This is important in developing countries where most citizens do not have access to water or sanitation facilities. Densely populated areas and middle-income areas can use water-based sewerage systems, while dry sanitation systems are more feasible for the outskirts and poor communities. Water based systems can be made more efficient by reducing the amount of wastewater, improving treatment methods and modifying them to produce gas which can be used for energy production. Activities carried out in informal settlements and industrial areas should be monitored to ensure that water sources are not polluted (Ranhagen and Groth, 2012). Freshwater sources

such as rivers, lakes, dams, reservoirs and catchment areas are most vulnerable to pollution and should be carefully managed. The maintenance of infrastructure will minimise water leaks which are common in cities in developing countries. These measures, carefully implemented, will ensure the security of potable water in cities. The cooperation of waste and wastewater sources is essential since water sources are often polluted by wastewater (De Paola et al., 2015).

2.6.8 Urban Systems Synergies

The interrelations that exist between different dimensions in a sustainable city design can be put into an Eco-Cycle Model. Institutional factors are key to facilitating stakeholder cooperation.

2.6.8.1 Transportation Systems and the Location of Urban Functions

The integrated land use model should be in conjunction with an efficient transportation system and mobility (UN-Habitat, 2016f). It helps in the reduction of greenhouse gases by cutting down on travel distances. Ideally, transport hubs must be located at high density nodes or along transportation corridors, which can help mitigate urban sprawl (Ranhagen and Groth, 2012).

2.6.8.2 Energy, Landscape Planning, Waste and Water Resource Management

Organic waste to be used in biogas reactors can be obtained from grey water and waste systems. Nontoxic waste can be used as fertiliser for crops or for green vegetation in parks and recreational areas (Scarlat et al., 2015). Biofuel crops can be fertilised using compost and sludge from wastewater in small energy production plants. The risk of sludge toxicity must be considered when using it for fertilisation. Waste areas such as landfills can be carefully integrated and converted into recreational areas such as green parks, while using treated wastewater for irrigating (Ranhagen and Groth, 2012).

2.6.8.3 Building Design, Layout, Microclimate and Surrounding Landscapes

Layouts of buildings can maximise the position of the sun during the day to produce solar energy. It can also reduce the energy needed to warm the buildings in cold conditions, caused by exposure to wind (Ranhagen and Groth, 2012).

2.6.8.4 Synergies and Climate Change

Measures should be taken to reduces the sources of Carbon Dioxide. Greenhouse sinks that are capable of absorbing toxic gases must be devised. The natural system can be tailored to adapt to changes in the surrounding environment. Infrastructure must be designed with low technology solutions to adapt to climatic conditions for functionality and occupational comfort (Ranhagen and Groth, 2012). The Symbio City approach focusses on departmental synergies to improve sustainability and is more tailored for cities in developing countries. In the developed world, the Smart City approach is used, which consists of methods from the Symbio City approach infused

in technology. The following section presents the concept of Smart Cites and how it is helping most cities in developed countries to become more sustainable.

2.7 Smart City Approach

The definition of a Smart City has been fuzzy since its inception in the 1990s, causing confusion among stakeholders. It is highly dependent on the context, which includes locality, government, knowledge, capacity and the availability of natural resources (Margarita, 2015). The words intelligent, ubiquitous and digital have been used in defining a Smart City. Some suggested the use of sensors and embedded devices to monitor critical infrastructure, creating 'intelligent' products and real-time instrumented data to maximise services. Constant monitoring would also help in managing and integrating natural environments and ecosystems. Some also defined it without the technological context, with focus on providing healthy and liveable environments under the prevailing conditions. They emphasized that it is "a community of average technology size, interconnected and sustainable, attractive and secure" (Vito et al., 2015). They were also defined as spaces for learning, innovation and knowledge creation using digital platforms for effective communication. The concept and the definition of smart cities was defined in three main areas, namely the industry, governments and by academia.

A smart city is, therefore, a 'futuristic city that seeks to enhance quality of life, environmental, social, and economic sustainability through an integrated approach, using Information and Communication Technology' (Robertas et al., 2014). The city provides an intelligent and multidisciplinary synergy between people, infrastructure and business with technology at the core of this development. Some scholars argue that SMART stands for Strategy, Multidisciplinary, Appropriation, Roadmap Technology. Technology enables the improvement and easy access of services, saving energy and resources, economising time, monitoring parameters, and fostering public participation (Chiara et al., 2016). It also plays a facilitator role by enabling platforms that offer user centred services. Data collection helps in making informed decisions, encouraging collaboration among entities and enhancing participatory policies. Efficient use of information requires societies that are knowledgeable and willing to use ICT platforms to continuously learn about their surroundings (Rama et al., 2017). ICT also provides freedom of speech as well as easy and affordable accessibility to information and services. Smart cities consider humans as the forerunners, with their ability to generate viable and intelligent solutions towards development using technology. Figure 2-14 shows the fundamental systems that make up a smart city.

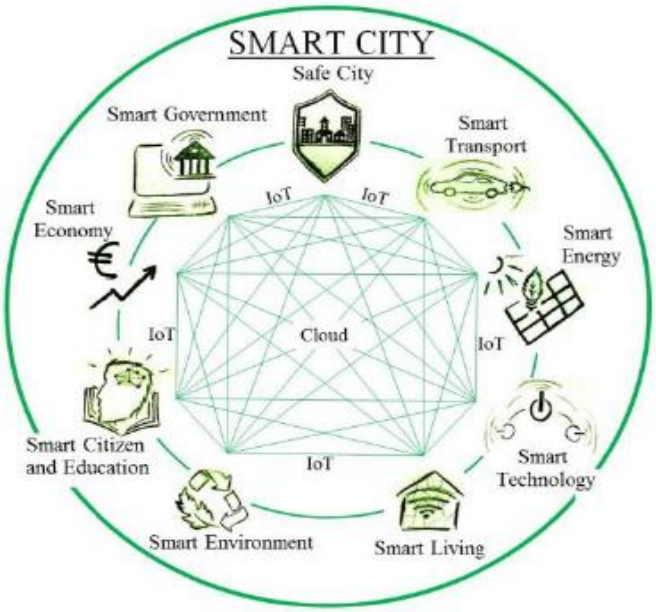

Figure 2-14. Smart City framework (Lacinák and Ristvej, 2017)

Consumer behaviour has become increasingly digital, hence there is need to harness technology to improve the social and service experiences of a city. It should not, however, have preference over citizens as technology is merely a facilitator to the improvement of services (Gionanni et al., 2014). This approach is fully effective where citizens are willing to embrace the use of technology and freely allow two-way flow of information and data. The enhancement is due to creative strategies obtained from intensive knowledge through a skilled labour force, high tech facilities and open network linkages. Ultimately, all these facilities work together systematically to enhance the quality of life for citizens, while creating a greener city with a positive environmental impact (Vito et al., 2015). Smart cities have received criticism for their top-down approach to design, but it has also been shown how technology can be used to empower citizens by adapting to these technologies and employing advanced city information systems (Robertas et al., 2014). Various dimensions of smart cities have been proposed, with the first one comprising of four dimensions:

1) The use of devices and technology to create a knowledge based cyber city.
2) Use of technology to assist with work and general lifestyle.
3) Integration of technology with the city's infrastructure to allow for monitoring.
4) Integration of people and technology to create a harmonious environment (Letaifa, 2015).

Vienna University of Technology then devised six revised dimensions, which were later adopted by the Smart City committee in Europe and are still used today. Figure 2-15 shows the dimensions of a smart city currently in use.

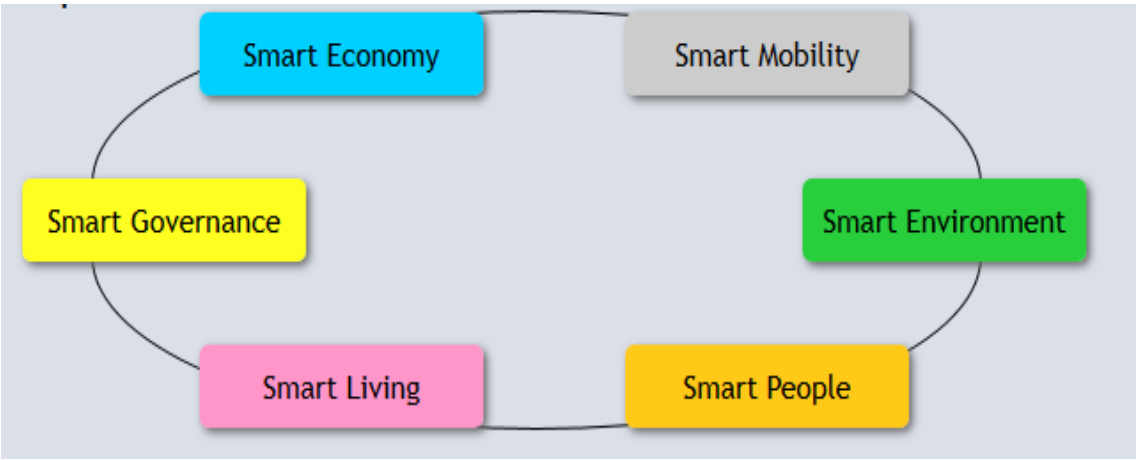

Figure 2-15. Dimensions of a Smart City (Vito et al., 2015)

2.7.1 Dimensions of a Smart City

Even though these dimensions are separate, they are one coherent unit in the city's framework (Vito et al., 2015). The following sub section gives a brief description of each dimension and its influence in creating a smart city.

2.7.1.1 Smart Governance

Smart Governance entails the offering of e-services, social media and crowdsourcing. Through online services, they rid the city of barriers related to language, culture, education and disabilities. This promotes citizen participation, allowing for transparent decision-making processes and for the citizens' voices to be heard (Letaifa, 2015).

2.7.1.2 Smart People

Citizens are involved and willing to interact and contribute to the system through crowdsourcing of information to create personalised services. They are tolerant of differences in culture, religion and beliefs. Smart citizens also indulge in lifelong learning to increase the social capital of a city (Vito et al., 2015).

2.7.1.3 Smart Mobility

Smart Mobility focuses on collective forms of transportation over individuals through careful urban planning. Intelligent traffic systems ensure the smart mobility of citizens in and around the city. The concept of smart mobility also tackles issues such as the use of fossil fuels, congestion in cities, and applying measures to ensure cleaner and improved forms of transportation. The effectiveness of a smart transportation system will involve the integration of physical and technological aspects, coupled with human and social needs. This is, however, complex and requires further research to assess its feasibility and application. Cities are now employing

services such as bike and car sharing as a measure to improve the sustainability of transportation systems (Chiara et al., 2016). The use of electric vehicles has reduced the need of fossil fuels for transportation and making progress in achieving the zero emissions target. The use of hydrogen fuel cells and natural gas to power vehicles is a promising concept, with the availability of appropriate technology. This can be applied to private cars, public transport and municipal fleets. A smart transport management system must be put into place to integrate all related aspects in the transportation of goods, people and services (Bedini et al., 2014).

2.7.1.4 Smart Environment

This involves the use of the latest and most innovative technologies to produce energy and manage waste to enhance the surrounding natural environment and ecosystems. Environmental wellbeing is crucial as most cities draw resources from their surroundings. Technology helps to monitor various critical parameters such as air quality and pollution in water bodies (Bibri and Krogstie, 2017).

2.7.1.5 Smart Living

Smart living involves a high quality of life for citizens, creating a conducive environment for tourism which brings social and economic benefits. Public safety is enhanced by using constantly monitored surveillance systems. It also includes the provision of e-health and cultural facilities, social services and emergency networks (Letaifa, 2015).

2.7.1.6 Smart Economy

Smart economy is the leveraging of technology to devise innovative ways to conduct economic activities and manufacturing processes. It also entails the promotion of equality through the fair distribution of resources among different areas and communities within the city (Vito et al., 2015). The six dimensions are the building blocks for most smart cities. There are different aspects that make up a smart city, and these are outlined in the subsequent section.

2.7.2 Intelligent City

An Intelligent City merges a knowledge society with the digital dimension, in which ICT is used to transform the way people live, work and commute. It also empowers its inhabitants to learn, develop and constantly innovate solutions for a common good. There is close relation between an intelligent and digitalised city. Artificial intelligence is a major aspect, where machines and devices are capable of suggesting and making informed suggestions (Margarita, 2014).

2.7.3 Virtual and Digital City

This city consists of a hybrid system in which the inhabitants and the virtual concept coexist in parallel dimensions. It also seeks to kill distance in that services can be accessed without physical

presence. The aim is to weave technology into everyday lives of citizens to the point that it becomes indistinguishable to the user. Elements within the city are reproduced by visualising them in the virtual space. Embedded systems can also make technology invisible and yet available when needed. A digital city combines broadband and communications infrastructure that meets the needs of citizens, governments, and businesses. The final goal of a digital city is to create an environment for information sharing, collaboration, interoperability, and seamless experiences anywhere in the city (Jucevičius et al., 2014).

2.7.4 Data Driven City

The use of Open Data enables authorities to provide an average citizen with information that can be used and interpreted. It is a way of governments to show transparency and accountability to its citizens and relevant stakeholders. Big Data is enabling cities to provide real time information of what is occurring (Molinari et al., 2014). A combination of smartphones, portable devices, personal computers, sensors and applications allows for a two-way flow of information to help with acquiring data or relevant information. The Internet of Things (IoT) is supported by these electronic devices and allows the tailoring of personalised services for every individual on the network. Collection and processing of data is usually done in the four stages stated below:

i. Data Collection
ii. Data Processing
iii. Integration
iv. Alerts and Device Control

2.7.5 Knowledge Intensive and Creative City

This is a city that treasures the acquisition and nurturing of knowledge. This is encouraged by the introduction of cloud based and urban monitoring systems. Data collected needs to be processed into useful information for both organisations and citizens. It also prides itself with being the centre of education, with educated and skilled individuals in the workforce. This smart city seeks to promote a creative and knowledge intensive environment. This is a key element in the creation of a green and sustainable urban environment (Ranhagen and Groth, 2012).

2.7.6 Interconnected (Network) City

Smart cities are interconnected networks within a digital dimension which uses technology to enhance sustainability. Interconnectivity ensures constant interaction with various services no matter the location. Networks also provide a platform to generate ideas and strategies individually or collectively using social networks. Telecommunication is another aspect that can facilitate meetings without the need for physical presence. Constant internet connectivity is achieved by using Wi-Fi networks and satellite communication. The use of mobile applications can also help

in checking information and how many citizens that are connected to the network (Anna et al., 2014).

2.7.7 Smart Community

A community based smart city uses a bottom up approach by considering citizens as the shapers and promoters of growth in the city. Their participation is important, thereby inspiring a sense of belonging among the inhabitants (Kramers et al., 2014).

2.7.8 Smart Energy

The European Smart Cities Initiative, together with a variety of organisations, have contributed to the development of smart cities in Europe. One of the main aims was to use renewable energy sources and green transportation to create a smart city model. A target was set to reduce the use of greenhouse gases by promoting more sustainable measures of producing and using electricity. A smart city energy model, which is decentralised and constantly monitored, with real time feedback, is essential for the promoting a sustainable energy model. This can be achieved through the use of smart meters in conjunction with mobile applications (Anna et al., 2014). It enables two-way communication between customers and service providers, and also helps customers to be aware of their consumption. Using technology helps to reduce energy usage, based on the Environmental Impact Assessment (EIA). ICT has the potential to reduce energy usage in four main dimensions which are:

i. Dematerialisation

Dematerialisation entails the phasing out of physical information storage devices such as compact discs and hard drives. This is substituted by tools such as cloud computing where information is stored and accessed using an ICT network.

ii. Demobilisation

This process involves the transportation of anything that can be digitised over a network instead of doing it physically. The replacement of letters by electronic mail, the facilitation of electronic bill payments and teleconferencing for meetings are some of the few examples that smart cities can implement in this dimension.

iii. Mass Customisation

Mass customisation is the tailoring of goods and services to meet the specific needs. It also offers a platform for the customisation of personal services, such that the system learns the preferences of citizens on a personal level. For instance, the system can learn travel routes to work and thus inform commuters on the best times to leave for work using the most efficient route. This system uses less resources through intelligent operation, personalisation and adaptation.

iv. Intelligent Operation

Intelligent operation ensures the efficient use of resources to all systems in a Smart City framework, such as transport and energy. Sensors are used to control aspects such as lighting in buildings, recycling, and sharing electricity with neighbouring buildings. These structures strive to achieve the Zero Energy Building status (Aditya et al., 2015).

2.7.8.1 Zero Energy Buildings

Zero Energy Buildings have very little to no greenhouse gas emissions, with systems that ensure efficient usage and recycling of energy. These buildings can produce their own energy using renewable means such as solar, wind, geothermal energy and biogas. The European Union's directive on green energy stipulated that in 2020, buildings must reduce using energy sources from the consumption of fossil fuels. Smart appliances that store and release energy on demand are incorporated to ensure increased energy savings (Kylili and Fokaides, 2015). Zero Energy Buildings can be integrated into the smart city framework by using environmental design and analysis methods. This system must be complimented by smart transportation systems as mentioned in Section 2.6.1.3 (Gionanni et al., 2014).

2.7.8.2 Smart Grids

Smart Grids are electricity networks that allow two-way communication between consumers and electricity distributors. It helps increase savings in that electricity is provided and stored on demand. The most important parameter is the amount of electricity produced in relation to the amount of electricity consumed by end users. This is done using automated systems, and ICT contributes to efficient supply and consumption of electricity (Gionanni et al., 2014).

A smart city, therefore, has the same end vision as the Symbio City approach, but aims to improve on sustainability using a different and more technological approach. A comparison of the two methods is shown in the following section.

2.8 Comparison between Smart City and Symbio City

Sections 2.5 and 2.6 show that cities can adopt different approaches to attain sustainability. The two approaches considered have general applications in any city in the world, from the developed to the developing world. Application of these concepts differ as cities adopt different strategies to improve living conditions. Table 2.5 outlines a summary of the different approaches used to improve sustainability in cities.

Table 2-5. Summary of Smart vs Symbio City Approach

Symbio City Approach	Smart City Approach
More flexible to be applied to a developing country's context	More suited for cities in developed countries
Focus is on the basic symbiosis of different areas and sectors within a city framework	Synergy is achieved using ICT
Provision of basic needs and services (poverty alleviation)	Improvement of already existing services
Physical exchange of information between different stakeholders	Crowdsourcing and Real-Time information use
Law enforcement authorities use physical means of monitoring	Extensive use of sensors and cameras for monitoring

The comparison between the Symbio City and Smart City approaches highlights the differences in methods by which cities are employing to improve on sustainability. They both seek to reach the same ultimate goal, which is to be sustainable but using different strategies. The Symbio City incorporates a more back to basics approach, focussing on the synergy between the different dimensions within a city. This symbiosis is essential for improving service delivery in cities where basics such as potable water, electricity and shelter are not readily available to the average citizen. With most government departments in developing countries struggling to synergize development within their cities, the Symbio City concept provides guidelines towards a more coordinated approach. It also helps in clearly defining roles within governing bodies by highlighting areas of overlap and which require maximum coordination. This will ensure the efficient provision of basic services, including alleviating poverty in marginalised communities. This makes the Symbio City concept more applicable to a city in the developing world.

Cities in developed countries have lower poverty rates, hence their focus is not sorely on poverty alleviation or the provision of basic services. Their focus is on improving the already existing services within their cities by using ICT as the core of their development strategies. Technology is essential in the integration of systems and improving on efficiency. This approach is better suited towards cities in developed countries, where basic services are readily available to the average citizen. Technology has been infused in almost every aspect of their daily lives, including the extensive use of sensors in and around the city to collect real time data. In contrast, the Symbio

City uses technology to a lesser extent, with the improvement of living conditions employing a more physical approach. This is more applicable to a city in the developing world and better suited to develop a framework for cities in Africa. Once the issue on the provision of basics has been addressed, cities in developing countries can then move towards fully adopting the use of ICT to further their development, eventually evolving into a Smart City. The challenges described in Section 2.2 are mainly focussed on challenges facing cities in developing countries, in which the Symbio City approach would be flexible and adaptive enough to create s sustainable framework for a typical African city.

Sustainable city frameworks make use of indicator systems, which are used to craft, monitor and implement policies aimed at improving conditions in cities. Sustainability Indicators have become common over the years, with most cities subscribing to their use (Aschkenazi et al., 2012). The following section introduces and outlines the role of sustainability indicators in cities, and how they can be used to achieve liveable and environmentally friendly conditions in cities.

2.9 Sustainability Indicators and Rating Systems

Sustainability Indicators are tools that provide information to enable the measurement of a city's performance. They simplify complex phenomena into an easy and understandable form, enabling communication channels between different stakeholders in a city (Aschkenazi et al., 2012). These indicators also enable linkages between different sectors and departments of a city to be identified and compared. They can also be used to hold governments, municipalities and communities accountable in their efforts towards sustainability. Political relationships between citizens, public officials, companies and experts may be improved through working together to create a framework by using sustainability indicators. The indicators also guide in decision-making processes towards the crafting of new policies or altering existing ones, enabling the effective allocation of resources and identification of critical areas. They are relevant in an environment where certain targets must be met before negative events affect the effective operation of a city. Sustainability planning is critical on a municipal level as it enables solutions to be devised in cheaper and more innovative ways suited to a particular city. Most cities worldwide have adopted the use of sustainability indicators as a means of monitoring progress and guiding their development processes (Mahsa et al., 2017). Before cities choose their indicators, they must have a clear vision of what they aim to achieve and the actions to be taken. This will help to inform citizens and relevant authorities to review different methodologies that can be used to devise and implement a sustainable plan.

The most common functions of indicators include the prescription of technical solutions. Those that offer technical solutions are known as perspective indicators, which require weighting

methods to allow for evaluation. Weighing of indicators means that an indicator is given higher or lower value in its contribution to a result as compared to another. The weighting is target specific, and involves complex mathematical calculation and expert analysis to guide city managers, policy makers and planners (UN-Habitat, 2009). Sustainability Indicators must have the following general properties for them to be useful:

- Must be readily available, current and be annually updateable
- Enable ready comparability among cities
- Relevant to the local context of decision-making processes
- Cheap to collect
- Must be meaningful to all cities across the globe, regardless of cultural, geographical and political differences
- Flexible and be readily modified with time
- Easily understandable (Siemens, 2011)
- They must be a true reflection of facts
- They must aggregate information
- They must be able to detect a small change in the system
- Must be reliable and easily repeatable by another expert/ researcher
- The indicator must have meaning to both laymen and technical experts
- People must get to know the indicator and the impact it has on their lives
- The indicator must solicit institutions to want to produce new knowledge and information (EU, 2015)

Sustainability Indicators can be chosen using either a top-down or bottom-up approach, which was outlined in Sections 2.2.2 and 2.2.3. The key difference between these two approaches is the level of complexity involved in obtaining and evaluating the indicators (EU, 2015). It also requires the study of current models and available data. A baseline must be chosen to help the city to achieve its targets and monitor progress. Targets chosen should be Specific, Measurable, Achievable, Realistic and Timed (SMART). There must be cooperation between stakeholders to enable and foster a culture of trust and integrity. Most municipalities do not have environmental sustainability plans in place, largely because they did not consider the holistic approach required to solve modern day challenges. Factors such as the ability to summarize issues, relevance to subject matter and inclination towards the municipalities' goals must be taken into consideration when choosing the indicators. The most important feature is ability to show multidimensionality as different aspects pertaining to sustainability need to be addressed.

One of the major challenges faced in obtaining indicators is lack of information. Most cities in Africa do not have accurate information with regards to issues such as population numbers and

urban GDP figures. For example, information on informal settlements in most African cities was not defined in a uniform manner. This lack of information means that some of the assessments will be qualitative and towards policies, which only enables future performance to be measured. This challenge needs to be addressed to ensure that sustainability policies are crafted based on accurate and reliable data (Aschkenazi et al., 2012). Great effort is required for indicators to be noticed by decision makers, as they make decisions based on a fixed set of sources. Effort is also required to get the indicators into a setting where decision makers will see it. There exists a risk of some indicators going unused as they might not align with community values. Indicators that are crafted by communities, therefore, may be of more significance than those obtained using the top down approach. Further, substantial efforts have been devoted to creating lists of indicators that address the concept of sustainable development in a comprehensive way. This has been done by organisations such as the United Nations' Commission on Sustainable Development (UNCSD), European Union's Sustainable Development Strategy (EU SDS), World Bank's World Development Indicators (WDI) (EU, 2015).

2.9.1 Current Benchmarking Systems

Most benchmarking systems use indicators to evaluate various aspects of urban performance. Linear models are used for aggregation, and a few the benchmarking systems currently in use are the City Prosperity Index (CPI), Sustainable Cities Index (SCI), Cities in Motion Index (CiMI), Global Power City Index (GPCI), Mercer's Quality of Living and the Spatially Adjusted Living Index. In this research, the indicators were based on the City Prosperity Index developed by the United Nations in 2012. This method focusses mainly on the synergies between different aspects of the way the city functions. This was in line with the Symbio Cities concept, which focusses on synergies and is better suited for cities in developing countries. CPI also had better coverage of indicators, while the other benchmarks focussed mainly on ranking and comparison between cities. This research is about developing a framework for an African city, therefore comparison between the framework and those of other cities would not be considered as the first step. The City Prosperity Index was also used as a guide in determining the different dimensions for the overall indicators, together with the dimensions described in Section 2.2.

2.9.2 City Prosperity Index

The City Prosperity Index (CPI) was developed by the UN Habitat in 2012 to foster synergy aspects such as infrastructure, the quality of life for citizens, economic and agricultural productivity, social cohesion, and environmental sustainability. CPI looks to shift focus on economics and include a people centred approach. It consists of a set of indicators that are used to gauge progress towards achievement of sustainability goals. It also focusses on how the connections between the different aspects can be maximised to ensure efficient execution and use of resources. However, the UN Habitat does not have a clear method or explanation as to how the

weighting of the indicators is carried out. They stated that refinement was still required to assign specific weightings to each respective indicator (Wong, 2015). The issue of weighting will always be subject to debate, hence it was encouraged that discussions be opened to reach a common ground on this matter (UN-Habitat, 2012). In this research, the 'weighting' of the indicators would be substantiated by the challenges described in Section 2.2 together with case studies conducted and described in Section 4. The cross comparison of the two sections were used to determine the indicators for a sustainable city in Africa.

The City Prosperity Index focusses on five major aspects of interest:

1) Environmental Sustainability to ensure that the growth and development of cities does not impact the surroundings and overuse resources.
2) Productivity pointing towards economic growth and agricultural development.
3) Infrastructure focussing on the improvement of the physical environment.
4) Improvement of social services and provision of basic human needs.
5) Social inclusion of people regardless of social or economic status (UN-Habitat, 2014)

The inclusion of different dimensions in a framework makes them open to different interpretations by people and organisations. This results in a fuzzy concept that requires a lot of input in terms of the indicators, so they can help in relating these different dimensions (Wong, 2015). The main difficulties lie in the collection of data, which is one of the main challenges of cities in developing countries. In this research, the system of indicators devised will be suited towards a typical African city, with the available data and case studies backing up the proposed indicators. They can be modified to suit a typical African city and used as a guideline in obtaining indicators for various cities, depending on factors such as resources, geographical location, and political will. The accuracy of the data determines the effectiveness of the framework, which influenced the indicators that were chosen in this research.

Indicators must meet certain criteria for them to be valuable in the research. These entail:

- Accurate scientific data
- They must be measurable. However, soft indicators like satisfaction and comfort cannot have quantifiable measurements.

The following section presents the sustainability indicators that were derived from the Literature Review.

2.10 List of Sustainability Indicators

This section presents the list of worldwide sustainability indicators. They were obtained from literature and publications from organisations such as the UN, WHO, World Bank and African Municipalities, who have conducted extensive research on sustainable cities. The indicators were categorised according to the twelve sections in line with the urban challenges defined in Section 2.2. The Sustainability Indicators were collected from a worldwide perspective, inclusive of those in the developed countries. This enabled a wide coverage of aspects to be considered, and they would then be narrowed down to those applicable to an African city. Each indicator has a rationale on why it was chosen, and how it will help in the creation of a sustainable city. The sources from which the indicators were obtained are included in the tables.

Table 2-6 Sustainability Indicators for Governance and Legislation

Governance and Legislation		
Indicator	**Description/Rationale**	**Reference**
% citizens with knowledge of the city's vision	The more people that are aware of the city's visions, the better they can contribute to crafting effective and balanced policies	Aschkenazi et al., 2012
% community meeting attendance	Creates a platform for discussion between different stakeholders	Aschkenazi et al., 2012; Maparet al., 2017
Sectors represented at community meetings	Encourages coordination of sectors in policy making	Aschkenazi et al., 2012
% Women in governance	To promote equality in decision making processes	Aschkenazi et al., 2012; EU, 2015
Availability of city data	Shows current city conditions which impacts future decision making	EU, 2015
Transparency and Accountability levels	Promoting trust between the citizens and authorities	EU, 2015; Mapar et al., 2017
Level of corruption	To eradicate corruption and promote lawfulness in cities	Aschkenazi et al., 2012; EU, 2015
Immigration tolerance	To be able to accommodate and integrate immigrants looking for opportunities	EU, 2015
% budget on green projects	Demonstrates government's commitment to environmental conservation	Aschkenazi et al., 2012
% qualified personnel	Enhances informed decision making by qualified personnel	
Council representatives per resident	Emphasizes the representation of residents by government personnel	EU, 2015; Mapar et al., 2017
Local revenue collected	Influences the city's budget and guides in the improvement of collection methods	Mapar et al., 2017
Voter election turnout	Helps in gauging citizen participation in electing leaders	EU, 2015
Accessibility to public services	Citizen access to governance platforms	Aschkenazi et al., 2012

Table 2-7. Sustainability Indicators for Urban Infrastructure and Planning

Urban Infrastructure and Planning		
Indicator	**Description/Rationale**	**Reference**
Urban population density	Indicates the level of crowdedness in the city	Aschkenazi et al., 2012; Siemens, 2011
Number of dilapidated buildings	Enables authorities to identify buildings to renovate or decommission	EU, 2015; UN, 2007
% green buildings	The amount of sustainable buildings in the city	Aschkenazi et al., 2012; Siemens, 2011; Mapar et al., 2017
% abandoned buildings	Enable authorities to identify disused buildings so that they can either be refurbished or demolished	Aschkenazi et al., 2012
% infrastructure in good condition	Enables maintenance and upgrade of existing infrastructure	EU, 2015
% area green spaces	The amount of green areas in relation to the total area of the city. Allows for environmental protection and preservation of biodiversity	EU, 2015; UN, 2007
% area of productive land	Enables knowledge of crop and vegetation producing land	(ERM, 2008)
Buildings with automated systems	The number of buildings equipped with systems to manage resource usage and maximise efficiency without human input	(OECD, 2008)

Table 2-8. Sustainability Indicators for Housing

Housing		
Indicator	**Description/Rationale**	**Reference**
Average living area per inhabitant	Indicates the level of crowdedness in houses	EU, 2015
% low cost housing	To cater for the marginalised and homeless communities, particularly in developing countries	Aschkenazi et al., 2012
% legal housing	To enable authorities to provide services and to know which houses were built according to urban laws and standards	Aschkenazi et al., 2012
Number of informal settlement dwellers	Enables authorities to know the number of people who will need low cost housing and subsidies for services, particularly the urban poor	Aschkenazi et al., 2012; Siemens, 2011
Satisfaction with housing situation	To obtain feedback and improve current housing conditions	EU, 2015
Number of resettled families	People who have migrated to cities in search of opportunities	Aschkenazi et al., 2012
Rent to income ratio	Average rent to household income	UN Habitat, 2004
Availability of housing finance	Provides facilities to purchase their own homes	EU, 2015
Interim services in informal settlements	Improves living conditions in otherwise inhabitable settlements	EU, 2015
% population living in hazard prone areas	Enables authorities to implement protection measures for citizens	EU, 2015

Table 2-9. Sustainability Indicators for Transportation

Transportation		
Indicator	**Description/Rationale**	**Reference**
Number of private vehicles	Enables authorities to address the issue of traffic congestion and GHG emissions	Aschkenazi et al., 2012
Public transport capacity	It must be able to cater for those who do not have private cars	Aschkenazi et al., 2012; Mapar et al., 2017
Public transport cost per capita	Enables authorities to gauge the affordability of the transport system to the public	EU, 2015
Number of road fatalities	Helps to implement measures to reduce fatalities in road accidents	Aschkenazi et al., 2012; Mapar et al., 2017
Public transport coverage per km^2	Public transport must cover as much of the city as possible	Aschkenazi et al., 2012; Siemens, 2011
Noise pollution	To be able to gauge the levels of noise pollution due to vehicles	Mapar et al., 2017
Travel times	To enable citizens to know the time taken to make a trip	Aschkenazi et al., 2012
Number of traffic violations	To gauge the level of responsibility for the drivers	Aschkenazi et al., 2012
Number of road accidents	To identify hot spots and improve driving and road conditions	Aschkenazi et al., 2012
Number of modal splits	To improve transport nodes such as train and bus stations	Aschkenazi et al., 2012; UN, 2007
Number of bus stops and train stations	To provide coverage of transport nodes around the city	Garau, 2016
Route information availability	To guide passengers with routes and to help with travel plans	Garau, 2016
Lanes dedicated for public transport	To enable high occupancy vehicles to reduce their travel time	Aschkenazi et al., 2012
Ease of intermodal change	To improve the changing of one transport mode to another	EU, 2015
Emission monitoring	To monitor and curb GHG emissions from vehicles	Mapar et al., 2017

Coverage of cycle and walking paths	To encourage citizens to use other forms of sustainable	Aschkenazi et al., 2012; EU, 2015
Availability of parking space	To provide parking for vehicles for personal and commercial purposes	EU, 2015

Table 2-10. Sustainability Indicators for Energy

Energy		
Indicator	**Description/Rationale**	**Reference**
Primary energy consumption per capita	Enables energy to be channelled to relevant areas and to penalise overconsumption between industrial and domestic consumption	Aschkenazi et al., 2012; Siemens, 2011; EU, 2015
% buildings with renewable energies	Enables authorities to gauge the efficiency of buildings	Aschkenazi et al., 2012; EU, 2015; Mapar et al., 2017
% houses with electricity	Houses with electricity from the conventional grid	Aschkenazi et al., 2012; Siemens, 2011
Transmission losses	Enables authorities to know the actual amount of electricity delivered to homes and the efficiency of the grid system	Aschkenazi et al., 2012
% primary energy producers	To know the number of electricity producers contributing to the main grid	Siemens, 2011
Clean Energy Policies	Demonstrates commitment to implementing clean policies	Siemens, 2011
% renewable energy production	Shows the amount of renewable energy used in relation to the conventional supply	Siemens, 2011

Table 2-11. Sustainability Indicators for Water and Sanitation

Water and Sanitation		
Indicator	**Description/Rationale**	**Reference**
Water consumption per capita	To enable authorities to gauge demand	Aschkenazi et al., 2012; Siemens, 2011
Access to potable water per capita	To gauge the extent of clean water provision in the city	Aschkenazi et al., 2012; Siemens, 2011
Water Quality Index	To control the quality of water in and around the city	Aschkenazi et al., 2012
% water recycled	To save water and energy through reuse of water	Aschkenazi et al., 2012; Mapar et al., 2017
Water leakage and loss	Enables authorities to find a fix leaks to efficiently provide water	Aschkenazi et al., 2012; Mapar et al., 2017
Residents with access to sanitary toilets	To enable authorities to provide clean sanitary facilities for residents	Aschkenazi et al., 2012
Drinking water in public spaces	The provision of potable water in parks, stations, stadiums, etc.	EU, 2015
Coverage of sanitary sewerage	Availability of sewer disposal systems in communities	Aschkenazi et al., 2012
Number of water meters	Enables authorities to monitor water usage and tariffs	Aschkenazi et al., 2012
Amount of pollutants in water bodies	To manage water sources and levels of pollution	EU, 2015
% water treated before discharge	To minimise water pollution and regulate factories from polluting water sources	Siemens, 2011
Water costs	Affordability of water services for the citizens	Siemens, 2011
% houses with municipal water	Number of houses with clean potable water	Aschkenazi et al., 2012; Siemens, 2011

Table 2-12. Sustainability Indicators for Waste Management

Waste Management		
Indicator	**Description/Rationale**	**Reference**
Waste generated per capita	To enable effective waste collection and disposal methods	Siemens, 2011
% waste recycled	To encourage a culture of recycling among citizens	Aschkenazi et al., 2012; Mapar et al., 2017
Energy extraction from waste	To improve efficiency of the grid through clean energy production	Aschkenazi et al., 2012; Mapar et al., 2017
Solid waste collected and deposited into landfills	To enable authorities to implement effective waste disposal methods	Aschkenazi et al., 2012; Mapar et al., 2017
Hazardous waste generated	To separate waste that is hazardous to the environment	EU, 2015; Mapar et al., 2017

Table 2-13. Sustainability Indicators for Environmental Degradation and Climate Change

Environmental Degradation and Climate Change		
Indicator	**Description/Rationale**	**Reference**
Air Quality	To assess the quality of air breathed in by citizens	Aschkenazi et al., 2012
Consumption of ozone depleting substances	To limit the use of substances which damage the environment	Aschkenazi et al., 2012; UN, 2007
Reforestation – Deforestation rate	To enable authorities to control the cutting and planting of trees	Aschkenazi et al., 2012
Levels of Particulate Matter	To assess the risk associated with contaminated air	Aschkenazi et al., 2012
% area of land under sustainable management	To control land degradation and biodiversity preservation	EU, 2015
Citizen perception on nature protection	To educate citizens on the importance of the environment	Mapar et al., 2017
Area of degraded land	To resuscitate damaged land	EU, 2015
Number of unhealthy days in a year	Enables authorities to warn citizens about unhealthy air	Mapar et al., 2017
Industrial regulation compliance	To control environmental damage by industries	EU, 2015
Environmental monitoring levels	To monitor the integrity of the surrounding environment	Siemens, 2011
% trees per unit area	Trees improve the air quality of a city through oxygen production	Siemens, 2011; UN, 2007
Levels of climate change resilience planning	Demonstrates the levels of commitment to the city's resilience	Mapar et al., 2017
Number of environmental awareness programmes	To educate citizens and industries on environmental preservation	Aschkenazi et al., 2012; UN, 2007
GHG emissions per city	Enables cities to monitor greenhouse gas levels	Aschkenazi et al., 2012
Climate change policies	Plans to mitigate climate change	Aschkenazi et al., 2012; EU, 2015; Mapar et al., 2017
Public Awareness	The level of public knowledge in relation to their environment	EU, 2015

Table 2-14. Sustainability Indicators for Disaster Management

Disaster Management		
Indicator	**Description/Rationale**	**Reference**
Houses in hazardous locations	Enables rescue authorities to be more alert pertaining to these areas	Aschkenazi et al., 2012; Mapar et al., 2017
Disaster warning instruments	Automated instruments to warn residents of impending disasters	EU, 2015
Number of firefighters per 1,000 population	Signals the manpower and efficiency of rescue services	UN Habitat, 2004
Emergency response times	Allows citizens to know how long it takes to emergencies to be addressed	EU, 2015; UN, 2007
Number of emergency operation centres	Enables coverage of the city's emergency response system	EU, 2015; UN, 2007
Education levels for disaster response	Educates citizens on how to carry out emergency rescue operations	Aschkenazi et al., 2012; EU, 2015; Mapar et al., 2017
Real time data availability	Provides data to early warning systems	EU, 2015

Table 2-15. Sustainability Indicators for Health and Safety

Health and Safety		
Indicator	**Description/Rationale**	**Reference**
Number of hospitals and clinics	Coverage of health services in a city	Aschkenazi et al., 2012
Number of doctors and nurses per capita	Number of health staff in a population	Aschkenazi et al., 2012
Infant mortality rate	To curb the deaths of infants and improve their health	Aschkenazi et al., 2012; UN, 2007
Life expectancy	To gain knowledge on the average lifespans of citizens	Aschkenazi et al., 2012
Crime Rates	To enable authorities to identify areas of crime and eradicate them	Aschkenazi et al., 2012
Adults with healthy weight	To improve health among adult citizens and promote healthy living	EU, 2015
Respiratory diseases per 1,000 population	Diseases caused by air pollution	EU, 2015; Mapar et al., 2017
Violent/Intentional homicides	Enables authorities to control crime	Aschkenazi et al., 2012
Adolescent birth rates	Education of teenage pregnancies	Aschkenazi et al., 2012
Prevalence of tobacco usage	To know the number of smoking and non-smoking citizens	EU, 2015
Distances to nearest health centres	Travel distances to obtain medical attention	UN, 2007
Chronic illnesses per 1,000 population	To know the number of citizens with terminal conditions	Aschkenazi et al., 2012
Number of police officers	To show the levels of law enforcement in the city	EU, 2015
Number of immunised children	To improve health conditions among children	EU, 2015
Number of malnutritioned children	To enable the provision of food to marginalised children	EU, 2015
Number of children abuse cases	To protect children from crime and to educate citizens	EU, 2015
Number of women abuse cases	To protect women from crime and educating citizens	EU, 2015

Table 2-16. Sustainability Indicators for Education, Science and Technology

Education, Science and Technology		
Indicator	**Description/Rationale**	**Reference**
Number of primary and secondary schools	Coverage of educational institutions	Aschkenazi et al., 2012; Mapar et al., 2017
Number of tertiary institutions	Level of higher education in cities	Aschkenazi et al., 2012; Mapar et al., 2017
Male female ratio in educational institutions	Gender equality in education	Aschkenazi et al., 2012
Literacy rate	Number of people who can read and write	Aschkenazi et al., 2012; EU, 2015
High school and primary school pass rates	Enables the assessment of education quality	Aschkenazi et al., 2012; Mapar et al., 2017
Number of libraries	Encourages a culture of reading among citizens	EU, 2015
Research and development expenditure	Commitment of authorities to developing new skills and concepts	EU, 2015
Number of patent applications	Highlights the level of research and development	EU, 2015
Number of computer literate people	Encourages authorities to educate	EU, 2015
Number of internet users	Level of internet usage in the city	EU, 2015
Number of IT initiatives	Levels of technological development	Aschkenazi et al., 2012
Environmental education programs in schools	Educate children about the environment	EU, 2015
Broadband internet access	Accessibility to internet	EU, 2015
Mobile telephone subscribers	Number of people with access to mobile phones	EU, 2015
Number of computers per school	Fosters computer literacy among students	EU, 2015
Number of computers per household	Enhances computer literacy	EU, 2015
Student teacher ratio	Has a direct influence on the quality of education	EU, 2015

Table 2-17. Sustainability Indicators for Social, Cultural and Economic aspects

Social, Cultural and Economic		
Indicator	**Description/Rationale**	**Reference**
% population formally employed	People working on listed company jobs	Aschkenazi et al., 2012
% population informal traders	People working informally to earn a living	Aschkenazi et al., 2012
% population unemployed	Number of citizens without a formal or informal job	Aschkenazi et al., 2012
Male to female ration in formal employment	Gender equality	Aschkenazi et al., 2012
Net import and export rates	Indicates the level of economic development in cities	Aschkenazi et al., 2012
Foreign Direct Investment	Level of development through investments from outside the country, this can also boost tourism	Aschkenazi et al., 2012; UN, 2007
Debt status	Number of people who are in debt	Aschkenazi et al., 2012
Poverty rate	Number of residents living below the poverty datum line	EU, 2015
Cost of Living	Money spent on basic household goods and services	EU, 2015
Suicide rate	Indicates the level of social quality of life	EU, 2015
% population with disabilities	To enable the provision of facilities for disabled people	Aschkenazi et al., 2012
Living conditions index	Level of satisfaction with living conditions	Aschkenazi et al., 2012
Income distribution and equality	Equality of income among different ethnic groups, races, gender, etc.	Aschkenazi et al., 2012
% access to leisure	To provide relaxation facilities for residents	Mapar et al., 2017
Recreation equipment	To provide relaxation facilities for the citizens	Mapar et al., 2017
Child headed families	To enable governments to aid with subsistence	Aschkenazi et al., 2012

Cultural activities per year	Allows interactions from people from different social, economic and ethnic backgrounds	Aschkenazi et al.,2012, EU, 2015
GDP per capita	Gross Domestic Product represents the total value of all products and services within the city	EU, 2015

The sustainability indicators from Tables 2-6 to 2-17 are the basis upon which the framework of indicators for a typical African city will be developed in this research.

2.11 Conclusion

The Literature Review outlined the challenges being faced by modern day cities, particularly in Africa. From these challenges, current frameworks derived from worldwide initiatives aimed at improving conditions in cities were outlined. The most recent initiatives were the Sustainability Development Goals, aimed at reducing poverty, promoting gender and economic equality, the provision of basic human needs and services, and climate change. The SDGs influenced the creation of a platform to review different approaches used to attain sustainability. Two main approaches applicable to the developed and developing countries were also reviewed. This gave rise to the concept of the Smart City and Symbio City, providing a guide on the applicability of each of these concepts to developing countries. A comparison of the Smart and Symbio city approaches provided a summary of the differences in the way they perceive sustainability. From this, the concept of Sustainability Indicators, common to all cities, was introduced. The next chapter involves the methodology of this research, which shows how the indicators derived were used to create a framework for an African City of the Future.

3 Methodology

3.1 Introduction

The methodology for this research was largely influenced by information derived from the literature review. The Literature Review was therefore the first step in the methodology, which outlined challenges faced by modern day cities. From these challenges, current solutions being implemented were highlighted in the form of a sustainable city. The sustainable city was taken as a general approach to resolving urban challenges. Two approaches to creating a sustainable city, namely the Smart and Symbio City, were identified and reviewed. These concepts enabled a comparison to identify common trends between these two approaches towards sustainability. This would help to derive an optimal and balanced approach in cities that are aiming towards attaining sustainability in an African context. The definition of these two concepts led to the introduction of Sustainability Indicators, which are used as measures of sustainability within a city. These indicators form the building blocks of the proposed framework for a typical African City of the Future.

The Sustainability Indicators in Section 2.10 were collected based on literature, organisational reports and municipal publications. The indicators were collected from a worldwide perspective, with a universal applicability to both the developed and developing countries' contexts. The collection of 144 Sustainability indicators from various publications ensured that they cover a wider area in terms of applicability. These indicators formed the basis of creating a framework that caters to all the main pillars of sustainability and giver a more balanced approach with regards to the different dimensions in a city.

3.2 Methodological Approach

Section 1.5 in the Introduction shows a flowchart for the methodology used in this research. The first part of the literature review outlined the challenges being faced by modern day cities. Defining these challenges was the first step in encouraging the engagement of different stakeholders within the city. This current section breaks down the methodology as outlined in Section 1.5 and detailed further in Figure 3-1 on the following page.

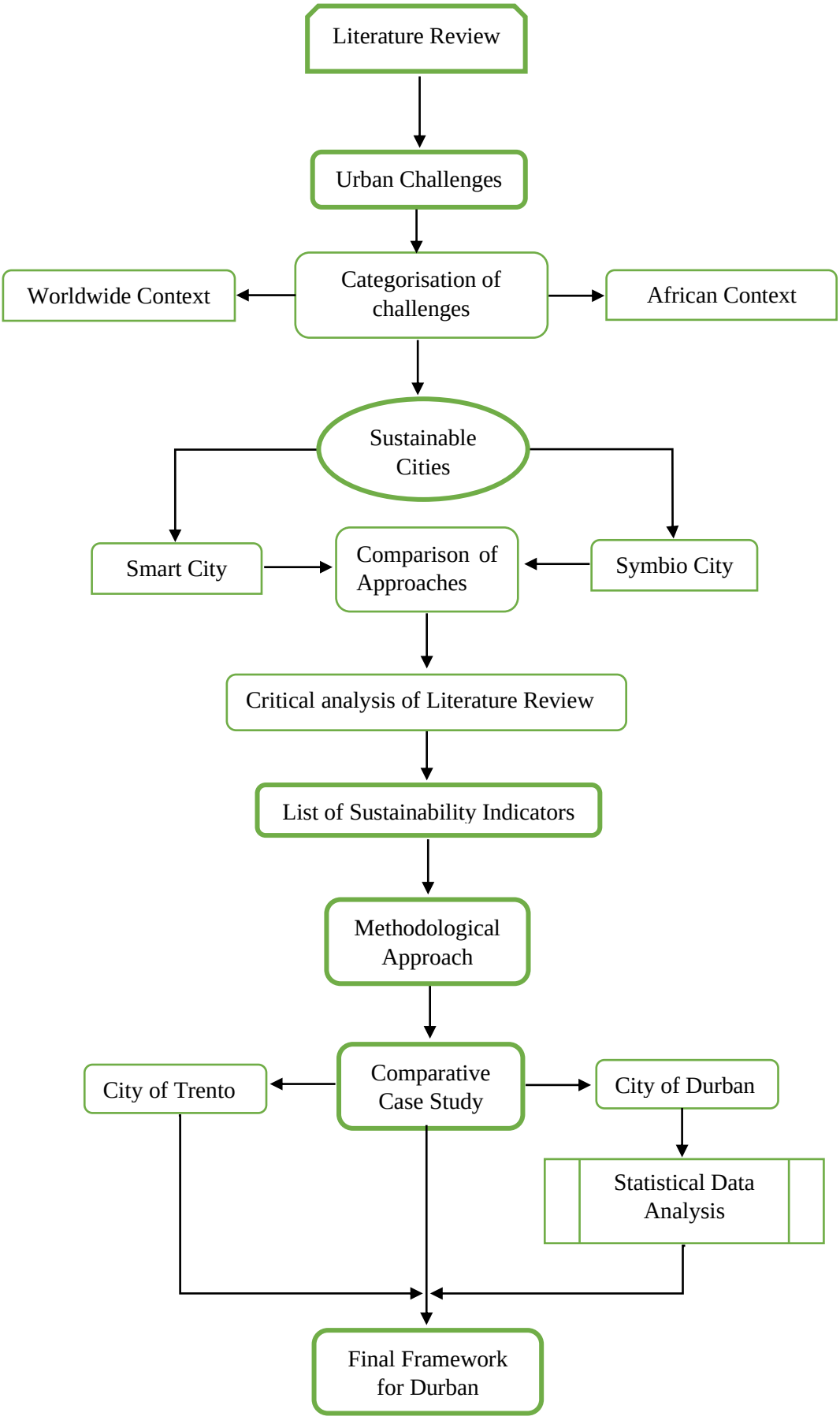

Figure 3-1. Methodological Approach

3.2.1 Analysis of Urban Challenges

The Literature Review firstly provided a detailed outline of urban challenges currently being faced by cities from a general and worldwide context. The conclusion was that challenges caused by rapid urbanisation were outweighing opportunities and would not be easily resolved unless cities change the way they operate. The transition of countries from a rural to urban based population, particularly in Africa, is straining cities. This has had negative consequences for the environment and quality of life for residents and visitors alike (Bibri and Krogstie, 2017). A definition of challenges therefore enables a clear and near accurate assessment of critical conditions currently prevalent in cities, as well as noting trends and identifying areas that require attention. It also allows authorities to understand and anticipate future challenges such as demography, the economy, the environment, spatial and social aspects. Urban challenges encourage a more inclusive approach with different stakeholders, offering solutions in line with their expertise (Wong, 2015).

Multidisciplinary problem definition and solving approach is an effective way to devise holistic solutions. This approach would also guide in decision making and policy direction, prompting different municipal sectors to take responsibility for their respective departments. It also laid a foundation to assess current operational methods and measures of change to ensure effectiveness. Identification of critical vulnerabilities in a city was also important to ensure that resources are allocated to resolving challenges, particularly for vulnerable citizens. They also highlighted the vulnerabilities and risks which encourage authorities to rethink new strategies with regards to urban development trajectories. Defining urban challenges created a platform for categorising them into different sectors (Verma and Raghubanshi, 2018).

3.2.1.1 Categorisation of Challenges

Categorisation of urban challenges enabled them to be clearly defined within a specific context. It also highlighted challenges specific to certain departments to allow for more direct solutions. The grouping of Sustainability Indicators was based on the categorisation of challenges. This has a few problems as some of the challenges are interlinked and have direct bearing on each other. It also fragments departments, which can lead to overlaps in roles. Eleven major categories were chosen following those in Section 2.2 in the Literature Review. They were chosen systematically to cover the managerial, infrastructural and service provision aspects of the city. The categories were as follows:

a) Indicators for Governance and Legislation

Sustainability Indicators for governance look at the managerial aspects which allow for effective management. Governance is an important aspect as this is where all decisions stem from, thereby affecting every other sector within the framework (UN-Habitat, 2016b). Most of the challenges

faced by African cities are due to ineffective administration, corruption and lack of qualified personnel. Departmental fragmentation makes it difficult to coordinate projects and enforce laws as they may clash. This results in the disregarding of urban laws by citizens, businesses and mostly manufacturing industries with respect to the environment. It also creates environments that are hard to regulate, resulting in ungovernable cities. For cities to improve, municipal governments must take initiatives to ensure effective and environmentally friendly operation. Sustainability Indicators will ensure that governments are held accountable with regards to their performances. The onus falls upon them to ensure policies result in an improvement in living conditions and the quality of life for every citizen (eThekwini, 2017).

b) Indicators for Urban Infrastructure and Planning

Since Urban Planning and infrastructure entails the overall design of the city, indicators ensure efficient performance and functionality. Poor governance systems have a direct bearing on the general planning and infrastructural layout of a city. Lack of legislation enforcement has resulted in development that is sometimes not in accordance with the city's plans. This has resulted in urban sprawl and the creation of informal settlements. In most African cities, the conglomeration of formal and informal settlements has led to the birth of megacities (Fu and Zhang, 2017). The use of indicators will ensure that the development of cities is kept within reasonable limits which authorities are able to handle. Most cities do not have adequate resources and manpower allocated to maintaining existing infrastructure, which is already failing to cope with increasing population. The use of Sustainability Indicators ensures that action is taken with regards to maintaining infrastructure to cater for the city's population (UN-Habitat, 2016e). It is important that urban laws are used to govern the design and functionality of general infrastructure such as waster reticulation systems, sewer systems, drainage systems, public spaces, roads and buildings.

c) Indicators for Housing and Informal Settlements

Due to increasing population and rising demand for housing cities, accommodating migrants is becoming increasingly difficult. This has been further exacerbated by inadequate urban planning, resulting in the growth of informal settlements. Indicators can keep track of housing supply in relation to demand and acceptable levels of urban densities. Municipalities need to find ways of providing affordable services to citizens, particularly in informal settlements (UN-Habitat, 2016h). The provision of housing services is now a basic human right which is pivotal in the creation of a stable environment in the city. Low cost housing schemes have not been effective as most of the urban poor cannot afford to purchase or rent these houses as they rely on government subsidies. More wealthy citizens purchase these properties, thus widening the economic and social gap between them and the poor (Girardi and Temporelli, 2017).

d) Indicators for Transportation

Transportation is the lifeblood of a city as it involves the movement of people, goods and services. The challenges affecting current transportation systems will help to devise solutions to ensure effective mobility in the city. The solutions look at aspects such as congestion, the state of road networks, ease of mobility and the modes of transport (UN-Habitat, 2016f). It also involves the regulation of carbon emissions from vehicles. This is important since transport now accounts for a fair share of carbon emissions due to its reliance on fossil fuels. Road surface maintenance and improvement enhances safety and helps in the creation of an efficient transportation system. The collection and analysis of transportation data can help in defining indicators that improve mobility while minimising environmental damage (WBSCD, 2015).

e) Indicators for Energy Production and Consumption

Energy production is responsible for 75% of greenhouse gas emissions. Municipalities must find cleaner and decentralised means of generating electricity to reduce greenhouse gas emissions which are responsible for climate change. By using indicators, they are able to monitor, educate and encourage customers to be conservative in electricity usage and, if possible, produce their own electricity. One way of achieving this is through installing clean energy generation methods such as solar energy in every household (Mohammed et al., 2013). Energy consumption must be regulated in factories as they consume energy in their production processes. The use of indicators in the energy sector will help guide in the production of electricity and guide consumers in using electricity effectively. They also point in the direction of alternative and renewable sources of energy, which can create new markets and employment in the city (Weisz and Steinberger, 2010).

f) Indicators for Water and Sanitation

The United Nations stated that the provision of clean, potable water and sanitation facilities is a basic human right. Most informal settlements do not have municipal water supply, and most residents get water from unsafe and polluted water sources. In Africa, inadequate water and sanitation facilities have resulted in rapid spread of water borne diseases such as cholera. They have been responsible for many deaths, particularly children under 5 years of age (Carriço et al., 2014). Cities also need to manage the available water resources as climate change has caused a drastic decrease in the amount of rainfall received. Adequate measures must be put into place to ensure water conservation by industries, agricultural institutions and the citizens. Alternative forms of clean water provision must be sought to ensure that people in remote areas have access to potable water. It is also imperative that over fertilisation and clogging of water streams due to human waste are regulated to avoid contamination of potable water (UN-Habitat, 2009). The aspects of water and sanitation must be closely monitored, and indicators will help ensure the provision of information for effective decision making.

g) Indicators for Waste Management

Proper waste management measures must be implemented to ensure that it does not culminate into a health hazard. It is imperative that waste produced be quantified to aid with waste recycling processes. Africa has the potential to experiment with new technologies as their systems are still developing. Waste can be converted to a resource by using it to generate electricity. This can reduce energy deficits in African countries with minimal environmental damage (Sembiring and Nitivattananon, 2010). The use of indicators will ensure that cities keep track of waste generation and disposal.

h) Indicators for Environmental Damage and Climate Change

Rapid urban growth and inadequate management of human and natural resources has resulted in unsustainability in cities. Some of the contributing factors include overconsumption, destruction of ecosystems and waste accumulation. It is important to consistently monitor parameters that have adverse effects on the environment. Indicators to monitor and regulate emissions, natural resource consumption, replenishment, and environmental wellbeing must be implemented by municipalities (Mirabella and Allacker, 2017). This will ensure that cities improve their operational methods as climate change and environmental degradation will affect future generations. Industries and businesses must be at the forefront of using indicators to monitor emissions as their activities have more impact on the environment. This will also help municipalities to ensure that emissions and environmental damage are kept to a minimum. Regulations could be enforced on industries to properly dispose waste or treat it before release into water bodies. It is also important that citizens are aware how their everyday lifestyles affects their immediate surrounding environment, which ultimately has an effect on human health (UN-Habitat, 2016d).

i) Indicators for Disaster Management

Modern day cities are now more at risk of natural and man-made disasters as compared to the past. Cities must have a department dedicated to warning citizens of impending disasters and to assist those affected. This will improve the resilience and safety of a city, particularly among the poor and vulnerable who live in hazard prone areas. Sea levels are rising, and weather patterns are now unpredictable due to climate change. There is potential for rapid spread of diseases due to globalisation, therefore it is imperative that cities are well prepared for sudden disasters (Sawada and Takasaki, 2017).

j) Indicators for Health and Safety

The provision of facilities in cities ensures that citizens have accessible and affordable medical health care. Africa has been ravaged by diseases such as cholera, typhoid, HIV/AIDS pandemic and recently, Ebola. Health care facilities must be equipped to handle such emergencies as citizen health directly affects the city's productivity. Careful and consistent monitoring of the health faculty increases the living standards and life expectancy of the citizens (Sarkar and Webster, 2017). Citizen safety is also important, therefore information such as crime rates and hotspot areas must be included in the city's development. Crime rates have increased in most African cities, mainly due to poverty and socio-economic disparities. This has a negative impact on the tourism industry as visitors are discouraged from visiting crime prone areas. Constant monitoring using either technology or an increase in police presence may improve safety in cities (Mahsa et al., 2017).

k) Indicators for Education, Science and Technology

Investing in citizen education ensures that residents are equipped with knowledge on how to best maximise the city's resources. With education, sustainability concepts and practices are carried down for generations, maintaining cities in their optimal state. Indicators pertaining to education, the use of science and technology are pivotal to the survival of a city (Paroutis et al., 2014). It is important to provide and monitor the technical skills needed to run the city efficiently. Science and technology are immense contributors at enhancing living and operation conditions. Technology is a facilitator for educating citizens and using scientific principles to solves problems. Cities must, therefore, have a synergy between these three elements to improve living conditions in cities (Ranhagen and Groth, 2012).

l) Indicators for Socio-economic and Cultural Challenges

Most of the challenges experienced by cities ultimately become socio-economic problems as citizens are at the receiving end of all implemented policies. Social and economic disparities have been the root cause of instability, crime and tension in cities. Addressing the challenges outlined before will alleviate socio-economic problems. Cities must also cultivate a tolerance for different cultures as the world is becoming more diverse. Urban challenges need to be promptly addressed, otherwise cities will be rendered ungovernable and unliveable (eThekwini, 2017).

3.2.1.2 Sequence of Challenges

In the Literature Review, urban challenges were outlined beginning with the managerial aspects. The managerial aspect constituted of governance of cities by municipalities. Poor governance was cited as the root cause of urban challenges, which affects infrastructure and services. Inadequate infrastructure results in limited services, which ultimately affects the citizens. Sequencing the challenges showed that urban problems start at the governance level, down to the infrastructural

and physical level. This ultimately bears down on the average citizen, particularly the poor and the vulnerable. The Literature Review concluded urban challenges with socio-economic effects that poor governance has on its citizens.

3.2.1.3 Common Challenges and Challenges peculiar to African cities

Urban challenges were first defined on a worldwide scale. This highlighted problems that are being faced by cities all over the world. This was followed by challenges peculiar to Africa, as this thesis aims to address issues mainly affecting the African continent. Issues facing the African continent consist of lack of basic needs and services such as food, water and sanitation. Lack of maintenance has resulted in the dilapidation of infrastructure, compounded by lack of resources and skill (Vito et al., 2015). Civil wars are still going on in some African countries, destroying infrastructure and rendering cities uninhabitable. Resolving these challenges requires a knowledge of the African environment, cultures and government operational methods. The framework in this research was aimed at identifying problems and improving conditions in African cities (UN-Habitat, 2014).

3.2.2 Existing Solutions

Global solutions to solving urban challenges were outlined in Section 2.3, where universally accepted mitigation measures were outlined. These solutions have been long used as guides to resolve challenges faced by cities, and they have not been tailored to suit particular localities and environments. However, these generalised solutions were used as a platform to derive indicators for benchmarking the development and sustainability of an African city. Sustainability Indicators were introduced in Section 2.9, forming the building blocks to the framework of a sustainable African city. Sustainability Indicators for this research were largely derived from publications and guided by the challenges outlined in the Literature Review. The following section provides a list of Sustainability Indicators from a global perspective. Cities and industries currently use these indicators to monitor progress, identify challenges and preparing action plans to address these problems.

3.2.3 List of Sustainability Indicators

The list of indicators presented in the Literature Review was obtained from various academic and organisational sources that conducted studies on sustainability. These indicators, collected from a worldwide perspective and applicable to cities either in developing or developed countries, were used to derive indicators for a typical African city, Durban in this case. Although the indicators were grouped into different categories, there is a high level of interdependence and applicability to more than one sector. The grouping was, however, dependent on how the challenges they sought to resolve were defined in the Literature Review. These were backed up by journals and

organisational publications on Sustainability indicators. The rationale or description aimed to elaborate the importance of each indicator and supported by the relevant literature references.

3.2.4 Comparative Case Study between Trento and Durban

From these indicators, a comparative case study between two cities, with one in a developed country and the other in a developing country, was conducted. The city of Trento in Italy was an example of a case study in the developed world, as they have made progress in achieving their sustainable goals across the different dimensions. The author got to experience the living conditions in Trento and also interacted with the municipal officials on how they managed to tackle the issue on sustainable development. Findings from the Trento case study were compared and contrasted with those in the city of Durban, one of the African countries that has also made good progress in sustainable development. The comparison between the Trento and Durban was therefore based on available information and first hand experience of living in these two cities.

Data was collected for the city of Durban in order to further guide in the derivation of the city's framework. This data was collected from the municipal website for Durban, displaying various types of living conditions and service provision in the city. This data was analysed statistically, and the results displayed in Chapter 4.2.4. It was based on the 103 wards located within the jurisdictional boundaries of the city. A combination of Sustainability Indicators obtained in Section 2.10, the comparative Case Study in Chapter 4 and the results of analysis were used to determine the final framework of indicators for the city of Durban, a typical African city that is striving towards achieving sustainability.

4 Case Studies

This chapter presents case studies carried out in two cities in two different contexts. The first case study was conducted in the city of Trento in Italy where research was done for a period of five months. This was in the context of a developed country, and Trento is considered as one of the smart cities in Europe. The city has put in place measures to improve sustainability through efficient energy usage, mobility systems and the citizens' quality of life. The case study involved different aspects which involved engaging municipal officials, academia, citizens and the author's personal experience in the city. This was in terms of services and general perception of the city. The second case study was carried out in a developing country's context, in the city of Durban. Durban has been one of the leaders of sustainable development in Africa through the use of integrated development plans. It is also considered as one of the most liveable cities in Africa, therefore was a good starting point to conduct a case study for a typical African city. These two case studies were conducted and compared in order to emphasise the choice of indicators for the final framework for a typical African city. The following section presents a case study of the city of Trento, which entailed detailed plans for improving services and sustainability in the context of a developed country.

4.1 The city of Trento (Italy)

The city of Trento is located in the province of Alto-Adige, in the north of Italy. It is built in a valley, covering an area of approximately 160km^2. It is classified as a small to medium sized city according to IEEE Smart Cities, with a population of 120,000 inhabitants. This population, however, is expected to increase due to migration, mainly due to economic opportunities available in the city. Trento has a high smart city ranking, and is considered as one of the cities with the highest quality of life in Europe (Bedini et al., 2014). This is largely due to the inclusion of various stakeholders in its developmental process, particularly the University of Trento. The university fosters a culture of innovative research and collaboration between experts, municipal officials and the general public. Technology is a major part of the city's development and is viewed as a facilitator of change. Trento has made great strides in improving the living conditions and the use of environmentally friendly systems in energy, transportation and waste management. These factors provided motivation to earmark the city as a case study in a developed country (Gionanni et al., 2014).

A study of the city was done to observe, interact and engage with the systems that make the city highly ranked in terms of sustainability. This was done over a period of five months, involving consultation with municipal officials, working with academics who have contributed to the city's development, and engaging citizens with regards to how the city works. This would be compared to the conditions in the city of Durban, which is a typical city in a developing country. The early

stages of the study pointed out that some of the basic concepts applied in the city of Trento would be useful in guiding the development plans of African cities. The following the most important aspects were considered in conducting the case study:

a) A study of the municipal current and future plans
b) Engagement with academia and municipal staff in the city of Trento
c) General citizen perception and participation
d) Personal experience as a resident of the city of Trento

These aspects were aimed at improving operational methods and the quality of life for its citizens. The following section outlines the municipal plans devised by the city officials and academia. This included all possible stakeholders, particularly the citizens. Figure 4-1 shows a geographical map of the city of Trento.

Figure 4-1 Geographical Map of Trento (Geoplan, 2021)

4.1.1 Municipal Plans

The municipal plans were outlined through consultation with municipal officials from the Trento Smart City Office. A collaboration between stakeholders and the municipality was set up with the office with help from the university. From then, regular meetings were held where the plans and implementation methods devised by the city officials were discussed. The level of application of these concepts in developed countries was also assessed, and plans outlining the development plans of Trento were issued. From 2001 – 2013, the city of Trento did not have a specific vision

for being a smart city but had measures in place to improve on sustainability. The city formed partnerships with research and innovation centres within the University of Trento. It collaborated with the provincial authorities, setting up a list of smart projects to be carried out over the years. Despite not having a set framework for smart development, the city was highly ranked in terms of sustainability. The city developed a cycle programme, which was later adopted by other municipalities in the province (Trento, 2014). The programme consisted of the following plans:

i. Environmental Energy Plan (2001)
ii. Social Policy Plan (2001)
iii. Youth Policies Plan (2002)
iv. General Land Use Plan
v. Tourism Policy Plan
vi. Urban Mobility Plan
vii. Total Quality Management Plan
viii. Executive Management Plan

These plans were in use for several years and led to an improvement in conditions within the city. In 2014, Trento decided to take concrete actions towards building a sustainable city. The first action involved sending an application to the IEEE Smart Cities Initiative, aimed at improving the quality of life for its citizens. This was carried out through collaboration with academics and industrial experts, and six scientific journals were developed in the process. The city's main areas of focus were:

1) Sustainability – It not only included environmental but also social sustainability
2) To become an Immaterial Factory – This entailed service provision and improved quality of life through the use of technological innovations
3) To develop what is already there – This was to be done according to historical and cultural values

The plans involved all stakeholders, which encouraged interaction and discussions to come up with flexible agreements. Its vision included the use of ICT and Real-Time Information from systems, infrastructure and citizens to render innovative services. The vision also included an improvement in the well-being and quality of life for the citizens and the adoption of a clear strategy involving, businesses, institutions, citizens and all stakeholders through a participatory approach (Trento, 2014).

4.1.1.1 The first Operational Plan

The first operational plan involved a four-step methodology to improve the way the city operated:

1) Analysis of the situation on the ground

Trento was already highly ranked according to iCity Rate and the Smart City Index. It was also ranked first among other medium sized cities according to the University of Vienna studies on medium sized cities in 2007. The city was ranked 3rd in 2012 and 1st in 2013 according to the iCity rating. Most of the projects planned by the city had already been financed or started. Figure 4-2 shows the state of Trento as compared to the rest of Italy when the first operational plans were put into place.

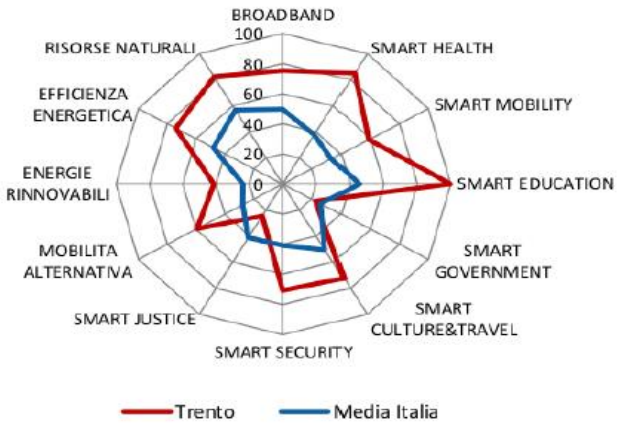

Figure 4-2. Trento's progress in 2014 compared to the Italian average (Trento, 2014)

The city had already made good progress towards being sustainable, and these plans would help to reinforce the city's progress.

2) Defining general but concrete objectives

Goals were thoroughly defined to gain extensive knowledge of the reality on the ground within the territory. This involved mapping available data and integrating all databases. The integration of databases helped in making informed decisions. The availability of data also improved relations between businesses and citizens through interactive and personalised services. This was carried out as simply as possible to make services more efficient and less expensive to the average citizen (Trento, 2014).

3) Identify a working method based on infrastructural data

The main goal was to gain knowledge about existing and used databases, which was central to the development of the city. Data was to be managed and integrated with all businesses, municipal authorities, and the citizens. It was provided in both its raw form and through interfaces such as dashboards which could be understood by laymen. Adequate data authorisation measures were

put into place to ensure the privacy of both citizens and organisations. The structure of the data used, which was the heart and core of the city, is shown in Figure 4-3.

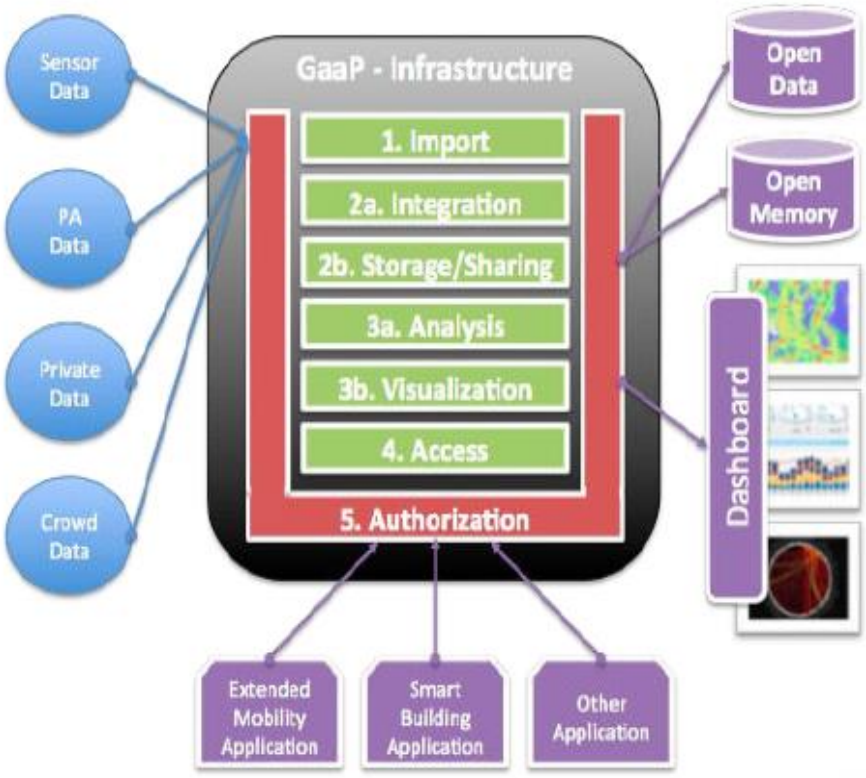

Figure 4-3. Data Structure for Trento (Trento, 2014)

This data was used by the city to improve services such as transport, energy, government services and crowdsourcing information. From this, detailed goals for specific areas were outlined.

4) Methods and Goals

Detailed methods and goals were outlined for each specific area of the city. This included setting targets, developing projects with partners, sourcing finance and consulting experts and relevant stakeholders. The Big Data and Open Data platforms were introduced to all the sectors within the city, which was the first stage in developing an academic workshop in which journals pertaining to the city's development were drafted.

These plans made the city competitive in its quest towards becoming a smart city. This resulted in more elaborate plans being developed, entailing the drafting of scientific journals. These were developed by experts and covered the six main areas of concern in the city. Section 4.1.2 outlines the white paper journals, which were developed and are still being used as guidelines to the city's sustainable development (Trento, 2014).

4.1.2 Trento White Paper Journals

The white paper journals were developed following the IEEE route, where six expert groups specific to each sector participated in the crafting of policies. A workshop was held to draft these papers, where they analysed the situation on the ground, defined targets and proposed projects to achieve the desired objectives. The results from the discussions were presented at the end of the workshop. It created more awareness concerning future projects and possible financing for the city. Six scientific papers were developed in a space of five months. These were posted online on the municipality's website in May 2015, and in October 2015, they put into place measures to involve the citizens. In September 2016, the city held a smart city week which involved citizen participation. Trento invested in spreading the word with regards to the smart city week, targeting all age groups. The city introduced a collaborative and sharing approach through crowdsourcing, citizen sensing, co-design, co-working and gamification (Trento, 2014).

4.1.3 2017-A New Start

In 2017, a smart city office was created, dealing specifically with the drafting of a new version of the smart city plan. The process began with the development of a horizontal multi-layered approach for governing the city (Trento, 2014). Layer 1 consisted of the infrastructural aspect, which involved the use of technology in energy, transportation, buildings, and urban planning. Layer 2 involved the use of sensors to monitor the condition and performance of infrastructure. The 3rd layer consisted of the service delivery platform, where the city would improve and consistently monitor services through stakeholder feedback. This included mobile applications, digital identity, online payment platforms, central control and open data. Layer 4 involved the use of applications services within the city. Mobile applications for sectors such as transport and energy were developed to improve user convenience and as a means of collecting data. Services were developed for energy, tourism, education, governance, water and sanitation. In order to improve their current system in 2017, the following lines of action were proposed:

1. Definition of a clear strategy
2. Completion of the city's operating system. This included the IoT Platform, service delivery tools and inter-operability tools.
3. Specific actions for each area which included applications, services, and the usage of OS Smart City

The city proposed the following pilot projects in line with the sectors outlined below:

- **Smart Parks** – these consisted of smart lighting, smart benches, and using dashboards to display real time information on screens

- **Smart Districts** – to create a region where innovative solutions were developed through stakeholder participation, starting with pilot projects that were later spread out to the rest of the city
- **Smart lighting** – experimenting with new lighting solutions in line with the existing system, beginning with the retrofitting of cycle paths
- **Smart mobility services** – availing real time information with regards to parking spaces, particularly for disabled people and freight loading/unloading areas
- **Participation** – new and innovative ways to allow citizens to express their opinions with regards to the city's operation
- **Dissemination** - to spread information to the city in order to fully engage citizens in the development process (Trento, 2014)

The proposed pilot projects offered a chance to assess policies that had been devised before being rolled out to the general public. The following section introduces the mobility plan for the city of Trento, which was developed by its transportation experts. It also includes plans discussed in meetings held with the smart city office, as well as the author's opinion gained through the use of the public transport system in Trento.

4.1.4 Trento's Smart Mobility System

Urban mobility plays a significant role in the way people move around and develop their communities. The main challenge in Trento was to convince citizens to utilise the public transport system. This was further exacerbated by the vast amounts of information provided for existing transit systems, which made public travel more complicated for the average user. The city decided to modify and use the correct information flow to improve journeys and make them less stressful. Surveys conducted in the city showed that more users were satisfied with the transit systems due to the availability of organised real time public information. The favourable responses were mainly from the younger generation which is well versed with technology. Mobility in this context not only referred to public transport, but also included the manner in which citizens move around the city. Cars, parking facilities, sidewalks, cycle paths and payment systems were integral parts of the mobility system. Mobility also occurs indoors, therefore it was important that a plan which interconnects the indoor and outdoor areas was devised (Bedini et al., 2014).

The integration of technology in the mobility system had a number of merits. The use of mobile applications to obtain information was meant to reduce travel times, which gave the residents time to pursue other personal activities. The availability of information made the system predictable, thereby allowing citizens more flexibility to plan and manage their journeys. Smart transportation systems were to improve access to workplaces, schools, municipal offices, medical centres, as well as enhancing the safety and security of Trento's citizens (Bedini et al., 2014). New systems

enabled smaller companies to offer specialised and customisable services to the users, which created employment opportunities in the city. The province of Trentino has currently seen at least seven mobile applications being developed, aimed at providing bus timetables and bus stop locations. It also began encouraging multi-modal forms of transportation, which reduced general fuel consumption, congestion and ultimately emissions. The city used platforms to create data systems that could be readily accessed and understood by the end user (Bedini et al., 2014).

The basis of this mobility system stems from the fact that as cities are developing and the population rapidly increasing, people need more efficient transportation. These systems must be energy and time efficient, while offering increased security for the general public. The future of sustainable urban mobility is highly dependent on current situations, including geographical and structural characteristics of systems in cities. For example, the city of Venice can almost be entirely pedestrian, while larger cities such as Dubai are more favourable to individual modes of mobility (UN-Habitat, 2009). Trento also has integrated pedestrian and cycle path systems with extensive coverage around the city. Figure 4-4 shows how they are arranged, and this spreads to a greater part of the city. Cities in less developed countries, such as Durban in South Africa, also incorporate minibus taxis as a mode of transport (eThekwini, 2017). Therefore, cities take different approaches to improving their transportation systems depending on their desired outcome. Different technologies are used to monitor behaviours, systems and stakeholders in order to provide detailed information to both local and international travellers. The city's transportation systems also aim to link coherently with regional and international infrastructure, including highways, railways, harbours and airports. Technologies that are applied to effectively manage mobility systems in cities belong to a general set of Intelligent Transportation Systems (ITS). The ITS platform supports areas such as information, traffic demand and smart ticketing systems. The Integrated Smart Mobility concept was also introduced, entailing a combination of Access Control and Enforcement Systems, Traffic Light Coordination Systems, Traffic Sensor Networks, Parking Management Systems, Ticketing Solutions and Information Services. Some cities such as Verona have already developed systems that prioritise public transport and emergency vehicles at intersections.

Figure 4-4. Pedestrian and cycle paths in Trento

The geographical structure of Trento is characterised by a long and narrow valley, resulting in a difficult infrastructural network. Commuting from the eastern to the western side of the city is challenging because of the river, the rail network and the main highway which pass through the middle of the city. This geography has also been the cause of congestion, unavoidable accidents, and excessive fuel consumption due to steep roads. The current transportation system is almost saturated, with an average of 358,700 vehicles on the main roads on an average weekday. In order to assess the situation on the ground, the city of Trento carried out a satisfaction survey on the current public transportation system. According to the citizens, the main areas of concern were travel time, comfort and the level of service, and this is shown in Figure 4-5.

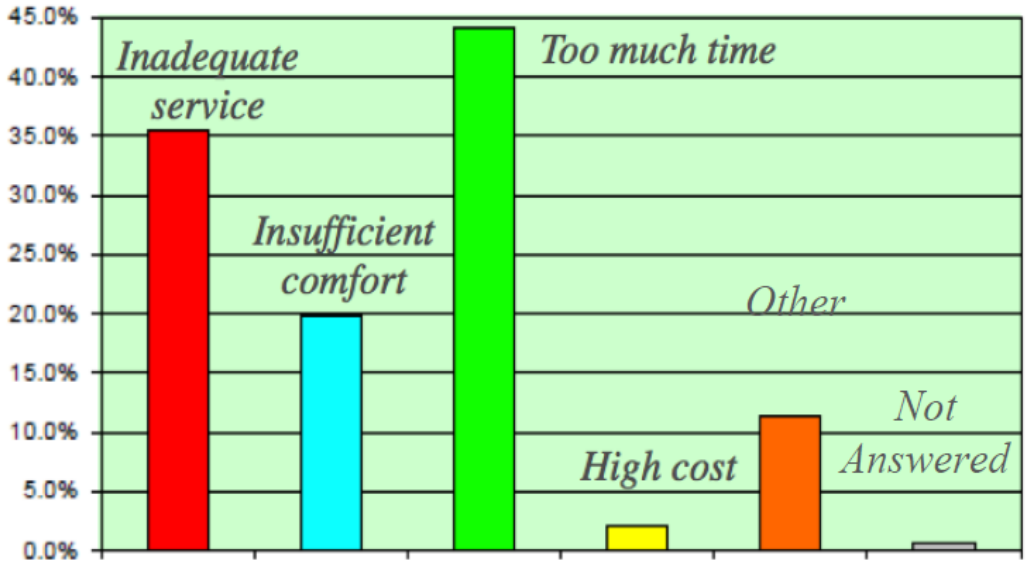

Figure 4-5. Citizen opinion of the transportation system (Bedini et al., 2014)

In light of the public's opinion, the city had already put into place development plans for multi-modal transportation services. The existent modes in the city include the train, bus, car, walking and bicycles. Organising the system involved stakeholders in the private and public sectors to allow effective information exchange. The development of car sharing and car-pooling options were prioritised, as public transport does not cover the full territory within the city. The provision of adequate infrastructure was also put at the centre of the smart mobility process. This not only involved roads, railways and parking, but also communication and sensing infrastructure that could be used to transmit information. Information infrastructure plays a huge role in the use of traffic lights, smart lights and reconfigurable indicators which use cameras to recognise vehicles. In light of this, the city also discovered that since most people spend their time indoors, there were no effective applications which helped in mapping the indoors.

In a city with ageing population, technology would be useful in assisting indoor mobility. They also recognised the need to cater for the disabled, children and tourists. Facilities catering for electric vehicles were also drafted in future plans, extending to delivery vehicles. The aim was to not let technology take over the systems, but rather use it to improve the livelihoods of citizens. Technology was seen as merely a facilitator of change, but the citizens had the final say as to whether certain technologies could be incorporated in the development of the city (Bedini et al., 2014). Trento put bus stops around the city, with designated buses plying specific routes. Figure 4-6 shows a typical bus stop, providing information on the arrival times for the bus. The bus shelter also provided commuters with protection from harsh weather elements such as snow and rain. In some roads, there were designated lanes for public transport as shown in Figure 4-7.

Figure 4-6. Typical bus stop in Trento

Figure 4-7. Designated lane for public transport

4.1.4.1 Citizen Engagement

Trento as a smart city would not exist without being inhabited by smart citizens. According to the municipality, “citizens are smart if they have easy and real time mobility information and if they can use this information in a dynamic way to suit their needs. This also entails the ability to know which resources and information to use in order to experience efficient mobility methods within the city” (Bedini et al., 2014). A smart citizen must also be aware of the impact of his/her choices in terms of emissions and carbon footprints, and actively participates in the improvement of mobility. In general, this means that there must be a change in the urban mobility culture. It was important that the city changes the attitude and raises citizen awareness, otherwise all the

investments made in improving mobility would be futile (Trento, 2014). Daily transportation modes are usually determined by habits and proximity to the destination, and in Trento, most people still believe that the car is the fastest from point to point. Considering the congestion that occurs during peak hours, it showed that citizens might not consider the existence of a faster and efficient way of travelling. This is due to lack of awareness regarding real time mobility information in terms of cost, travel time, carbon footprint and security. The city, however, improved bike and ride sharing, but it has been difficult to scale up due to fragmentation and resistance to change by the citizens. Figure 4-8 shows the facilities used in facilitating bike sharing within the city. In recent times, however, gamification has increased people's awareness and levels of participation, and harnessing ICT will greatly improve the way in which people move around the city (Bedini et al., 2014).

Figure 4-8. Trento's bike sharing system

4.1.4.2 Cooperative Systems

A smart city consists of cooperation, distributed intelligence, interaction and communication. This is mostly applicable to the mobility aspect where information is first centralised and redistributed due to the amount of infrastructure required. The first focus was on road safety management and the presence of short-range communication devices on vehicles, coupled with portable devices such as cell phones to enable communication with pedestrians and cyclists. Cooperation ranged from guiding drivers' manoeuvres to more complex systems such as assisted braking and anti-collision systems at intersections. The city of Trento also acknowledged the need for ad hoc networks with direct communication between devices in places with no access to Wi-Fi or 4G.

The city aimed to take advantage of the already existing technology such as Bluetooth to enable device to device communication. These ad hoc networks could be integrated into the main network with sensors which pick up aspects such as weather and traffic delays. Conventional media is currently used to spread information, but ad hoc networks have the potential to carry out the same tasks at virtually no cost in a more focussed manner. Provision of information can be specific to a user, depending on the type of information needed. Privacy must be prioritised so that decisions can be made without infringing user data. For critical applications, much development is still needed, as there is a risk of rapid spread of false information. This can lead to panic and chaos, such as false alarms on highways which can cause accidents instead of actually reducing them (Bedini et al., 2014).

4.1.4.3 Location Based Services

Location Based Services (LBS) are becoming more common due to the need for indoor mapping applications. Indoor mapping is believed to have potential and be a new frontier in the location services market. Companies such as Microsoft, Nokia and Google have already started making indoor maps and are also obtaining data through crowdsourcing. However, indoor mapping has caused challenges in that the owners of these buildings might not have control over who accesses the data (Aditya et al., 2015).

4.1.4.4 Data Layer

The Data Layer is one of the cornerstones of Smart Mobility infrastructure. This includes the intelligent collection of data, its integration, validation and sharing responsibly with relevant people without compromising the privacy of the people. Trento launched the Open Data Trentino project, where they tasked various authorities to run the data sets and in multiple phases until it reached optimum level. They also added more requirements to enhance the existing data sets. As mentioned before, crowd sourcing and sensing can be used in conjunction with already existing data to provide personalised services. Dashboards were used as a means of providing useful information to users. They usually merged real time data with historical data, dedicated analysis and visualisations. The data layer for smart mobility, however, required a lot of work in order to standardise (Bedini et al., 2014).

4.1.4.5 Services and Apps

Smart Mobility is enhanced by innovative services through mobile applications and sensors. This is all packaged to provide a cost efficient and socially enhanced means of mobility. These services require high levels of personalisation, targeting a wide spectrum of consumers. Trento's focus was to make sure that data was tailored to suit citizens and tourists alike. Raw and open data helped to produce predictable and precise information so as not to mislead consumers. It also informed citizens of available options if, for example, the bus was late, the system offered trains

as an alternative. Mobile applications revolutionised transport in that consumers could easily access relevant information, creating value for money in the system (Bedini et al., 2014).

4.1.5 Trento's Smart Energy

The city of Trento drafted a paper on Smart Energy during the two week workshop in December 2014. This formed the basis of the new energy system that would be adopted. Much of the focus was on distributed and decentralised energy generation, real time demand and response, which included citizen engagement. This was to be achieved through using ICT as a commodity, including technological innovations which were building blocks in the system. With the world's population on the rise, the demand for energy has also risen, and Trento has not been spared in this regard. The city put into place plans to find ways to generate electricity in a more efficient and environmentally friendly manner, such as Photovoltaic (PV) panels. Figure 4-9 shows the use of solar panels in a school residence. A commitment was also made to reduce emissions by 20%, which was in line with the European Union's goals. The adoption of new and efficient energy generating methods also involved a change in the lifestyles of citizens. The use of solar panels in homes converted the citizens into energy producers, rather than just consumers. The new energy system was also extended to smart street lighting with lower ecological impact. The technology used was to be as transparent to all stakeholders as possible (Gionanni et al., 2014).

Figure 4-9. PV panels of the roof of St Bartolomeo Residence in Trento

4.1.5.1 Smart Grids

Smart grids consist of energy production with a two-way flow of electricity, while conventional grids have a centralised system from large power plants. The new energy system for Trento would involve interaction at different voltage levels through control systems to balance the production and demand for electricity. The smart energy system is viewed as a combination of diverse energy distribution systems such as coal, geothermal energy and gas. In Trento, the number of generating units owned by users and connected to the distribution network is steadily increasing. The durability of coal fired power stations supplying electricity to Trento is sometimes affected by ramping up and down. This is due to varying electricity production from external sources caused by changing weather elements such as wind and sun intensity. This can be resolved by using large storage units such as batteries and flexible generators. In Trento, the main challenges were the dispersed generation of electricity from the customers' side. The injection of energy on the customer's side resulted in the inversion of power and violation of voltage. There was also a possibility of incorrect operation of distribution line protections, and loss of inertia of the electric power system which is fundamental to achieve equilibrium between power generation and loads. ICT was a major facilitator in implementing the smart grid network with key functions such as data acquisition, supervisory control, monitoring of power and flow management, real time communication between producers and distributors, and cyber security protocols to protect the grids (Gionanni et al., 2014).

The current consumption of electric energy is cyclic as demand varies with the seasons and the time of day. The randomness of consumer behaviour has an impact on the efficiency of alternative energies, and conventional power plants also struggle to quickly react to these rapid changes. The city currently solves this challenge either by continuously generating surplus power, or by using special equipment such as powerful generators to cover the shortfalls. This bears directly on the customers, who have to pay more tariffs to cover the costs. Solar and wind energy cannot resolve these issues as they are harder to manage due to a mismatch of peak production and consumption. In this case, energy storage is a feasible solution as energy can be stored and fed back into the system during time of peak demand. Hydro accumulators and batteries are some of the most efficient current storage mechanisms. Battery storage has more advantages as it responds quickly to power changes in the order of seconds. The limitations, however, are the costs associated and the need for longer battery life spans. This can be resolved through maintenance and systems which manage the charge in all the cells of the battery. A network of smart buildings has helped to save energy and manage power in response to the demand (Gionanni et al., 2014).

4.1.5.2 Smart Buildings

Buildings consume approximately 40% of the energy produced by the city for heating, lighting, air conditioning and ventilation. The European Union recommended energy saving methods in

the construction of buildings, but the use of ICT would be fundamental in adding technology to manage them smartly. Trento has smart buildings which have significantly reduced energy consumption in the city. It is known that intelligent building management systems are more likely to reduce energy consumption by at least 25%. To add to this endeavour, public and private spaces have been fitted with inexpensive and efficient systems through ICT. The city of Trento intended to make technology as invisible as possible, yet available when needed. Different kinds of sensors and embedded systems were incorporated to collect information and monitor physical processes to make buildings more energy efficient (Kylili and Fokaides, 2015).

With regards to energy consumption, most residents are keen to monitor their consumption to reduce their energy bills. However, current systems only give users feedback on their monthly bills, which does not indicate which activities and appliances consume the most power. The smart grid was proposed to be an ideal solution for the situation, but the challenge was to convince the customers to participate in the supply-demand interactions. The city planned to roll out smart meters, with end user programming controlling the devices and empowering users in addressing their concerns. Data for monitoring buildings could be obtained using sensors from different manufacturers. The main challenge was to provide a uniform interface in which users could access data from different devices manufactured by different companies. The use of smart plugs had the potential to eliminate this challenge, as most of the plugs were manufactured according to the same standards. The city also employed gamification, social networks and mobile applications in the energy sector (Gionanni et al., 2014).

4.1.5.3 Smart Lighting

Lighting is normally used for indoor and outdoor purposes. Indoor lighting is mainly divided into residential and commercial use. Currently, IoT based LEDs are the most efficient lighting devices and result in 40% of the city's total energy consumption. In European countries, the two main challenges are to retrofit old buildings and low market demand for intelligent light fittings. This is due to the complexity of installing and maintaining these systems. With regards to outdoor lighting, conventional bulbs are wasting energy. Current lampposts only have one function, but with the development of technology, they can become assets for CCTV, Wi-Fi and parking. This can reduce infrastructural costs for cities and promote synergy across different services on the lamp posts. The lampposts also create a network of Wi-Fi access points around the city, with interactive sensors allowing selective lighting on a city scale. Smart street lighting has also been incorporated in the city of Trento. These lights sense a person walking past and they switch on, and they switch off when the person is out of their range (Kramers et al., 2014).

4.1.5.4 Wastewater Management and Environmental Quality

The efficient management of wastewater is directly related to energy savings. The EU Water Framework Directive (WFD) policies provide a more integrated approach which acknowledges the relations between ground, surface and coastal water. Hydrological planning has also resulted in pollution control measures to reduce impacts, particularly in coastal areas. The WFD aims to ensure quality objectives for all water bodies. The integrated management of water bodies in cities includes the complete water cycle, from precipitation to wastewater which is dumped back into water bodies. Waste Water Treatment Plants (WWTP) are crucial to achieving the correct water quality standards and environmental quality standards. An upgrade of the treatment plants reduces the impact on ecosystems in saving energy and disposing waste. Management of the aerobic component of sludge and conventional biological systems results in high consumption of energy. The treatment plant can be upgraded to consume less energy and reduce the pressure on the environment. The water treatment process consumes a lot of energy, and it is difficult to recover the costs of this high consumption. The wastewater treatment plant in Trento is owned by the province and managed by a specific treatment agency. Thus, the city does not have full control of the amount of energy consumed in the treatment, causing uncertain energy consumption and lack of responsibility for the CO_2 emissions. These issues can be resolved by implementing technology and sensors which collect data that can be shared between the provincial governments and the city of Trento, resulting in measures that significantly reduce energy consumption (Gionanni et al., 2014).

The process of efficient energy production and consumption began with the 2007 EU document on "Energy for a Changing World," the EU Climate Energy Legislative package in 2009, and the Covenant of Mayors in 2014. The implementation of the smart energy plan was to involve all the citizens, which was the recommended practice. The implementation of the plans consisted of two parts:

1) The Baseline Emission Inventory (BEI) which provided detailed information on CO_2 emissions and the amount reduced. It also identified the critical areas and possible opportunities for sustainable energy development for the municipality, including the use of renewable energy sources.
2) The Sustainable Energy Action Plan (SEAP) identified the actions that the municipality intended to implement in line with the BEI. The SEAP included a Mobility Counsellor, Environmental Service Manager, Integrated Solid Waste Project Manager, an Energy Manager, an Enterprise and Citizens Desk Manager, a Planning and Urban Mobility Manager and an Officer for Research and Logistics.

The SEAP addressed the following areas:

a) Municipality Buildings consisting of kindergartens and schools
b) Public Lighting, which the municipality had implemented projects since 2012 to reduce light pollution, while improving safety and quality of life.
c) ICT facilities for citizens and tourists which included energy consumption data gathering instruments, real time energy optimisation systems, building databases and dashboards to analyse energy production and consumption.
d) Health, university infrastructure and the training of employees.

Trento is currently at the forefront of energy efficiency according to Smart City Index indicators. The city ranks high in terms of smart buildings, smart lighting and smart grids. This issue of climate is crucial for Trento, together with heritage properties owned by the municipality. The city has planned to retrofit some old municipal buildings, where 120 of these buildings have been responsible for 90% of the total energy consumption. The retrofitting process has seen a reduction in energy consumption by at least 30%. The municipality has also started educating its employees to promote energy saving methods in their households and in the workplace. This has made the employees aware of the impact of their actions, resulting in a 2% further reduction in energy and water usage. The city also created a certified and up to date database by aggregating existing databases on different aspects. The city currently consists of old houses which were not built using modern thermal insulation techniques. The residential sector has seen the least reduction in energy consumption due to population increase and older houses. Currently, the municipality has planned to implement the following actions:

i. Regulatory actions such as building by-laws and planning tools
ii. Compulsory energy certification for buildings
iii. Pilot projects involving the installation of centralised heating and ventilation systems
iv. Construction of new infrastructure and retrofitting old infrastructure
v. Engagement with financial institutions to identify products which will increase energy efficiency in the city
vi. Advertisement to ensure that the citizens are aware of the new technologies

These actions are expected to save approximately 25MWh/y of energy. Citizen involvement, particularly the implementation of energy saving methods in households, and the adoption of renewable energy sources, is therefore essential to make sure the energy saving targets are met. This should also involve tertiary industries and mobility systems (Gionanni et al., 2014).

4.1.5.5 Strategic Priorities and Challenges

The city is regarded as a body, which has a network of interrelated parts that are responsive to internal and external stimulations. The smart city organ, therefore, consists of a range of sensory organs (sensors), muscles (actuators), the neural system (communication layer) and the brain

(hardware and software) which control the whole system. Unfortunately, the smart city is not as connected as the physical city due to the focus on specific tasks that tend to ignore potential harmful events. If smart cities adopt a more organic approach, it can result in more optimised services, thereby reducing the cost of infrastructure. One of the most effective approaches is to divide the smart city areas into districts where new concepts can be tested, and the successful ones implemented on a larger scale. Infrastructure is seen to be more economic and efficient if it is implemented on a district scale. Services offered should be open to third party integrators, creating a marketplace for private companies. The new services could be potentially beneficial to the city. Citizen engagement is essential because it influences more mature economic and environmental decisions. Active citizen participation also provides valuable feedback essential for the system. Feedback, coupled with the knowledge of specific citizen needs, provides a better understanding of the trade-offs and choices to support decisions. This ensures that citizens comply with the given regulations and their rights are not violated. The provision of smart energy systems cannot be achieved using standalone solutions, but rather integrated ones involving multidisciplinary skills. The use of ICT and IoT will provide adequate answers to future smart cities, coupled with user engagement to improve the quality of life for the citizens. This will involve good governance measures to ensure that the system is carefully managed (Gionanni et al., 2014).

4.1.6 Trento's Smart Governance

The indicators of a smart governance system include the number of online services, their usage and level of interaction. The city of Trento launched an innovation project where all their systems were migrated to online platforms. This would provide a one stop shop and an innovative ecosystem of managing the city's affairs. This system was to be trusted, fully connected and open to improving the innovation needs of the city. For the past 20 years, Italy has embarked on the adoption of the e-government concept, comprising of electronic ID cards, internet portals and the use of the e-procurement model. This was done to match the citizen services offered by the private sector in order to rationalise costs, investments, improve public administration, and facilitate transparency and accountability to restore citizen trust. E-governance was therefore implemented to make public administration more efficient. This has been a priority in Trento for the past 15 years, aimed at improving the quality of life by reducing the time and effort required for stakeholders to carry out administrative processes. The city has developed services that not only address the needs of the citizens, but also involves them in the design process (Fioroni et al., 2014).

Currently, their solutions are being used by citizens to solve real life daily problems. However, there is still room for improvement as the level of adoption of online services is still low, with the exception of the civil registry. This was because of the city's focus being on efficient management of the backing of office processes rather providing front line services to citizens. The municipality

has achieved results with regards to open data, which was published on the government's website showing the number of visible datasets. The municipality is also working with the regional governments on electronic and micro payments aimed for all administrations in this region. The city has availed the payment of taxes using the "EasyPay" system and SensoRCivico to receive message warnings and suggestions from citizens. Social network pages were also created, with professionals chosen to constantly update them. With regards to online services, Trento has been mainly working on systems that provide citizens with information on waste management, tourism and mobility (Fioroni et al., 2014) .

4.1.6.1 Current Plan

The main target towards smart governance is to increase the number and usage of online services. This seeks to provide a convenient experience through integrated facilities that assist citizens in finding answers to their needs. The first step was to set up a standardised online service delivery system, where all the managing procedures of the municipality would be carried out. These were based on the citizens' needs and the necessary resources to manage all the access points to these services. A set of technical requirements entailed easy access, easy management, integration with existing portals, and support for simplified authentication methods. This was to promote the widespread use of electronic payments and exploit data usage as a source for all information. The city obtained the first steps of the plan from the city of Bergamo, which had carried out the same process and was therefore experienced in that area. After the adoption, the city of Trento evaluated the outcomes of the pilot project and decide on future implementation. With regards to the online service delivery system, the city of Trento adopted 'smart' solutions from Bergamo and exploited the process of offering new and interactive online services (Trento, 2014).

In delivering online services, the city aimed at catalysing the interests of project research and innovation bodies to accelerate the digitisation process. The main goal of the project was to increase the number and interactivity of online services and reduce time spent in lines by citizens and businesses by almost 50%. The access points to be used were to be trustworthy so that citizens gain confidence in timeous, reliable and secure services. The users would also be assisted during the entire service usage processes. Finally, the system would be open to support extension and integration of other services. The main priorities were:

a) To define tangible objectives through community building of capacity and accountability within financial and social policies. This was because of the social challenges and economic crises that societies are facing, together with a growing and ageing population. The process aimed to promote a multi stakeholder societal system to reduce conflict among citizens. Communities were to continuously contribute to the models in order to remark the relevance of the city's targets (Fioroni et al., 2014).

b) The Municipality of Trento recognised participation as an important factor in the online one stop shop service. Key players in ensuring efficiency of the implemented activities were universities and schools. Ten issues were identified in the quest to achieve a satisfactory level of participation. These were:
    - Promoting social co-design
    - To put actual people in the procedure
    - To empower people to contribute
    - Design tools for participation feedback
    - Take a reality picture through social storytelling
    - Aim for improvement in small incremental steps
    - Development of a system to evaluate public patterns
    - To get more active people online
    - To stress the importance of civic and digital lifelong education
    - Involve students and create new citizens, with the university as a laboratory

Trento employed an intensive bottom up approach, with public participation being more than just a promotion of online services or e-government. Public participation required a change in the cultural system that citizens and administrators aimed to bridge. This was improved by having "living labs" and open online courses for citizen education. Gamification improved their online services, which were adapted to encourage citizens to participate in the development of cities. It also encouraged citizen engagement at all levels within the city. The last important activity was to gain the trust of citizens by offering systems that decrease the digital divide and increase transparency. However, participation in both directions was important to ensure trust and maintain this relationship between the government and its citizens (Fioroni et al., 2014).

The development of citizen engaging platforms started with open services, allowing for their reuse and integration. This also allowed the integration of databases for public administration, mobility and online payments at a local, regional and national level. Another model, consisting of the three layer solutions, was proposed as follows:

i. The **information** layer which contains digital databases such as census and press releases
ii. The **platform** layer which has hardware for processing data in the information layer
iii. The **presentation** layer for helping government and private sectors to deliver sensitive government information digitally.

This was to be achieved by employing open and easy to use portals. Security was a main criterion which determined different access levels due to data sensitivity. By December 2014, the city was already running the following projects to enhance citizen engagement:

ComunWeb – This was aimed at creating a uniform portal to collect, aggregate, organise and distribute data, currently being used by the Municipality of Trento.

MyWEB – MyWEB was developed for the community to access services and information through a conversational profile. This improved community participation and communication on the portal.

PROMO – This was developed for the networking of business organisations, from a local to regional and international levels. It also allowed for businesses and organisations to be monitored and evaluated, thereby increasing the trust between governments and organisations.

FIDES – This was aimed at improving federal operability and identity management platform. It allowed users to log in and gain access to all services without being prompted to log in again at every one of the portals. Privacy was of importance as sensitive private data was shared on this platform.

WE-LIVE – This was a European 2020 project to introduce a new concept of administration based on mobile services created by citizens. This leverages the collaboration of different public administrations, businesses and citizens. The project began in 2015, with Trento being selected as a pilot city.

Every one of these projects was organised in three phases. The first phase included the piloting of an existing solution. In this phase, thorough assessments were carried out, with priorities and the initial set of procedures being evaluated. The second phase constituted of a scale up of the pilot, covering all the proposed procedures and government models. Trust building was also carried out in this step. The third phase was the opening of all the solutions and integrating them with different platforms. This phase was also open top third party development of these services. The implementation of these projects also saw them extending to other regions in Italy (Fioroni et al., 2014).

4.1.6.2 Citizen Engagement

The rapid transformation of social and economic lives has led to a changing demand for the types of skills required. This has resulted in acute unemployment and skill bottlenecks in some areas. The complexity and uncertainty of life has created problems for citizens regardless of their social and economic backgrounds. The need for profits and instant results has made the working life even more stressful. With rapid industrialisation, the public sector became responsible for the provision of public goods. However, there is now a growing need for more customised goods and services in today's highly developed and differentiated societies. The 'one size fits all' model no longer works today, leaving room for more localised initiatives. People now have developed

individual skills which they can pour back into the community. To achieve the goals and` strong citizen engagement, the city of Trento put forward a four-step plan.

1) PLAN
   - To define all stakeholders to be engaged
   - To define all the anticipated problems
   - To design all solutions with the relevant stakeholders
2) DO
   - To input the resources needed
   - To output facts and figures, measuring progress in terms of numbers
   - To change the description from the output to the outcomes
3) CHECK
   - Checking for missed aspects while measuring impact
   - The real impact of any project carried out
4) ACTION
   - To write a report to every stakeholder for review and opinions (Fioroni et al., 2014)

These plans were used to improve the governance of the city, which enhanced the lives of citizens. Further improvement was experienced through the creation of an effective health system to cater for the citizens, which is outlined in Section 4.1.7.

4.1.7 Trento's Smart Health System

The concept of health has been of particular concern since 1946, which was defined as a state of complete physical and mental wellbeing. A healthy environment is not simply defined by its physical characteristics only, but also as a space that offers social, practical, informational and economic opportunities. Europe is currently facing demographic transition and chronic disease challenges. Chronic diseases require new models of health support systems whereby ageing populations require high tech solutions to prevent frailty and disability. Current systems are also encouraging citizens to live healthy lifestyles by becoming more active partners. E-health systems can help citizens to better care for their personal health, with access to health professionals using communication devices. These services can be accessed anywhere and anytime in any location. Technology has been incorporated into the health system through mobile applications, network sensors and health management ecosystems. Sensors such as smart watches have been linked with mobile phones, and offer suggestions while collecting the physiological and lifestyle data (Nollo et al., 2014).

Gathering citizen data is useful for institutions, as they can monitor their daily health. This is efficient in the prevention and care of citizens by health institutions. Mobile devices can also gather information such as physical activity throughout the day. Infrastructure which connects

devices using the IoT approach allows users' actions to be sensed and interpreted. Apart from geotagging locations, which can be used .to help enhance abilities, gamification is also used to determine the movements of users. Technology has made citizens producers and consumers of information, allowing them to generate health and lifestyle information (Sarkar and Webster, 2017). The information is partially shared with health professionals without overwhelming their workloads. Citizens and professionals work together, with patients needing education and professionals providing the necessary information. Citizen engagement is therefore essential to ensure that citizens actively participate in providing personal information. However, privacy and confidentiality are a major concern. There is also a risk of clinical malpractices regarding professional boundaries and surveillance. The digital divide is also another challenge, as not everyone is technologically literate (Tzoulas et al., 2007).

Trento has involved various organisations in revamping its health system through innovative solutions. Adequate citizen engagement promoted a bottom up approach, with services and applications developed for portable devices. The regional government committed to developing solutions to provide integrated services involving multiple agencies and organisations. The province created smart hospitals with inclusive and integrated care. The three main sectors included wellbeing, healthcare management and accessibility, and innovative assistance and care. In 2010, Trento formed an e-health plan guiding how IT would provide integrated care to local citizens. All diagnostics were stored on digital databases, where the patients were given unified identification systems. A health care portal accessible to health care professionals was availed, with centralised clinical data for the province of Trentino. From then, patient information was shared among the professionals, providing a digitalised experience between health care givers and their partners. This allowed more than 3 million prescriptions to be offered in paperless mode. The information was then shared with the respective citizens through a portal called "Cartella Clinica Del Cittadino" where they could access their hospital records. A number of citizens were used to test the program in the living lab environment. The lab was used to monitor diseases such as asthma, hypertension and diabetes. Trento also followed with pregnancy treatment as a case study, from conception to weaning the child (Nollo et al., 2014). Figure 4-10 shows the level of integration of the smart healthcare system that is being used in Trento.

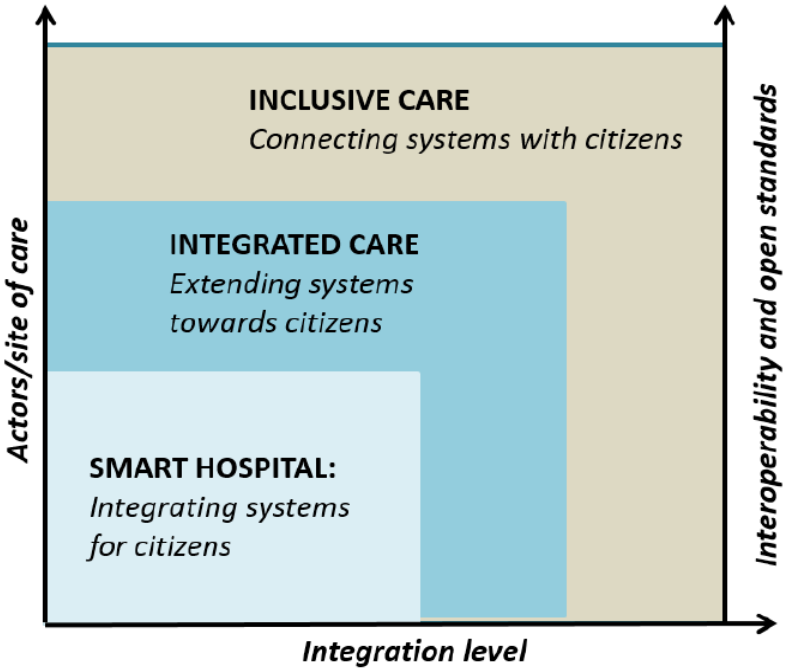

Figure 4-10. Level of integration for Trento's health system (Nollo et al., 2014)

The key actions to ensure smart health systems in Trento were as follows:

- Data protection and regulatory compliance in line with technological innovation
- Support for various stakeholders to be integrated into health care
- Collaboration of the IT system to improve efficiency, transparency and operability
- Leveraging existing IT capabilities
- Involvement of professionals and educated citizens in service design
- Multidisciplinary team helping with the aim of disease and frailty prevention
- Plan intervention and production of services using health, environmental and social data (Nollo et al., 2014)

The city has made significant progress in using technology to promote good health and lifestyles. This has been made possible by the integration and collection of millions of data sets. Managing these systems requires the use of Big Data capabilities, which are described in the following section.

4.1.8 Big Data

The production of data by citizens and organisations has become significant in the provision of information systems as well as opportunities in cities. This is because our everyday lives are now affected by electronic devices such as computers, tablets and smartphones. Data is being produced in large proportions and stem from different sources. The heterogeneous data has been causing

problems for the Information Technology department in the city as it must be standardised and be able to solve challenges. This was the basis of the term 'Big Data' as it entails different aspects. Big Data cannot be managed using traditional methods, therefore new methods needed to be devised. Approximately 90% of the data being used in the world today was produced in a space of a couple of years. Cities are big producers of data, hence this must be managed from data collection, integration and interpretation. The data must be engaging and understood by all stakeholders to provide added value through appropriate sharing methods (Molinari et al., 2014).

The city of Trento started the process of integrating Big Data and Open Data in 2014. This was expected to infiltrate into areas such as environmental monitoring to fiscal data which supports the detection of tax evaders. Most the data was extracted for use by the Statistics Office and the Office of Planning and Management control for the production of their early reports. This had two major disadvantages. The first pertains to the frequency at which the data was released, which led to delayed responses. The second was the dependency of the city on specific data structures and certain people only knowing how to handle the data. These two drawbacks led to a loss in the efficiency of data produced. The city decided to move to a shared information management system to improve efficiency and enable new services. The city, in collaboration with the province of Trentino, established Open Data sets (dati.trentino.it), which collected data from the entire territory (Trento, 2014).

Trento planned to enhance its smart dimension, with the city as a catalyst focussing on citizens' needs with technological and social innovation to improve their overall quality of life. The city developed technological infrastructure that enabled different types of services, which included the following:

- Improved data quality and processing to make it more accessible to the institutions and the general public.
- To use territorial and municipal data to improve access to information and improved quality of life.
- To provide companies and citizens to use and reuse data

Big and Open Data entails four different enablers which were used in the projects and visions for Trento. These were cultural, organisational, governance and technological enablers. These were outlined in the following sections.

4.1.8.1 Cultural Enablers

The cultural enabler offered an opportunity for the city's administration to change from being the sole owner of public data to sharing it among all stakeholders. This ensured transparency in

terms of public administration and the creation of social innovation, regional development and value-added services. The city put into place the following benchmarks adapted from Tim Davies:

- Choices based on communities' needs and demands
- Clarification of public data with frequent updates
- Allow users to create conversations with other data users
- To provide guidance to people who want to work with the various data sets and build skills for interpreting and using the data in the correct manner
- To provide feedback to improve the quality of data produced

Following the steps required, Open Data was published with a complete revision of data sources and the identification of reliable data. This involved a complete cultural overhaul of the way data was collected, evaluated and published. The city decided to improve the systems by holding a workshop twice a year on data principles and usefulness. It also enabled them to collect and monitor data for each stakeholder, offering customised solutions. The workshop also aimed to clarify differences between data and documents, the difference between documents readable by humans and machine-readable documents, and finally how to publish to the end users. It informed citizens about new services and applications on which the municipality published data (Trento, 2014).

4.1.8.2 Organisational Enablers

This included a review of the city's operational models and processes which changed information access rules. Citizens were the key elements of the model as they produce and benefit from the information for an Open Data management system. Citizen feedback would be used as input for improving data and system evolution (Fioroni et al., 2014). The enabling of a smart community also included the local government, the university, research centres and financial institutions. Each contribution would produce the required outcomes which included stakeholders' interests in making information sharing possible. With the geographical expansion of Trento as a smart city, Big Data and Open Data had to extend to the villages as well, fostering independent citizen virtual encounters. This involved going beyond municipal boundaries in order to improve citizen wellbeing (Molinari et al., 2014).

4.1.8.3 Governance Enablers

A smart city involves the generation of data to be ultimately shared as knowledge to make the city more efficient. Public policies in Trento were developed further to protect the citizens' rights in the provision and derivation of data. The city also identified the best rules for data circulation and restructured the management process to ensure they were oriented towards citizens' rights. This included access to licencing and policies for public documents, records and citizen privacy. Some aspects of the system were designed using participatory approaches suited for the privacy

of the citizens. The city had to balance the issue of privacy and transparency, with the latter needing accountability mechanisms to be put into place. In order to define the smart city rules, the Public Sector Information laws were considered. It also entailed a bottom up approach to the crafting of policies innovating growth and specialised knowledge in the city (Fioroni et al., 2014).

4.1.8.4 Technological Enablers

Trento had two major technological enablers essential to attaining their required goals. These were:

a) Infrastructure to automatically publish municipal data as Open Data to foster economic growth and transparency.
b) Development of the city's dashboard, which served as a portal on which citizens could access data.

To implement these processes, certain technological solutions were devised to make the data more authentic:

- Data was obtained from different sources such as municipal departments, companies, local institutions, with most of it coming from sensors and crowdsourcing techniques.
- Efforts were made to standardise the formats used for data exchange.
- Attention was paid to data quality which involved accuracy, certification and adherence to standards.
- The data had to be traceable for the it to be trustworthy.
- Data was integrated using platforms such as ComunWeb Platform.
- They collaborated with the province of Trentino for their projects to be synchronised with projects that were already being implemented (Fioroni et al., 2014).

The availability of data was expected to make the administration process more transparent to all the stakeholders in the city. It also stimulated innovative growth in the city, which was essential for economic growth. Some of the data was useful to both local and international tourists. The platform was managed by a multidisciplinary team of experts, thereby catering for all the aspects entailing the city. The four enablers mentioned were expected to improve the smart city status of the city of Trento for both its citizens and tourists alike.

4.1.9 Tourism

The purpose of a smart city in tourism is to give tourists and local citizens exclusive access to services and information. Technology is used as a facilitator to improve the overall experience of citizens and visitors alike. This is to keep up with consumer attitudes which have become digitally oriented. Tourists are the guests of a city, hence they must be able to access services and be given a platform to generate value. The guests are considered as 'smart' if they are able to use the

services offered to improve their experience. Tourists must also be treated in the same way as actual citizens, as they have the same requirements with regards to the level of service. A smart tourist destination must be able to show the visitor what the place offers. The system must be able to show the guest places of interest, reduce tourist downtime and according to the local context and real time events. There must be an anticipation of what the customer wants so that they may receive personalised services. A guest can also be a source of information through sharing on social media platforms such as Facebook and Twitter. This makes the guest a producer of local information which can be used by future travellers (Lorenzi et al., 2014). A smart tourism system begins with the digitalisation of services. The city of Trento made effort to ensure that all the services were availed to tourists using mobile devices and computers. It also included reputation monitoring through social media platforms. The city began to roll out a smart payment system in which tourists would pay in advance before travelling. It also created an integrated system which shows guests the transportation systems around the city and places of interest such as castles. The city harnessed technology to design a seamless experience for guests, who had a central role in the design of the city. Trento, therefore, improved their systems suited for tourists, using standards that were easy to implement, in line with their Smart City goals (Lorenzi et al., 2014).

4.1.10 Overview

The city of Trento has made great strides in the improvement of services within their city. The author's experience, both as a tourist and temporary resident showed that the city possessed an efficient system, from governance, to mobility, energy, tourism and waste management strategies. There was a sense of citizen ownership as they participated in energy saving and waste recycling methods. There was collaboration between the municipality and the citizens as they actively participated in waste separation and recycling. The city provided labelled bins to dispose different kinds of waste, which were collected on different days. Figure 4-11 shows a typical setup for waste disposal stations at the university residence.

Figure 4-11. Waste bins for disposing different types of waste

Most of the buildings have solar power systems to complement the grid. Student rooms had a power management system which switched off the main power when the chip card was removed from the slot. This ensured that power would be on only when the person was inside the room. This saved the municipality lots of money in terms of the cost of electricity production. The city also provided a waste recycling centre, where citizens would dispose waste such as electrical gadgets, clothes and biodegradable products. Overall, the experience showed the efficiency levels in the city, where a majority of the sectors were carefully managed and monitored. The case study for the city of Trento presents a sustainable city in the context of a developed country. The following section presents a case study of the city of Durban in South Africa, which is an example of a sustainable city in the context of a developing country.

4.2 Case Study of Durban (South Africa)

The city of Durban is located on the eastern coast of KwaZulu-Natal in South Africa. It is home to around 3,5 million inhabitants, with an increase in population expected as a result of rapid urbanisation. The city covers an area of approximately 2,300 km^2, which is 15 times the area of the city of Trento. Durban is culturally diverse, with a warm tropical climate that is ideal for tourism and hosting of business events and conventions. It is the third largest city in South Africa, with the largest port in Africa which receives shipments from all over the world. Durban is considered as one of the most liveable cities in South Africa, offering economic opportunities and a vast array of tourist attractions (Aschkenazi et al., 2012). The city achieved this by developing plans aimed at improving the quality of life for citizens and operational methods. The Integrated

Development Plan (IDP) was developed by the city, outlining the state of the city and plans to address the challenges being faced. A case study was conducted in Durban in comparison to Trento. This was done to derive a comparison of the way different cities approach the concept of sustainability as outlined in Section 2.4, and further reiterated in the literature review. Various aspects such as infrastructure, transportation, environment, waste management, citizen perception and the author's experience were looked at in this case study. This enabled a clear comparison between the city of Trento and the city of Durban, as both have the same underlying goals executed in different contexts. Figure 4-12 depicts a map of the city of Durban.

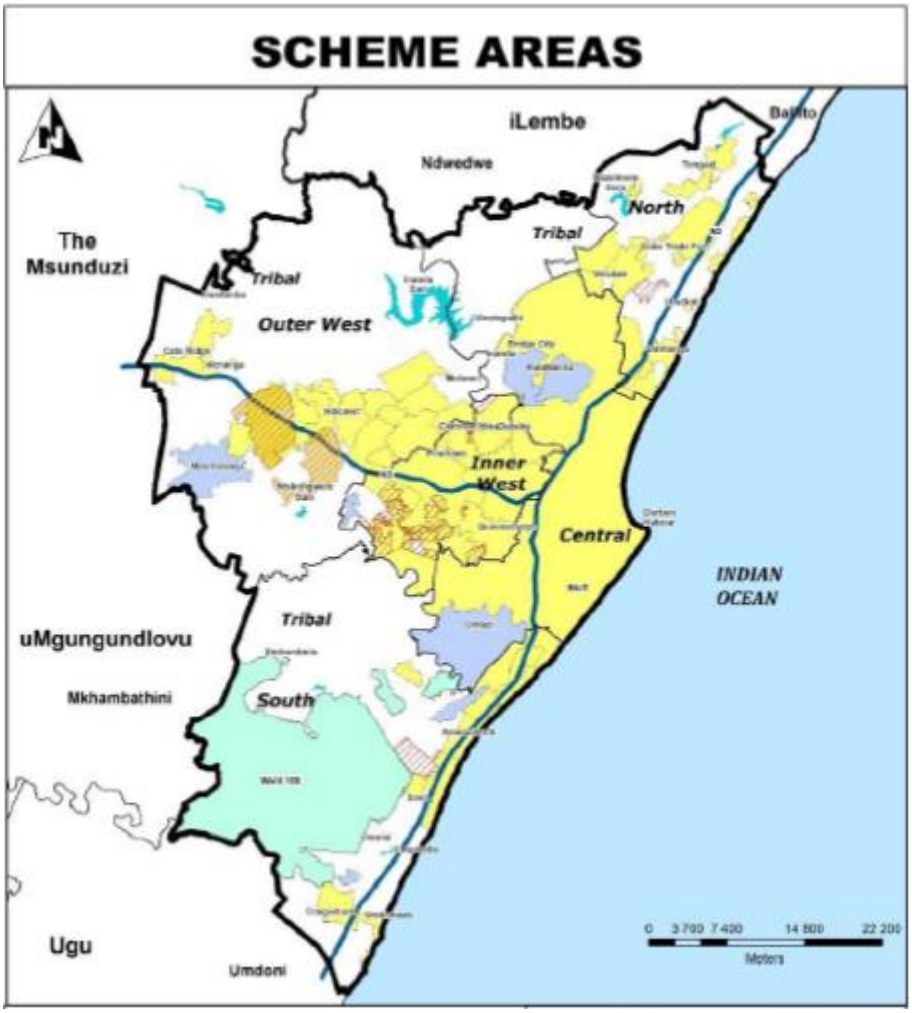

Figure 4-12 Geographical Map of Durban (eThekwini, 2020)

4.2.1 Challenges faced by Durban

Durban faces a multitude of challenges. The first one is rapid population increase as a result of increased fertility and rural to urban migration. Its demographics are reminiscent of a developing nation with high birth and infant mortality rates with a short life expectancy. Durban also has a diverse ethnic background, comprising of 74% Africans, 16% Indians, 3% coloured and 6%

white. The migration of citizens to Durban in search of better opportunities has had social and economic implications on the infrastructure, services and housing. Currently, the city faces acute housing backlogs due to this high influx. Most of the immigrants usually end up living on the streets and in informal settlements when they fail to secure housing. The city also has high levels of poverty, unemployment, poor service delivery in some areas, crime, health concerns, road safety concerns and power blackouts. Informal trading is considered as a challenge to the city's economy as it is difficult to collect tax revenues from the traders (eThekwini, 2017).

Gender imbalance still exists in Durban, where females make up 51% of the total population. Teenage pregnancies are also on the rise as most of the female teenagers have prospects to marry rich men. There is also the norm of being accepted by peers when a person is sexually active in their teenage years. This is further exacerbated by alcohol abuse and hazardous drinking among the youth, where lower levels of education are associated with high levels of binge drinking. The city is also rampaged by the HIV and AIDS pandemic as the region of KwaZulu-Natal registers the highest rates of infection. The city also faces an imbalance in the levels of education, where the central part of Durban has more educational institutions, resulting in higher education levels as compared to the rest of the city. Crime rates in the city have increased, with the majority of citizens being a victim of crime in the past five years. There was an increase in service rates, coupled with load shedding which led to more increase in electricity tariffs. The living conditions in informal settlements were also rendered as poor since there are little or no services to improve citizen quality of life. Traffic congestion in the city was a major concern for more than 52% of the citizens. Roads, traffic lights and infrastructure were dilapidating rapidly. Public participation has also declined substantially (eThekwini, 2017).

Durban has a high mortality rate as a result of diseases, vehicular accidents, and victims of crime. The current pollution levels are contributing to respiratory infections, heart diseases, strokes, and lung cancer. Conditions in informal settlements expose residents to environmental and social health risk. This is further compounded by lack of infrastructure, quality service, manpower, skills, and information systems. There are large disparities between the poor and the wealthy, resulting in social volatility and instability in the city. Durban's economy has been mostly affected by fluctuations in commodities and the rise in demand for raw materials. It is largely dependent on imports from China and the USA, reducing business and investor confidence, particularly in the private sector. eThekwini has a low unemployment rate as compared to the rest of the country, where they employ approximately 9% of the national population. 40% of the population currently uses public transport, consisting of taxis, buses and metro rail. The taxi and the bus routes cover Durban extensively, but the public transport system is generally regarded as inefficient. This is due to the direct competition between the rail and bus services, which have curtailed trip profits (eThekwini, 2017).

In order to assess living conditions and change methodological approaches to challenges in Durban, the municipality embarked on an annual household survey. The survey covered aspects such as living condition satisfaction, municipal service delivery and general day to day problems. Surveys conducted before yielded mixed results, but most of the citizen feedback was positive. The ratings showed that some key indicators significantly improved, where the quality of life was classified as above average. However, some citizens were dissatisfied with living standards, health, service provision, unemployment, crime and economic challenges. Most citizens were neutral in their responses, resulting in an incomplete set of results concerning general citizen satisfaction. Living conditions in suburban areas had high rankings, but issues such as illegal dumping and littering had a negative impact. The rise in cost of living was also a major concern as most citizens were battling to afford basic goods and services. eThekwini decided to cut the municipal rates to reduce the citizens' financial burdens. They also started hosting educational programmes with regards to the conservation of resources and the implementation of policies that are sustainable (Aschkenazi et al., 2012). This was aimed at the young children and the youth but was later extended to the older generations through the Adult Basic Education and Training Program. The city prioritised road and traffic management to improve the safety of pedestrians and motorists. They also made efforts to improve on current basic household services, emergency services and customer call centres. Measures were also taken to alleviate poverty and improve food security, particularly for the poor and marginalised communities. Internally, the municipality enhanced the skills of its staff so they could render efficient and sustainable services (eThekwini, 2017). Plans for the municipality's operation was outlined in the Integrated Development Plan, as outlined in Section 4.2.2. This document is one of the major development outlines alongside other publications such as the Spatial Development Plan and the Environmental Management Plans.

4.2.2 Durban's Integrated Development Plan (IDP)

The Integrated Development Plan (IDP) was developed by the eThekwini municipality in line with the Sustainable Development Goals. These plans were aligned to the available budget and national priorities as mentioned in the 2016 State of the Nation Address. The IDP aimed to implement a back to basics approach towards service delivery. The inner city of Durban was to be redeveloped, as current neglect had resulted in the migration of profitable investments to the outer areas of the city such as Umhlanga. The citizens' dire financial situation was also taken into consideration in the development of the IDP. Plans were made to educate the general public and young schoolchildren about energy conservation, water conservation and waste management. There were plans to address the issue of housing backlogs and improve living conditions in slums and informal settlements. The plans also involved road and traffic light maintenance, with law enforcement to reduce traffic violations. Law enforcement was also extended to controlling

littering and environmental damage. Public involvement was to be improved, which included community meetings, school meetings and door to door communication. Durban aimed to eradicate crime to improve citizen safety. The reduction in crime rates would be achieved through collaboration with law enforcement agents. To alleviate poverty, food security measures were to be employed, with citizens being encouraged to save as much money as possible. There was to be an increase in the participation of women in the development of the city (eThekwini, 2017).

4.2.2.1 Current Assets

Since 1994, eThekwini municipality provided 171,000 homes for the poor and unemployed citizens. This was done to curb the rapid growth of informal settlements. The provision of infrastructure also tied in with housing, which has seen the number of shacks in the city rising. In 2015, the city had a backlog of approximately 391,000 units and only provided 180,000. The timeframe the city came up with to address housing challenges was projected to be between 30 and 60 years, depending on funding. A Planning and Economic Development Committee was set up to oversee the economic projects undertaken by the city and to revive the declining economy. Durban currently possesses infrastructural assets which have boosted its popularity worldwide and have generated revenue for the municipality. The Ushaka Marine World precinct was developed to promote environmental conservation through fun activities, adventure, and knowledge sharing. The theme park, together with water world, generates revenue for eThekwini and improves conditions around the Point area. It also has social benefits as people from different walks of life can meet and interact. The International Convention Centre (ICC) is a famous hosting place and has been home to a variety of worldwide events such as the COP17 conference on global climate change and global sustainability resources. A substantial revenue has been generated through hosting such prestigious events (eThekwini, 2017).

The Moses Mabhida stadium is a landmark that defines the skyline of Durban, which doubles as a football and athletics stadium. It also offers sky car adventures, bungee jumping, bicycle rental and retail facilities, thereby creating an all in one experience for tourists who visit the area. Moses Mabhida was one of the homes to the 2010 soccer world cup, music awards and awards dinners. Durban has set aside a substantial amount of resources to address infrastructural backlog issues (Siemens, 2011). This is a major expenditure area for the municipal budget. The city also provides rebates for water, sewer, refuse and electricity for the poor and marginalised communities. There are energy management systems in place to ensure the adoption of more renewable energy options to supplement the current grid. The municipality also provides rural water and sanitation for areas on the periphery of the city such as Cliffdale and Umkomazi. Efficient provision of infrastructure is mainly affected by the following issues:

- Lack of funding to address backlogs in the city

- Most households are unable to pay for services due to high poverty and unemployment levels
- Illegal water and electricity connections which put infrastructure and lives at risk

Various projects being carried out can increase the number of dwellings and relocate citizens to areas with better living conditions compared to informal settlements. The municipality currently provides interim services for shacks, and this has been successful over the past years. The upgrading of informal settlements has seen these areas having ablution facilities for both men and women, refuse collection facilities, storm water channels, fire breaks, emergency escape roads and maintenance programs. This was done to improve living conditions in these settlements, as addressing the housing backlogs will take a long time. The provision of interim services is also a more cost-effective way as compared to building subsidised low-cost housing. Interim services can be provided rapidly, enhancing the social aspect of the city. Durban also installed low pressure solar heaters, promoting the use of renewable energy in households, as shown in Figure 4-13. However, the program came to a halt as the project was moved to a different department (eThekwini, 2017).

Figure 4-13. Installation of solar water heaters on low cost houses (eThekwini, 2020)

Durban also aimed to improve the harbour, road, rail and information infrastructure. There are a number of projects being carried out, such as Dube TradePort and the Cornubia mixed land use development. However, these plans were challenging to implement due to lack of manpower, skill, cost of doing business, lack of foreign investment and poor infrastructure. The Cornubia development is also expected to provide an additional 25,000 units to the housing sector. With regards to public transport, the city has catered for the disabled by providing buses with access ramps for wheelchairs. These buses service the inner city and provide good coverage in areas outside the CBD area. The main challenges affecting the public transportation system are limited

funding, lack of integration between different nodes, and lack of law enforcement over the sector (eThekwini, 2017).

Since the city is vulnerable to natural and manmade disasters, it was imperative that a system for disaster management be devised. The city already has Municipal Disaster Management Centre in place, which has satellite stations located around the city. The disaster centre ensures that the public is informed of impending disasters and then implement post disaster rehabilitation. There is a wide coverage of CCTV monitoring to improve the safety and security of residents. This also ensures a safe and healthy environment in the city. Disaster management is responsible for coordinating and managing major incidents that occur in and around Durban. The city has a vast number of volunteers who are trained in fields such as first aid and fire safety. There is also an information system which is supported by a fibre network around the city. There are call takers, police radio operators and fire radio operators. Durban also has early warning systems which are obtained from the South African Weather Services and relayed to the citizens. Future projects include the provision of sirens and public address systems which can be used to convey relevant information (eThekwini, 2017).

Two awareness initiatives exist in Durban, with one consisting of protective actions in the south of Durban due to toxic chemicals available in the area. The second protective action entails the promotion of risk awareness behaviour, particularly in informal settlements. The fire department has advanced equipment aimed at minimising social and economic losses associated with fire. Durban has the largest petrochemical storage facilities in the country and the continent's largest port, consisting of developed industries and central business districts. This has prompted the city to invest heavily in the fire and rescue department. Cato Ridge is a critical area in the city as it is rapidly developing and underserviced. This area is essential as it links the industrial area and the N3 route to Gauteng, therefore fire services have been deployed to avoid the destruction of properties. It is also essential to provide fire and emergency services in informal places where the highest number of fire deaths have been recorded (eThekwini, 2017).

4.2.2.2 Risk Management

Durban has a risk management process which deals with the identification, analysis and the evaluation of threats to the city. The risks identified had an effect on the following aspects:

- Business community
- Communication and loss of public confidence
- Non-compliance of legislation by citizens and organisations
- Limited finances to address service demand in the city
- Fraud, theft and corruption
- Contravention of supply chain policy management

- Uncoordinated government procedures resulting in poor service delivery
- Backlogs in human settlements
- Implementation of talent management such as scarce skills
- Ageing, dilapidating and vandalised infrastructure hindering service delivery
- Integrated Rapid Transport (IRT) services not being delivered on schedule
- Lack of investment hindering socio economic objectives
- Lack of capacity to adhere to IT policies which can ensure good governance
- Unstable employer-employee relations
- Non-adherence to economic transformation policies
- Prevalence of social disparities and lack of citizen integration
- Disruption of public transport services, affecting mobility
- Public protests due to delays in meeting service delivery targets
- Rapid urbanisation as a result of economic opportunities within the eThekwini area
- The city's inability to provide protection for its citizens
- Decrease in water sustainability due to ageing infrastructure and sporadic rainfall patterns (eThekwini, 2017)

With regards to crime, eThekwini put into place measures to ensure a safe environment for all its citizens. The South African Police Service (SAPS) was to provide data related to different forms of crime, with the eThekwini area having 44 stations. Between 2014 and 2015, the crime rate reduced to 168,000 reported cases, as compared to the 180,000 between 2012 and 2013. Visible policing and use of CCTV cameras were used to combat crime. A crime mapping process was also implemented to identify key areas affected by crime (eThekwini, 2017). Informal settlements were most affected, with the major crimes consisting of theft, armed robbery, rape and murder. The police used to oversee traffic laws and enforce by-laws in the city. Public transport vehicles, particularly minibus taxis, have caused the most problems for the municipality as they are not compliant with traffic laws. Monitoring of traffic is now being done by both traffic officers and cameras. Informal traders are also monitored as they can pose a threat to the formal business sector. A survey of the citizens indicated that the feeling of safety had risen from poor to marginally good. However, some aspects such as illegal land settlement, illegal street trading and drugs were still major issues in Durban.

With the global awareness of climate change on the rise, it was imperative that Durban's residents live in a sustainable and resilient manner. Durban has also been affected by climate change due to human activity which includes overdevelopment, illegal sand mining, pollution, destruction of habitats and the presence of invasive alien species (Siemens, 2011). The city of Durban is a biodiversity hotspot consisting of the coastline, rivers, estuaries, and approximately 75,000 acres

of open land. This has created a healthy living ecosystem in the city and attracted a lot of tourists, thereby generating revenue for the city. The natural ecosystem in Durban has provided a buffer for the city, particularly marginalised communities from the impacts of climate change by providing food, natural pollution regulation, water treatment, and erosion control. Continued maintenance and protection of this ecosystem will ensure the resilience of the city through ecosystem adaptation. However, development needs to address service delivery, climate change and regulate invasive alien species which now occupy more than 20 million hectares of land in the city. These species can be controlled, and degraded land rehabilitated to reduce the rate of land transformation (eThekwini, 2017).

In 2016, Durban's rivers and estuaries were in a poor state, with only six of them being classified as almost natural. Rivers were contaminated by illegal discharges from contaminated wastewater to solid waste. Eutrophication occurred as a result of wastewater treatment nutrients being discharged into rivers. It was also important that freshwater from neighbouring municipalities was clean as Durban gets some of the water from their catchments. To address global climate change, the city decided to invest in managing, protecting and restoring ecological features. Involving ecological infrastructure in the development of the city represented a unique opportunity as it could be expanded without straining the limited resources. Currently, Municipal legislation is an area that still needs review and improvement to curb environmental degradation. The national environmental laws have been set up such that municipalities can be held liable for any malpractices, which has financial implications. Durban has a Biodiversity Protection Division which reprimands those who break environmental laws and provide advice in areas that are not clear. There is also lack of acknowledgement of environmental thresholds in the city in its planning and development stages (eThekwini, 2017).

Durban still has a development deficit, and some social and economic thresholds have already been exceeded. This makes it hard to find solutions to the challenges faced by cities which are expected to make decisions based on reliable information and science (EU, 2015). The Sustainable Horizons Project is one of the many initiatives to monitor progress and provide an indicator level with regards to decisions made by the municipality. The Strategic Environmental Assessment (SEA) is being implemented through global approaches with a locally informed, human centred approach to development. The residents are Durban's greatest asset, and the city aims to equip them starting with municipal employees, to the citizens and finally nationwide implementation. This is being achieved through citizen education about the environment and the city's ecosystem. Sound understanding ensures that citizens and industries treat the city with consideration in their daily business. The consequences of exceeding thresholds can be used to inform strategic decision making and implementing sound policies in the city. To enhance the

capacity of the organisation as whole, the municipality has increased the number of employees and skills development programs (eThekwini, 2017).

Global climate change will increase the temperatures of Durban by 2.5 °C by 2065, coupled by an increase in average annual rainfall. The increase in rainfall is likely to be as a result of extreme events complemented with a rise in sea levels. The major challenges faced by eThekwini as a result of these phenomena constitute of the following:

1) A sharp increase in the frequency and intensity of floods
2) Decrease in water availability due to sporadic rainfall and increased evaporation
3) Increased erosion which affects the fertility of the soil and causes siltation in dams
4) Infrastructural damage due to extreme weather such as flooding and heavy winds
5) Coastal erosion due to rise in sea levels
6) Increased energy consumption due to increased electricity load
7) Decreased tourism and economic losses as a result of property damage
8) Increase in water borne and vector borne diseases such as cholera and malaria
9) Decrease in biodiversity due to climate change and invasive alien species
10) Reduction in yields of staple crops such as maize
11) Changes in planting and harvesting seasons
12) Increase in respiratory disease cases as a result of poor air quality

The Municipal Climate Protection Programme (MCPP) is an initiative that has been adapted to curb the adverse effects of climate change on Durban. With regards to spatial planning, the city aimed to manage its infrastructure to improve the quality of life for its citizens. Approximately 45% of Durban is rural, 30% is peri urban and 25% is urban. This presents a unique scenario in land and urban management as the city predominantly consists of rural land. This makes provision of services difficult, particularly allocating houses in urban areas that are less prone to erosion and flood damage, including access to public transport and economic opportunities. Given that eThekwini is diverse racially, socially and economically, the main issue is bridging the gap between the rich and the poor (eThekwini, 2017).

Durban's population is expected to grow to 4,4 million inhabitants by 2030. While international cities' population densities increase towards the city centre, Durban's population density tends to grow towards the outskirts of the city. The marginalised communities thus live far away from the city centre, resulting in their exclusion in social, economic and infrastructural developments. The spatial configuration of Durban is largely attributed to historical segregation which distorted the city's patterns (Yanti and Vidya, 2016). It also ignores the fact that land is a finite resource, resulting in long travelling distances which pose difficulties in developing a viable public transport system. In order to serve these areas, more money must be spent building roads and

water infrastructure to provide basic services to citizens. The municipality must somehow find ways to increase urban density in a city which spans an area of almost 2,300 km^2. To reduce rapid and uncontrolled expansion, eThekwini incorporated an urban line to limit spatial development to manageable levels. Development was to be concentrated mainly along key transport routes to provide equal opportunities in all areas in and around Durban. The municipality also implemented a Rural Development Strategy to cater for the strong interdependencies between the city and the peri urban areas. Different frameworks are now in place for spatial management, and these entail the Package of Plans, the Long-Term Development Framework and the Spatial Development Framework (eThekwini, 2017).

Food security is one of the major issues affecting the city. The main challenges in this aspect are the shortage of arable land and the identification of opportunities for food production. Durban has provided dedicated structures and frameworks to improve agriculture, to support poultry farming, aqua farming and community gardens. To also improve employment opportunities and curbing hunger, the municipality has an agro ecology programme which was meant to promote sustainable subsistence agriculture. Financially, the municipality has maintained a high overall credit rating. The healthy balance sheet is due to strong revenue generation coupled with mild expenditure and borrowings. This has also kept tariffs reasonably lower than most rates across the country. Much of the expenditure goes to addressing backlogs in service provision. Electricity tariffs, however, have risen by as much as 20% in the previous years. This is due to tariff hikes from Eskom, which is the country's electricity producer. Water tariffs also increased, and water revenues improved. Revenue streams were affected by electricity and water losses which were 7.7% and 39.7% respectively. Debt from the Department of Human Settlements amounting to R3 billion posed a financial risk to Durban as there was no guarantee of reimbursement (eThekwini, 2017). Figure 4-14 shows the municipal expenditure of eThekwini municipality or the 2020.

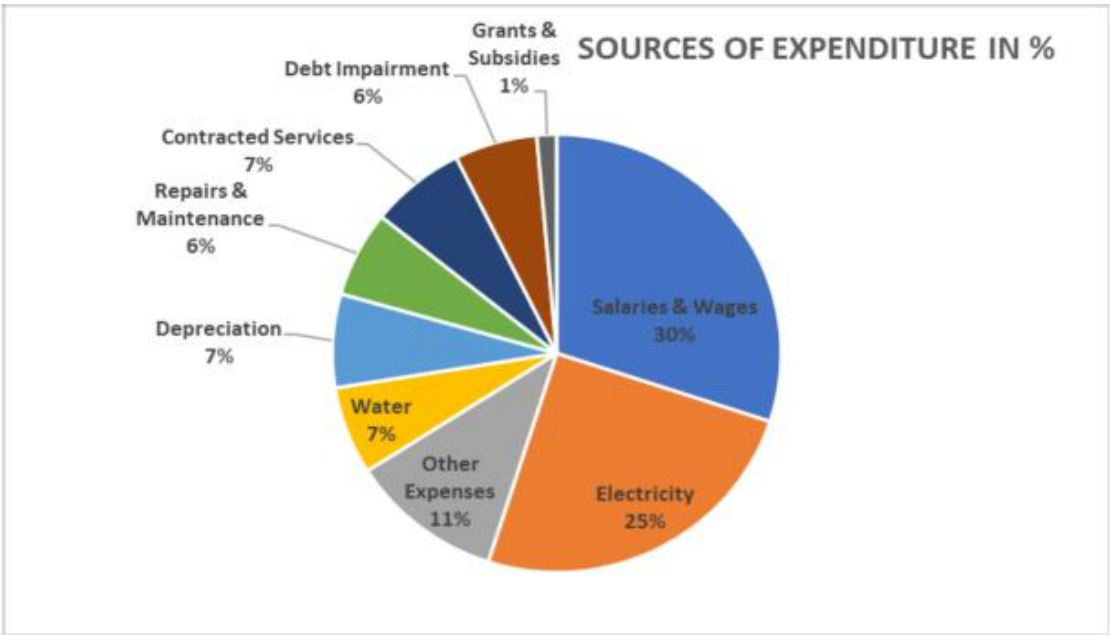

Figure 4-14. eThekwini Municipal Expenditure (eThekwini, 2020)

The expenditure shows that much of the municipality's budget went to employee salaries and electricity bulk purchases. This is because these services were once controlled by external entities and were moved to the municipality. The rise in the cost of repairs and maintenance contributed to escalating expenditure by the municipality. Refuse collection and security constituted of contracted expenses, which was 13% of the total expenditure. Other expenses were fuel, grants, special training, events and refuse bags. The municipality distributed 1,600 tenders for the year 2015/16, amounting to R6.5 billion. The major municipal expenditure in tenders and rendering services consisted of the following:

a) The rollout and maintenance of the Integrated Rapid Public Transport Network (IRPTN) estimated at about R4.8 billion.
b) Low cost housing delivery as an agency of the housing department
c) Rollout of free basic education services due to urbanisation. The poor communities and low value properties were exempted from paying rates for water, sewer and refuse removal.

Capital expenditure was directed towards infrastructure, land and buildings. A big chunk of the municipality's budget is currently spent on basic needs and service delivery. Some of the capital was spent on roads and transportation, and the rest going to sewerage and electricity. The IRTPN aimed to improve the transport system in the city, and Figure 4-15 shows part of the network. However, population influx and growth rendered it difficult to keep a consistent budget. Some of the money was spent on job creation projects such as the expansion of the harbour and the Dube TradePort precinct. More capital was spent on attracting tourism to Durban, which was expected

to generate substantial income for the city. Implementation of the IDP would not be possible without a proactive and effective approach to good governance. This was key as the governance level is where all the major decisions about the city's current and future operation plans are made (eThekwini, 2017).

Figure 4-15. Durban's IRPTN (eThekwini, 2017)

4.2.2.3 Good Governance

Governance is now an important aspect in Durban, as the challenges being faced by the city are now more diverse and complex. The municipality embarked on a set of programmes to improve their governance. They also devised a plan to set up a public participation committee which was responsible for dealing with marginalised communities, poverty alleviation, planning and citizen engagement programs. The IDP contains the city's comprehensive plans in terms of future development, which is in line with the Sustainable Development Goals and the National Development Plan. With adequate governance procedures, Durban aimed to address challenges such as:

- High rates of rural to urban migration
- High unemployment rates coupled with low economic growth
- Increase in poverty levels
- Lack of skills and literacy particularly among adults
- Alcohol abuse and teenage pregnancies
- Limited access to basic needs and services
- Increased risk of communicable and non-communicable diseases
- High levels of crime and lack of security
- Infrastructural dilapidation

- Inadequate water and energy supply
- Increased waste generation
- Climate change

These challenges hinder the city's development, and measures must be implemented to reduce their effects on efficient operation, service delivery and the quality of life for the citizens. Delays in rectifying most of these issues have resulted in the living conditions that are existent in the city today. Social and economic disparities between communities have exacerbated these problems, which have the potential to cause unrest in the city. In order to improve conditions in the city, the municipality identified six key areas of priority towards building a sustainable framework. These are shown in Figure 4-16 and were used to guide Durban's developmental process (eThekwini, 2017).

Figure 4-16. eThekwini's key strategic areas (eThekwini, 2017)

It was essential that the decision makers of the city devised a plan with a clear understanding of the prevailing conditions in the city. The scientific basis for these conditions was created by Policy Advocacy Department, which conducted satisfaction research on the citizens. The city also came up with a planning commission, which was the first in the country. The main aim was to revitalise Durban, particularly in the inner city. The inner city is the main developmental core, but most investors have moved away from the CBD towards newer areas such as Umhlanga and Durban North. An eight-point plan was devised to address the city's challenges, with projects that were interrelated. The plan entailed the following aspects:

1. To develop and sustain the spatial, natural and built environment for the citizens' benefit. This would enable the utilisation of Durban's resources without compromising the needs of the future, which involved the Municipal Climate Protection Programme.
2. To create employment by developing a diverse and prosperous economy to improve the material wellbeing of the citizens. This involved the alleviation of poverty, development of economical skills and the creation of jobs particularly for prioritised sectors.
3. To create an improved and quality environment through the provision of infrastructure, housing and community services. This would be achieved by providing low cost housing, rental strategies, tenure and addressing backlogs. It also extended to municipal transport plans and coastal management.
4. To create a socially equitable and safe environment. This included collaboration with law enforcement agents, social and health departments. The health department would spearhead combatting diseases such as HIV and AIDS, which have ravaged the African continent. Women's maternal health was among one of the main priorities.
5. To promote skills development for its citizens by creating sustainable growth platforms. Durban was to be a learning city which uses knowledge to enhance skills and also share knowledge with other municipalities. The citizens were to play a part in the economic growth of the eThekwini region.
6. Embracing cultural and social diversity, art and heritage by fostering a sense of citizen ownership and promoting healthy lifestyles and cultural diversity. The promotion of arts, culture, heritage preservation and sports were meant to bring people from all walks of life together.
7. Citizen centric and responsive local governments focussed on delivering services and implementing policies which benefit the citizens. The government planned on improving public management, fighting corruption and addressing past inequalities. eThekwini also aimed to create a comprehensive customer care policy and encourage citizen participation procedures. This would ensure a clean and transparent government that is accountable. The city also aimed to harness technology to create a robust data system and ICT infrastructure.
8. To become a transparent and financially sustainable city to boost confidence in external and internal investors. This would be achieved through updating plans annually, risk management, deadline monitoring, budget allocation, financial statements and municipal efficiency (eThekwini, 2017).

4.2.2.4 Implementation of the IDP

The implementation of the IDP is aimed at the city's development and the involvement of budgets, annual reports, public participation and performance monitoring. Every five years, a new office

of councillors review the development plans. This ensures that the new office develops in line with the long term plans of the city. The key performance areas entail service delivery, economic development, public participation, municipal transformation, cost cutting, financial viability and good governance. Financial viability was an important factor as service delivery issues had to be addressed without exceeding the municipality's budget. Since Durban is one of the cities with the highest economic inequality in Africa, it is imperative that transformation occurs in a manner that ensures fairness in availing opportunities. The renewal project at Warwick Junction saw the city council collaborating with the informal sector through the provision of spaces for vendors to sell their products. This saw traditional master plans being superseded by a collaborative and inclusive approach between the municipality and the informal sector (eThekwini, 2017).

Overall, eThekwini has made substantial progress in implementing the city's development plans. Most of the citizens now have access to basic services and more opportunities to participate in the economic development of the city. Democratisation of the society, protection of the environment, and an accountable government contributed to building and turning the municipality's vision into action (eThekwini, 2017). As mentioned, the IDP was developed around the morals of the Millennium Development Goals. The National Development Plan also influenced the IDP, which entailed economic and infrastructural development, and transitioning into a low carbon economy. The spatial configuration, which was influenced by history, was reversed through providing public transport, moving jobs and investing in marginalised townships. Investing in education for the younger generation will develop a knowledge intensive economy with quality healthcare, social protection, safer communities, professional public service and a less corrupt society. The municipal staff was trained continuously to ensure that post implementation issues relative to the new billing system were addressed. The city has made great strides towards becoming a sustainable city, and the quality of life has improved significantly. However, there are still a lot of areas that need to be rectified to create seamless operation and satisfied citizens.

4.2.3 Overview

From the case study conducted in Durban, it was found that the city has concrete plans to guide the development of the city. Overall, the experience with the city's systems was both positive and negative. The city has improved the quality of life for the citizens by providing basic services, particularly in informal settlements with marginal living conditions. The city's development was helped by a change in the citizens' attitudes, which were largely influenced by the move to educate the general public and school children about sustainability. The city also upgraded roads to cater for increased traffic and renovated buildings in the CBD. They have also made effort to make the public transport more efficient and safer. Low cost housing units were also built to accommodate the poor citizens and migrants. Developments such as Cornubia sought to integrate the wealthy

and poor communities whilst providing a mixed land use environment. This would also address social and economic disparities currently existent in the city. The city has also managed to conserve nature and biodiversity, with nature parks and conservancies. Tourism has also improved, with investments made to attract more visitors to Durban. However, some aspects such as the regulation of transportation industry are still in question. Crime rates are still high with women and children being the most vulnerable. In the African context, though, Durban has managed to improve its conditions and operation, which has put it on the path to becoming a sustainable African city.

4.2.4 Data Collection and Analysis for a typical African city

The following tables present a summary of the data collected for Durban, which would be used to derive sustainability indicators for the city. It includes a basic statistical analysis of the data, which highlighted the totals and the percentiles of data pertaining to the 103 wards in Durban. This is shown in Table 4-1 below:

Table 4-1. Statistical Analysis of Durban (eThekwini Municipality Website)

	Population	**Households**		
		Formal	**Informal**	**Traditional**
Total	3 745 859	679 750	197 242	86 688
25th Percentile	27 586	4 791,5	424	106
50th Percentile	35 000	6 518	1 047	311
75th Percentile	43 017	8 087	2 724	1 200

	Male	**Female**	**Disabled**
Total	1 795 827	1 937 460	136 610
25th Percentile	13 296,5	14 461,5	919,5
50th Percentile	16 986	18 639	1 194
75th Percentile	20 513,5	22 699,5	1 720

	Hospitals	**Clinics**	**Parks**	**Pools**
Total	31	196	785	36
25th Percentile	0	1	1	0
50th Percentile	0	1	4	0
75th Percentile	0	2	12,5	1

	Community Halls	**Sports Fields**	**Fire Stations**	**Police Stations**
Total	162	318	20	61
25th Percentile	0	1	0	0
50th Percentile	1	3	0	0
75th Percentile	2	4	0	1

	Employed	Unemployed	Pensioners	Not Active
Total	1 319 331	1 113 653	150 379	1 322 418
25th Percentile	9 733	5 658	1 006	9743,5
50th Percentile	12 863	10 949	1 274	12 212
75th Percentile	15 577	14 741	1 797,5	15 905,5

	Educational Institutions	Libraries	Literacy
Total	1071	68	2 054 981
25th Percentile	7	0	16 602
50th Percentile	10	0	19 501
75th Percentile	13	1	23 111

The summary of the data indicates the conditions that were and are still prevalent in the city of Durban. The data, together with an analysis of the two case studies of cities aiming to become sustainable, were used as a guide to develop the framework of sustainability indicators for the city of Durban. The following chapter presents case studies of the city of Trento in Italy and the city of Durban in South Africa, from which the framework of indicators was derived.

4.2.5 Summary

- The data showed that 48% of the population comprised of males, while 52% were females. This showed that women constituted the majority of the population, therefore their opinions and contributions must be considered in the crafting of policies.
- Approximately 67% of households are formal, 20% are informal and 8% are traditional. This requires a balanced approach to issues such as service provision, as almost 30% of Durban households do not have full access to basic services such as water, electricity and sanitation.
- Around 3% of the city's population consists of the disabled, and infrastructure must be able to accommodate wheelchairs and ramps. Services in the city must also prioritise the disabled so they do not have to stand for long hours in queues.
- The city has a high number of educational institutions, averaging 10 schools per ward. This offers plenty of educational opportunities for the city's young population.
- The city has 68 libraries in total, which is below par as the average number of libraries per ward is zero.
- The employment rates were low in 2012, as those in formal employment constituted of approximately 35% of the total population. This had improved by the year 2017. eThekwini has one of the lowest unemployment rates as compared to the rest of South Africa.
- The city of Durban had a total of 31 Hospitals, with an average of zero hospitals per ward. Some wards had more than one hospital, resulting in unequal distribution of health facilities.

- Overall, the city had 200 fire stations, which were rated as having good response times as mentioned in the city's IDP (eThekwini, 2017).

The summary of the data gathered for Durban was from the year 2012 and will have changed at the time of publishing. However, this data was meant to highlight how we can derive and assess current conditions within a city. Some of the data is missing, as it does not cover all the aspects that were identified in deriving global indicators. The following chapter presents a comparative case study between the cities of Trento and Durban. This was done to sift out indicators suited for a city in a developing country based on the information contained in the case study.

4.3 Comparative Analysis of Case Studies

The cities of Durban and Trento have one main goal in common, which is to become sustainable cities in their respective environments. Various approaches were analysed in the case studies, and it was found that the two cities employ different methods of development. This is largely because of the context of these cities, with Trento being in a developed country and Durban being a city in a developing country. Different factors also influenced their approaches to resolving urban challenges, such as the geography, resources, skills and manpower. The two cities had some similarities and differences in the way they operate and how citizens interact with their surroundings. Table outlines the comparison between the two cities:

Table 4-2. Comparison of Trento and Durban

Comparison between Trento and Durban	
Trento	**Durban**
Smaller geographical area of 160km^2	Vast geographical area of 2 300km^2
Challenges to improve services and systems	Challenges involving basic needs and services
One of the highest qualities of life in Europe	High rankings in quality of life in Africa
University participation in city's development	Incorporating universities in its development
Developed six journals for development	Integrated Development Plans in use
Data integration of all stakeholders	Data still fragmented among different sectors
Use of ICT to improve the quality of life	Use of more basic and physical approaches
Implementation of Big Data and Open Data	Integration of data still being implemented
Collaborative approach with citizens	Not all citizens involved in city development

Dedicated smart city office created	No dedicated smart city office
Organised real time public information	Limited public information available
Intelligent transportation system	Disintegrated transport system
Congestion due to geography and increased number of vehicles	Congestion due to increased number of vehicles
Car sharing and carpooling prioritised	Carpooling more of voluntary decisions
Less transport modes	More transport modes including minibus taxis
Priority sensors installed for public vehicles	Priority sensors in few areas
Use of ad hoc networks in vehicles	Electric boards to convey information
Decentralised Energy System	Central energy system from national grid
Mandatory waste separation	Waste separation not fully implemented
Use of Smart Grids	Conventional grid still in use
Use of sensors and embedded systems	Sensors in limited areas of the city
Retrofitting of old buildings	Older buildings being retrofitted
Most houses fitted with solar panels	RDP housing and some private houses fitted with solar geyser systems
Migration to online governance systems	Combination of both physical and online systems
Education of municipal employees on energy and water saving methods	Education of citizens on conservation, particularly children and the elderly
Living labs and online citizen courses	Citizen education through community meetings and adult literacy classes
Online citizen engagement platforms	Some aspects offer online engagement platforms
E-Health systems currently in place	Public health system not efficient
Paperless health prescription	Physical patient record keeping
Big and Open Data Platforms	Data still being collected and integrated
	High rates of urbanisation and migration
	Social and economic disparities
	Informal settlements and urban sprawl
	Provision of low-cost housing for the homeless

The table shows a summary of the comparison between the city of Trento, and some approaches they are taking to resolve urban challenges. Trento has more resources as compared to the city of Durban, therefore most of their projects were carried to completion. Some projects in Durban aimed at improving sustainability were abandoned midway due to lack of resources, and poor management. Durban has a lot of lessons to take from cities such as Trento, even though they differ in context and aspects such as size, environment, climate, and socio-cultural aspects, just to name a few. Some technologies currently in use can be leap frogged, such as the use of applications in mobility, energy and governance. However, due to social disparities, it might be perceived as favouring the wealthier communities, as not everyone has access to internet or can afford a smartphone. Durban also has to deal with informal settlements, homeless people and rapid urbanisation, coupled with inefficient governance systems and corruption. Basic issues such as the provision of basic goods and services to the citizens need to be addressed before putting into place some measures implemented by the city of Trento. The case studies reinforced some of the sustainability indicators introduced in Chapter 3. The next chapter introduces the results of the research, supported by the literature, the methodology and case studies conducted in the city of Durban and Trento.

5 Results and Discussion

From the indicators derived in Chapter 2.10, and data collected and Chapter 4.2.4, together with the comparative case study, the indicators for the city of Durban were derived. They were based on the set of worldwide indicators from the Literature Review. The data collected for the city of Durban was on a ward to ward basis, backed by statistical analysis. The data was obtained from the eThekwini website, and the analysis gave an indication of some of the prevailing conditions in the city. Overall, the city has numerous measures in place to address urban issues and cater for the rapid increase in population. The Integrated Development Plan has been a pillar in addressing urban challenges faced by Durban. This chapter outlines a list of indicators for Durban, derived from the Literature Review, the Global Indicators, and the comparative Case Study analysis in Chapter 4. The next section presents an overview of the framework outlined for the city of Durban, which can also be applicable to a typical African city.

5.1 Overview

The final framework for the city of Durban was based on the sectors presented in the literature review, which were in a root, stem, and leaf format. The roots consisted of the main causes of urban challenges being experienced today, and the stem dealt with the deterioration of conditions in and around the city. The leaf constituted of inefficient operation, poor service delivery and a decrease in the quality of life for the citizens. The framework for Durban was presented in the same format, with a set of sustainability indicators for each sector. It was derived to be adaptable to conditions in the city, hence the indicators can be modified, added or removed. Stakeholder participation will ensure that the modification of the framework will benefit everyone in the city. The following section presents the list of indicators for the city of Durban, together with the rationale for choosing the indicators and a section showing the relevant literature presented in this thesis. The framework is not final, as the city is still generating more data for all the different sectors.

5.2 Indicators for Durban

Sustainability Indicators applicable to Durban are outlined in tables 5-1 to 5-12.

Table 5-1. Durban's Indicators for Governance

Governance and Legislation		
Indicator	**Rationale**	**Reference Derived From**
Number of qualified personnel in government	The city of Durban requires skilled employees to participate in the city's development. Lack of skill and qualifications is one of the main challenges affecting the effective making of decisions in most African municipalities.	Literature Review (Ch 2.2.1) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
% budget on green projects	Durban needs more green projects to enhance its sustainability. Currently, the city has high levels of GHG emissions due to high industrial activity, and green projects have the potential to reduce these emissions and improve climatic conditions in and around the city.	Literature Review (Ch 2.2.12) Case Study (Ch 4.2) Global Indicators (Ch 2.10)
% Residents with knowledge of the city's vision	The city's vision must be clear enough to encourage residents to actively participate in the improvement of living conditions. Citizen education is essential, and information must reach every facet, from the rich to the poor and marginalised communities. Communication channels must accommodate various languages used in the city.	Literature Review (Ch 2.4.1) Case Study (Ch 4.2.2) Global Indicators (Ch 2.10)
Sector representation in the municipality	Good representation ensures that none of the sectors are neglected in terms of resource allocation. It also promotes coordination so that services do not clash among the sectors. Some of these areas are closely related, therefore it is important that efficient coordination is carried out.	Literature Review (Ch 2.2.1) Global Indicators (Ch 2.10)

Community meeting attendance	Community meetings ensure that authorities and the citizens meet consistently to discuss issues that arise in Durban. It is important that residents attend these meetings so their opinions and contributions can be heard.	Case Study (Ch 4.2.2) Literature Review (Ch 2.4) Global Indicators (Ch 2.10)
% women in governance positions	This encourages the participation of women in decision making process, ensuring that Durban's development also addresses the needs of females. Previously, they were not included in the city's development, therefore their involvement will result in gender balance. This is also considering that the majority of Durban's population is predominantly female.	Literature Review (Ch 2.2.10) Literature Review (Ch 2.4) Case Study (Ch 4.2.2) Global Indicators (Ch 2.10)
Voter turnout at elections	Voter turnout is important as it highlights the level of citizen participation in the development of Durban. It is also an encouraging sign of citizens who want their voices to be heard in the crafting of a city they need.	Literature Review (Ch 2.4.2) Literature Review (Ch 2.7) Case Study (Ch 4.1.6) Case Study (Ch 4.2.1)
Immigration tolerance	This ensures that those who migrate to Durban feel welcome and develop a sense of belonging. It also fosters knowledge and culture sharing so that people understand and tolerate one another. There have been cases of xenophobia in Durban, and it is imperative that the city creates a peaceful environment for immigrants and tourists alike.	Literature Review (Ch 2.2.11) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Availability of City Data	City data informs both citizens and authorities about prevailing conditions in the city. It also helps to gauge the progress of initiatives in the city, allowing to plan for future actions and endeavours.	Global Indicators (Ch 2.10)

Transparency and accountability levels	With high corruption levels in most African cities, the city of Durban needs to be transparent in all its undertakings to gain citizen trust. In Durban, some development projects have been stalled as a result of inconsistent practices.	Literature Review (Ch 2.7.4) Global Indicators (Ch 2.10) Case Study (Ch 4.1.6)
Number of corruption and bribery cases	This looks at the interaction between authorities and citizens, as corruption is still an issue in Durban. This ranges from the bribing of traffic authorities, the national police, and city officials with the intention of engaging in unlawful practices which override the city's laws.	Literature Review (Ch 2.2) Literature Review (Ch 2.4) Global Indicators (Ch 2.10)
Service delivery levels	Service delivery has been a major issue in Durban, resulting in disgruntled citizens. There are large disparities in service delivery between the wealthy and the poor communities, which has the potential to cause social unrest. The provision of low-cost housing and corresponding water and sanitation services have not been able to keep up with the rapidly changing demography.	Literature Review (Ch 2.2.6) Literature Review (Ch 2.4.7) Case Study (Ch 4.1.6) Case Study (Ch 4.2.1)

Table 5-2. Durban's Indicators for Infrastructure and Planning

Urban Infrastructure and Planning		
Indicator	**Rationale**	**Reference**
Urban population density	This gives an indication of urban densification and areas where citizens are concentrated. It is important as authorities know where to concentrate their services and plan development accordingly.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.2)
Level of urban growth control	This will curb urban sprawl that has resulted in peri-urban areas and megacities which are difficult to manage. Cities must ensure that boundaries of growth are set, so they do not have to spend resources servicing areas that are outside their jurisdictions.	Literature Review (Ch 2.2.2) Literature Review (Ch 2.2.4) Literature Review (Ch 2.2.12)
% infrastructure in good working condition	This gives an indication of the city's assets, how much they have and must invest to either maintain or upgrade the existing infrastructure.	Literature Review (Ch 2.2.2) Literature Review (Ch 2.4.3) Global Indicators (Ch 2.10)
% dilapidated and abandoned buildings	Cities need to repair or demolish buildings that are not fit for human occupation. Usually the homeless take shelter in these buildings, which are poorly sanitised and pose a risk of collapse. Some of these buildings have become a crime haven with security threats to the city of Durban.	Literature Review (Ch 2.2.2) Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)
% of green buildings	Green buildings save the city from excessive electricity and water consumption, which has economic benefits for the city. They also help alleviate the prevalence of emissions as plants absorb these harmful gases, at the same time reducing their own emissions.	Literature Review (Ch 2.2) Literature Review (Ch 2.7.8.1) Global Indicators (Ch 2.10)

% green areas	Green areas such as parks improve the city's aesthetics and provide residents with places to relax. Durban has a hot climate, therefore green areas provide good microclimates that regulate temperatures. Green areas can also be conservancy and education centres for residents and visitors.	Literature Review (Ch 2.4) Literature Review (Ch 2.6) Global Indicators (Ch 2.10)
% area of agriculturally productive land	Agriculturally productive land is essential for Durban's food security. These areas must be protected from pollution and pests, which may affect crop yields and lead to food shortages.	Literature Review (Ch 2.2) Literature Review (Ch 2.4.4) Global Indicators (Ch 2.10)
Regulatory and policy frameworks	These ensure that regulations and policies are effectively implemented and maintained. Efficient urban by laws will prevent most of the challenges occurring in Durban from compounding into more complicated issues. Policies also help the city to develop in line with their masterplan and overall vision.	Literature Review (Ch 2.4.10) Literature Review (Ch 2.9) Urban Challenges (Ch 3.2.1)
Infrastructural backlogs	Durban experiences infrastructural backlogs due to lack of resources and corruption. This needs to be addressed so that all citizens receive basic services such as water and electricity in their homes. It will also ensure that infrastructure such as roads are in good condition to prevent fatalities.	Literature Review (Ch 2.2.2) Case Study (Ch 4.2)
Synergy between planning and regulatory bodies	This is important as development must occur through coordination of regulatory bodies. Synergising also ensures that tasks carried out are not redundant and overlapping.	Literature Review (Ch 2.2.2) Literature Review (Ch 2.4.2)

Table 5-3. Durban's Indicators for Housing and Informal Settlements

Housing and Informal Settlements		
Indicator	**Rationale**	**Reference**
% legal housing	These are houses that are registered with the municipality and included in the city's development plans.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10)
Average living area per inhabitant	This depicts the space available for citizens in their houses and inhabited buildings to ensure occupant comfort.	Global Indicators (Ch 2.10)
% low cost housing	Low cost housing is essential as most of the urban poor cannot afford adequate housing. This can help to curb the rise of informal settlements as these houses are equipped with all the basic services.	Literature Review (Ch 2.3) Literature Review (Ch 2.4.1) Global Indicators (Ch 2.10)
Number of informal settlement dwellers	This provides an indication of the number of people in informal settlements so the city can offer interim services. It informs the city of the number of families that require low-cost housing.	Literature Review (Ch 2.2) Literature review (Ch 2.6.4) Global Indicators (Ch 2.10)
Level of satisfaction with current housing	Allows the municipality to know the opinions of the current housing situation, including those who benefit from the RDP housing schemes.	Global Indicators (Ch 2.10) Case Study (Ch 4.1.4)
Number of resettled families	This gives an indication of the number of people migrating to Durban, and the city must try to implement measures to cater for the migrants.	Global Indicators (Ch 2.10)
Rent to income ratio	This indicates the amount of rent paid in relation to household income.	Global Indicators (Ch 2.10)
Availability of housing finance	Availability of finance enables citizens to purchase houses with the help of financial institutions. This improves house ownership in the city.	Literature Review (Ch 2.2.3) Global Indicators (Ch 2.10)

Interim services in informal settlements	These services improve the conditions in informal settlements due to lack of municipal services, which are essential to the wellbeing and safety of citizens.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.1)
% population in hazard prone areas	This is important to the municipality as the city is only as strong as its weakest inhabitants. The city needs to keep a constant lookout in these areas as the residents are vulnerable to any natural or man-made disaster.	Global Indicators (Ch 2.10)

Table 5-4. Durban's Indicators for Transportation

Transportation		
Indicator	**Rationale**	**Reference**
Travel times	This enables citizens to know the amount of time taken to travel from one point to another, allowing residents to plan for their trips in advance. This can save time and money.	Literature Review (Ch 2.2.4) Literature Review (Ch 2.6.2) Global Indicators (Ch 2.10) Case Study (Ch 4.1.4)
Number of private vehicles	Gives a rough indication of expected traffic on Durban's roads, and this information can be used to improve traffic flow and transportation infrastructure in the city.	Literature Review (Ch 2.2.4) Global Indicators (Ch 2.10)
% area of parking space	Indicates the amount of parking spaces in and around the city, particularly in areas such as shopping malls, offices, and places of interest.	Literature Review (Ch 2.6.5) Global Indicators (Ch 2.10) Case Study (Ch 4.1.3)
Number of accidents and fatalities	Enables the city to identify critical dangerous spots and improve conditions around the area. The city can also educate drivers on implementing safer driving methods and encouraging consideration of other road users.	Literature Review (Ch 2.2.4) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Number of traffic violations	Gives an indication of driver behaviour on public roads and educating them about the rules of the road to ensure safety.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2)

Capacity of public transport	The majority of Durban's citizens use public transport to move around the city. Durban must, therefore, have an adequate transport system capable of handling passenger demand.	Literature Review (Ch 2.2.4)
Public transport cost per capita	Public transport must be affordable to the general public, as it is mostly used by low income groups.	Literature Review (Ch 2.4.4)
Public transport coverage per km^2	Coverage is important as public transport must be available in all parts of the city. Currently, Durban has a wide public transport coverage, with most of the routes being serviced by minibus taxis.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.1)
Modal splits and ease of change	Gauges the ease of passengers to switch from one mode of public transport to another, such as from taxi to train, or bus to taxi.	Global Indicators (Ch 2.10)
Number of bus stops and train stations	Bus stops and train stations enable passengers to board and disembark from public transport. More stations improve convenience for passengers.	Global Indicators (Ch 2.10) Case Study (Ch 4.1.4)
% lanes dedicated for public transport	Public transport must be prioritised as they are high occupancy vehicles and, on average, ferry more people at a single point in time.	Global Indicators (Ch 2.10) Case Study (Ch 4.1.4)
Route information availability	Route information enables travellers to plan their routes and inform them about their journeys. It is also helpful to visitors who do not yet know their way around the city.	Global Indicators (Ch 2.10)
Vehicle emission monitoring	This enables the city to monitor vehicular emissions to improve the environmental conditions around the city.	Literature Review (Ch 2.2.4) Literature Review (Ch 2.6.5)

Noise pollution levels	The city must monitor noise pollution levels to ensure resident comfort, as high traffic levels generate a lot of noise. In Durban, the hooting has been a source of noise pollution, particularly in congested areas such as the CBD.	Literature Review (Ch 2.2.4) Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)
Coverage of cycle and walking paths	Coverage of cycle and walking paths encourage the public to use other means of transport, with added health benefits. However, services must be within a reasonable walk or cycling distance from residences, workplaces and schools.	Literature Review (Ch 2.6.3) Global Indicators (Ch 2.10) Case Study (Ch 4.1.4)

Table 5-5. Durban's Indicators for Energy

Energy Production and Consumption		
Indicator	**Rationale**	**Reference**
Primary energy consumption per capita	Energy consumption must not outweigh production, as this deficit results in power rationing and load shedding. All electricity users must know their consumption levels so they can implement respective energy saving measures.	Literature Review (Ch 2.2.5) Literature Review (Ch 2.4.8) Global Indicators (Ch 2.10) Case Study (Ch 4.1.5)
% houses with electricity	Enables authorities to know the number of houses with access to electricity through legal connections. Illegal connections have been on the rise, and this damages infrastructure and puts lives at risk. Those without power mainly use firewood, charcoal, and other sources whose smoke can be harmful if inhaled. It also contributes to air pollution in the city.	Literature Review (Ch 2.4.8) Global Indicators (Ch 2.10) Case Study (Ch 4.1.5)
% renewable energy production	This shows the amount of energy being produced by the city using renewable sources such as solar, wind, etc. Durban has an abundance of solar and wind, therefore it is important that mechanisms and measures to harness the energy are in place.	Literature Review (Ch 2.4.8) Literature Review (Ch 2.7.8) Case Study (Ch 4.1.5) Case Study (Ch 4.2.2)
Existence of clean energy policies	Clean Energy Policies encourage and guide the implementation of green measures to produce energy, thereby curbing GHG emissions. Durban currently has high levels of air pollution.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Grid transmission losses	Gives power generating authorities and indication of the efficiency of the system.	Literature Review (Ch 2.6.6) Global Indicators (Ch 2.10)

% primary electricity producers	This shows the number of buildings/residents whose electricity does not come from the grid, but instead utilises solar panels, windmills, etc.	Methodology (Ch 3.2.1) Global Indicators (Ch 2.10)
Number of power cuts in a year	Power cuts give an indication of power shortages within the city.	Literature Review (Ch 2.2.5) Global Indicators (Ch 2.10)
Household and Industries using polluting energy sources	This shows the number of households and industries using electricity that is generated from fossil fuel sources such as coal and diesel.	Literature Review (Ch 2.2.6) Global Indicators (Ch 2.10)
% houses with subsidised electricity	These are houses in poor and marginalised communities where residents cannot afford to pay for the rates. These residents receive free electricity, which improves their lives but at a cost to the municipality.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10) Case Study (Ch 4.2)

Table 5-6. Durban's Indicators for Water and Sanitation

Water and Sanitation		
Indicator	**Rationale**	**Reference**
Water consumption per capita	This enables the city to know the amount of potable water produced and that which is consumed. It also allows the city to plan for the upgrading of existing infrastructure.	Literature Review (Ch 2.2.6) Literature Review (Ch 2.2.8) Literature Review (Ch 2.4.6) Global Indicators (Ch 2.10) Case Study (Ch 4.2.2)
% houses with municipal water	These are houses serviced by the municipality, which supplements the information on consumption. It also helps to identify areas without municipal water services.	Literature Review (Ch 2.2.6) Global Indicators (Ch 2.10)
% houses with alternative potable water sources	These are houses which do not obtain water from the municipal line, but instead use alternatives such as boreholes.	Literature Review (Ch 2.2.6)
Water Quality Index of water bodies	This indicates the level of contamination and quality of water that is used for domestic and industrial purposes.	Global Indicators (Ch 2.10) Case Study (Ch 4.1.5.4)
Water tariffs	This is the cost of water for the consumer. Water must be affordable, particularly to the urban poor. Marginalised residents usually end up using contaminated water sources, which is a cause of water borne diseases.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.2)
Water leakage and losses	It is an indication of the infrastructure's condition due to factors such as the age of pipes, level of vandalism, etc.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2)

Number of water meters	Water meters provide the municipality and consumers with a clear indication of their consumption, and also allows the water bill to be calculated. Illegal water connections are a norm in Durban, and the city must address the issue as treated water is lost or misused.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2)
Drinking water in public spaces	Potable water must be availed in public places such as parks. The city of Durban provides water in these public spaces, but vandalism has destroyed some of the infrastructure.	Literature Review (Ch 2.6.7) Global Indicators (Ch 2.10)
% water recycled	Water must be recycled to prevent further strain on water sources. This includes educating the citizens to use water sparingly and efficiently to avoid water outages in cases of drought. This is expected to begin on a household level and extend to the city as a whole.	Literature Review (Ch 2.2.6) Literature Review (Ch 2.4.6) Literature Review (Ch 2.6.3) Global Indicators (Ch 2.10)
Number of citizens with sanitary toilets	Sanitary toilets are important as their lack results in rapid spread of diseases. Most residents in informal settlements do not have adequate sanitation, therefore it is essential that the city provides interim toilets. This will significantly benefit the communities, particularly women, children, the disabled and the elderly.	Literature Review (Ch 2.2.6) Literature Review (Ch 2.2.10) Literature Review (Ch 2.6.7) Global Indicators (Ch 2.10) Case Study (4.2.2.1)
Sanitary sewerage coverage	Good coverage results in adequate disposal of harmful sewer water.	Literature Review (Ch 2.2.6) Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)

Waste water produced per day	Allows the city to design adequate infrastructure to cater for the load.	Literature Review (Ch 2.2.12) Literature Review (Ch 2.4.6) Literature Review (Ch 2.6.7) Case Study (Ch 4.1.5.4)
Number of WWTP	This shows the capacity of the city to treat wastewater	Literature Review (Ch 2.6.7) Case Study (Ch 4.1.5.4) Case Study (Ch 4.2.2.2)
Existence of water treatment standards	Water Treatment must be done according to standards and must not result in environmental damage. Durban has water treatment standards in place to ensure the process in carried out efficiently.	Literature Review (Ch 2.6.7) Case Study (Ch 4.1.5.4)
Number of subsidised houses for services	This indicates the number of houses being serviced by eThekwini which the residents do not pay rates.	Case Study (Ch 4.2)

Table 5-7. Durban's Indicators for Waste Management

Waste Management		
Indicator	**Rationale**	**Reference**
Daily waste generated	Enables the municipality to know the amount of waste generated so they can tailor their services to meet demand.	Literature Review (Ch 2.2.8) Literature Review (Ch 2.4.6) Global Indicators (Ch 2.10)
Waste collection days per week	These are the number of days in which waste is collected. This has direct bearing on the amount of waste that is properly disposed.	Global Indicators (Ch 2.10)
% waste recycled	This is essential as not all the waste must end up in landfills. Recycling is generally cheaper as compared to manufacturing new products, therefore waste must be recycled to preserve the environment and reduce landfill costs.	Literature Review (Ch 2.6.3) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
Extent of waste-energy conversion	Durban has a waste to energy conversion facility, therefore some of the waste is converted to a useful resource.	Literature Review (Ch 2.6.6) Case Study (Ch 4.2)
Number of sanitary landfills and capacity	This indicates the capacity of the city to cater for proper waste disposal measures	Literature Review (Ch 2.2.7) Literature Review (Ch 2.4.3) Literature Review (2.6.6) Global Indicators (Ch 2.10)
% waste deposited into sanitary landfills	This shows the amount of waste that is properly disposed and enables the municipality to gauge the amount of waste that litters the streets.	Literature Review (Ch 2.2.7) Literature Review (Ch 2.4.3)

	Recycling also reducing the amount of waste in landfills. Durban has clear waste management strategies in place to ensure proper waste disposal.	Literature Review (Ch 2.6.6) Global Indicators (Ch 2.10)
Amount of hazardous waste generated	Hazardous waste must be disposed in an appropriate manner, therefore it is essential that hospitals and chemical industries are monitored and their disposal methods carefully managed.	Literature Review (Ch 2.2.7) Literature Review (Ch 2.4.6) Literature Review (Ch 2.6.6) Global Indicators (Ch 2.10)
Informal waste collectors	Residents who make a living by salvaging waste and sending to recycling centres. It is essential that the municipality integrates them into the system as they are contributing to reducing waste in the city streets.	Literature Review (Ch 2.2.7)

Table 5-8. Durban's Indicators for the Environment

Environmental Degradation and Climate Change		
Indicator	**Rationale**	**Reference**
Air Quality	This indicates the type of air prevalent in the city, whether it is healthy or polluted.	Literature Review (Ch 2.7.1.4) Global Indicators (Ch 2.10)
GHG emissions in the city	This shows the amount of emissions in the city, which has direct bearing on the air quality. Durban produces a large amount of GHG emissions due to industries and the oil refinery by the port.	Literature Review (Ch 2.2) Literature Review (Ch 2.4) Case Study (Ch 4.2.2)
Particulate Matter levels	This indicates the levels of particulate matter in the air. High levels have negative respiratory effects on humans and animals.	Literature Review (Ch 2.2.4) Literature Review (Ch 2.2.8) Global Indicators (Ch 2.10)
Ozone depleting substances consumed	These substances are deposited into the atmosphere and damage the ozone layer.	Global Indicators (Ch 2.10)
Environmentally damaging products consumed	These are substances that pollute the environment and are not biodegradable, such as plastic bags.	Literature Review (Ch 2.2.8) Literature Review (Ch 2.4) Literature Review (Ch 2.7) Global Indicators (Ch 2.10)
Number of air polluted days in a year	Gives an indication of the frequency of air pollution in Durban	Literature Review (Ch 2.2.10) Literature Review (Ch 2.4.5)
Deforestation and reforestation rates	Durban has a wide variety of flora and fauna, therefore vegetation must be preserved. Current deforestation levels are on the rise as	Literature Review (Ch 2.2.8) Literature Review (Ch 2.4.5)

	people use wood as a source of energy. The city must curb the cutting down of trees and plant more trees to improve the environment.	Global Indicators (Ch 2.10)
% area degraded land	Indicates the amount of land that needs to be rehabilitated for either inhabitation or for agricultural purposes.	Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.2)
% area under environmental protection	Durban has stringent measures to protect the environment. The city must put more areas under environmental protection to prevent the destruction of biodiversity and curb invasive alien species.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10)
Number of trees per unit area	Trees are important as they absorb carbon dioxide and improve the climatic conditions of Durban. They also contribute to the aesthetic appeal of the city.	Literature Review (Ch 2.2.8) Literature Review (Ch 2.4.5) Literature Review (Ch 2.6.4) Global Indicators (Ch 2.10)
Number of environmental awareness programmes	Awareness programmes educate citizens to take care of the environment and actively participate in the city's development	Literature Review (Ch 2.6.6) Global Indicators (Ch 2.10) Case Study (Ch 4.1.2) Case Study (Ch 4.2.2.1)
Climate change and resilience policies	These are important as they guide in implementing measures to improve the climate and environmental conditions around the city.	Literature Review (Ch 2.2) Literature Review (Ch 2.4) Literature Review (Ch 2.6) Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)

Industrial regulation and compliance levels	Industries must be regulated so they do not dispose harmful substances into the atmosphere or the surrounding environment.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10) Case Study (Ch 4.1.7) Case Study (Ch 4.2.2.2)
Environmental monitoring	The city needs to monitor and improve the state of the environment. Constant monitoring also ensures that relevant stakeholders comply with environmental rules and regulations.	Literature Review (Ch 2.3) Literature Review (Ch 2.7) Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)

Table 5-9. Durban's Indicators for Disaster Management

Disaster Management		
Indicator	**Rationale**	**Reference**
Number of hazard prone areas	This enables rescue services to pay attention to these areas as they are more vulnerable than the rest of the city.	Literature Review (Ch 2.2.3) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Disaster warning instruments	These are essential as they alert the citizens and authorities of impending disasters. This then prompts the relevant authorities to respond appropriately.	Literature Review (Ch 2.2.9) Global Indicators (Ch 2.10) Case Study (Ch 4.2.2.1)
Number of firefighters per 1,000 population	Firefighters are essential in rescue operations, particularly in fire outbreaks and general disasters. Informal settlement fires have resulted in many deaths in the city of Durban.	Literature Review (Ch 2.2.3) Literature Review (Ch 2.2.5) Literature Review (Ch 2.2.7) Global Indicators (Ch 2.10) Case Study (4.2.2.1)
Emergency response times	Response times give an indication as how quick rescue services attend to a disaster. The shorter the response times, the better the city is more equipped to deal with disasters	Literature Review (Ch 2.2.9) Global Indicators (Ch 2.10) Case Study (Ch 4.1.4) Case Study (Ch 4.2.2.1)
Number of emergency centres	This is essential as more emergency centres are an indication of wider coverage. There must be coordination between these	Literature Review (Ch 2.2.9) Global Indicators (Ch 2.10) Case Study (Ch 4.2)

	centres, and the city of Durban has a number that are fully operational.	
Education levels for disaster response	The citizens must themselves be educated on how to respond during disaster times. This will help particularly when there is a delay in response to a disaster.	Literature Review (Ch 2.2.9) Literature Review (Ch 2.2.11) Global Indicators (Ch 2.10)
Availability of real time data	Real time data enables emergency information to be conveyed to the citizen and prompting quick responses from authorities	Literature Review (Ch 2.2.11) Literature Review (Ch 2.7.4) Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)

Table 5-10. Durban Indicators for Health and Safety

Health and Safety		
Indicator	**Rationale**	**Reference**
Number of hospitals and clinics	The city has a good number of hospitals and clinics. It is imperative that these hospitals cover the city's geographical area. Good coverage ensures that people have access to health facilities, which must ideally be in a good condition.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)
Number of doctors and nurses	This indicates the level of qualified staff available to attend to those who seek medical attention.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)
Infant mortality rate	This is important as children are vulnerable to diseases. It enables authorities to find ways to reduce the death of children before the age of 5.	Literature Review (Ch 2.2.10) Literature Review (Ch 2.3) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Life expectancy	Life expectancy is a measure of the quality of life, and the city has low life expectancy. The city must aim to increase life expectancy by encouraging good health practices and providing an unpolluted environment. Life threatening aspects such as crime and disasters must also be alleviated to protect the citizens.	Methodology (Ch 3.2.1) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
Average distance to health centres	These are an indication of the accessibility of health facilities. The lesser the distance, the more accessible the medical facility is.	Literature Review (Ch 2.2.10)

Number of immunised children	Children must be immunised against diseases in order to boost their immune systems. This in turn may reduce infant mortality rates.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)
Number of malnutritioned children	This enables authorities to address the issue of children living under poverty conditions.	Global Indicators (Ch 2.10)
Adolescent birth rates	This relates to teenage pregnancies. They need to be educated on the impacts and how to care for their children.	Global Indicators (Ch 2.10) Case Study (Ch 4.2)
Adults with healthy weight	Most adults are obese and lead unhealthy lifestyles. It is imperative that they are encouraged to live healthy by watching what they eat and exercising regularly.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)
Respiratory diseases per 1,000 population	This shows the quality of air in the city and the effects it has on the citizens. Currently, Durban has high emission of greenhouse gases and particulate matter. The city needs to address this issue to improve citizen health.	Literature Review (Ch 2.2.4) Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10) Case Study (Ch 4.2.1)
% population with HIV/AIDS	This indicates the number of people living with HIV/AIDS. This is prevalent in KwaZulu-Natal, and the city must educate citizens and put measures in place to prevent the spread of the disease.	Methodology (Ch 3.2.1) Case Study (Ch 4.2.1)
Crime rates	Crime rates are indicative of the citizens' level of safety. Durban has high crime rates and city must improve on its safety measures as there is a high influx of tourists.	Literature Review (Ch 2.2) Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10) Case Study (Ch 4.2)

Number of violent/intentional homicides	This carries on from the crime rate indicator. It focusses on more severe crimes which include bodily harm and those that cause severe psychological trauma.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
Number of carjacking incidents	Carjacking crimes are also common in Durban, and authorities must enforce the laws to prevent these types of crime in the city.	Literature Review (Ch 2.2) Case Study (Ch 4.2)
Teenage crimes	This involves crimes committed before the age of 18. Children must be educated to not indulge in crime and the effects it has on their futures.	Literature Review (Ch 2.2) Case Study (Ch 4.2)
Victims of scams and cyber crimes	This has been on the rise in South Africa. Criminals usually target the elderly and less technologically inclined with large amounts of money.	Literature Review (Ch 2.7) Global Indicators (Ch 2.10)
Number of police officers per 1,000	This gives an indication of the expected police presence in the city. Wider coverage ensures a reduction in crime related activities.	Literature Review (Ch 2.4). Literature Review (Ch 2.2.10)
Number of child abuse cases	Children are victims of abuse around the world, and measures must be put into place to curb child abuse thorough educating both adults and kids.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
Number of women abuse cases	Women have also been victims of abuse, particularly domestic violence. Authorities must ensure that women are protected from harm, particularly from crimes such as rape. This also extends to minors.	Literature Review (Ch 2.2.10) Global Indicators (Ch 2.10)
Social workers and psychologists	Social workers and psychologists form part of the professional team that helps victims with their ordeals. With high crime and abuse levels, victims must have easy access to for counselling purposes.	Literature Review (Ch 2.2.12)

Table 5-11. Durban's Indicators for Education, Science and Technology

Education, Science and Technology		
Indicator	**Rationale**	**Reference**
Number of primary and secondary schools	This is an indication of the availability of schools in the city. The more schools there are, the more opportunities available for children to get a good education. Schools must also be affordable to ordinary citizens to ensure their children also access education.	Durban Data (Ch 4.2.4) Literature Review (Ch 2.2.10)
Number of tertiary institutions	Universities and technical colleges are important as they train the city and country's workforce. Research on new methods of operation and planning can also be carried out by universities. Durban has institutions such as UKZN, DUT and MUT to help in the city's developmental research.	Global Indicators (Ch 2.10)
Male to female ratio in educational institutions	This gives an indication of gender balance in educational institutions. Durban has seen an increase in the number of females enrolling in schools, which is in line with achieving gender balance in the education system.	Case Study (Ch 4.2) Literature Review (Ch 2.2.10)
Literacy rate	The ability to read is an essential skill as communication is mostly transmitted through writing. This also applies to the elderly. Durban has an adult education programme to cater for the literacy deficiencies.	Durban Data (Ch 4.2.4) Literature Review (Ch 2.2.10) Case Study (Ch 4.2.1)

High school and primary school pass rates	These are indicative of the quality of education in the city, and Durban must aim to increase their pass rates to produce more skilled and disciplined future professionals.	Case Study (Ch 4.2.2)
Student teacher ratio	Student teacher ratios show the efficiency and the ease of teaching and learning in schools. Normally, low student teacher ratios enable more effective communication and better quality of education.	Case Study (Ch 4.2.2)
Number of libraries	Libraries encourage a reading culture among citizens. eThekwini has a number of libraries which also involve community engagement activities.	Durban Data (Ch 4.2.4)
Research and development expenditure	Research and development are essential in improving the efficiency of the city. This can be carried out in conjunction with tertiary institutions or within the municipality. The city must collaborate and invest in academic institutions as they spearhead research.	Case Study (Ch 4.2)
Number of patent applications	This shows the level of research and useful findings which can be patented. It is essential as research output can have an influence on the city's development.	Global Indicators (Ch 2.10)
Number of computer literate individuals	Electronics are now common sources of communication and finding information. It is essential that citizens have a basic working knowledge of computers, particularly the elderly.	Literature Review (Ch 2.2.12) Literature Review (Ch 2.7.4) Global Indicators (Ch 2.10)

Number of internet users	The internet is now a medium for communication and a source of information. This allows efficient and environmentally friendly communication by reducing the use of paper. More internet users mean information can be conveyed quickly and efficiently.	Literature Review (Ch 2.2.11) Literature Review (Ch 2.4.2) Global Indicators (Ch 2.10) Case Study (Ch 4.1.6)
Number of IT education programmes	This indicates the number of programmes in place to educate the general public about the benefits of information technology and how it can be used to improve the quality of life for the citizens.	Case Study (Ch 4.1) Literature Review (Ch 2.2.10) Literature Review (Ch 2.4.10)
Environmental awareness programs in schools	Environmental awareness must begin at grass roots level, which are primary and secondary schools. This enables the city to empower children to protect the natural environment and biodiversity, even in their homes.	Case Study (Ch 4.1) Case Study (Ch 4.2.2)
Accessibility to broadband internet	Accessibility to internet is important as it now contains information platforms. The city partnered with Telkom to install fibre cable and Wi-Fi hotspots in and around the city.	Literature Review (Ch 2.2.11) Literature Review (Ch 2.4.2) Global Indicators (Ch 2.10)
Mobile telephone subscribers	This shows the number of people with mobile telephone services, which enables easy and on the go communication.	Global Indicators (Ch 2.10) Case Study (Ch 4.1.3) Case Study (Ch 4.2)
Number of computers per school	This is indicative of schools' computer facilities, which can help kids to become computer literate.	Literature Review (Ch 2.2.11)
Number of computers per household	This shows the number of households that make use of computers in their daily lives.	Literature Review (Ch 2.2.11) Global Indicators (Ch 2.10) Case Study (Ch 4.1.8)

Table 5-12. Durban's Indicators for Social, Cultural and Economic aspects

Social, Cultural and Economic		
Indicator	**Rationale**	**Reference**
% population formally employed	Gives an indication of the population that is formally employed in relation to the total population.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10) Case Study (Ch 4.1.4) Case Study (Ch 4.2)
% population informal traders	Shows the number of people who make a living through informal means of trade. This allows the city to implement measures to work together and make them contributors to the formal economy.	Literature Review (Ch 2.2.12) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
% population unemployed	Shows the number of unemployed individuals in relation to the total population of the city.	Literature Review (Ch 2.2) Global Indicators (Ch 2.10) Case Study (Ch 4.1.6.2)
Male to female ratio in formal employment	This is an indication of gender equality in the city. Durban has seen a significant improvement as compared to previous years.	Global Indicators (Ch 2.10)
Net export and import rates	These have a direct bearing on the economic development and its position on the national and global scale.	Global Indicators (Ch 2.10)
Foreign Direct Investment (FDI)	This shows global economic confidence in the city, and more funding means more resources are allocated to the continual development of the city.	Global Indicators (Ch 2.10)

Debt status	This is an indication of how debt ridden the population is.	Case Study (Ch 4.2)
Poverty rate	Shows the number of people who are living below the poverty datum line. Social and economic disparities are also prevalent in Durban, and it is important that these gaps are addressed, and the marginalised people empowered to sustain themselves.	Literature Review (Ch 2.2) Literature Review (Ch 2.3) Global Indicators (Ch 2.10) Case Study (Ch 4.2)
Cost of living	An indication of the day to day costs of individuals and their families.	Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)
Suicide rate	This is an indication of stress levels in the population due to various factors such as poverty, financial debt, and social problems, just to name a few.	Global Indicators (Ch 2.10)
% population with disabilities	Gives an indication of those living with disabilities.	Literature Review (Ch 2.7.1.1) Global Indicators (Ch 2.10) Case Study (Ch 4.1.7)
Living Conditions Index	This shows the overall satisfaction of the living conditions of the city. The majority of the citizens were satisfied, but there is room for improvement.	Global Indicators (Ch 2.10) Case Study (Ch 4.1 & 4.2)
Income distribution and equality	This shows the level of economic disparities between the highest paid and lowest paid workers. It also indicates the level of wealth distribution in the city, as some areas have more capital investment as compared to others.	Literature Review (Ch 2.2.12) Case Study (Ch 4.2)
Access to leisure	This relates to the number of parks, relaxation places, and general accessibility to entertainment concerts, sporting events, etc.	Global Indicators (Ch 2.10)

Child headed families	Indicates the number of families without parents and are headed by someone below the legal age. These families should receive help from the authorities as they do not have sustainable means and a source of income to survive.	Literature Review (Ch 2.2.12) Global Indicators (Ch 2.10)
Cultural activities per year	Indicates the number of cultural activities which bring the population of Durban together to foster cultural exchange and unity in the city.	Literature Review (Ch 2.2.11) Case Study (Ch 4.1)
GDP per capita	Indication of the market values for goods produced by the city, either for local consumption or for export.	Case Study (Ch 4.2.2)

5.3 Review of Framework

The indicators presented in Tables 5-1 to 5-12 constitute of a framework for the city of Durban. This was based on the information provided and analysed in Chapter 4.2.4, together with the comparative analysis of the cities of Durban and Trento. The framework of indicators derived may be used by municipalities, particularly in developing countries. The framework was made to be flexible so it could be applicable to developing cities with different operating environments. Since the scope of these indicators was mainly based on the literature used in this research, some indicators might need to be added, removed, or modified depending on new information and changing conditions. New indicators can also be added from different points of view, such as economic and social aspects. Some of the indicators are applicable to more than one sector, and this requires extensive consultation to avoid overlaps. For example, the indicator on emissions can be classified under Transportation or Climate Change. In this research, however, the indicators were kept in fixed sectors as establishing the sectorial relationships would require a lot of time, effort, and extensive consultation of municipal experts.

5.4 Discussion

The framework of indicators for the city of Durban was developed in line with the Integrated Development Plan for eThekwini Municipality, which was outlined in the case study in Chapter 4. The case study of the city of Trento would also guide in the implementation of new policies involving the use of technology, which must first be adapted to suit the environment in Durban. The sectors for the indicators can ideally be overseen by a specific municipal department. However, collaboration is important as the framework must be implemented in a holistic manner. Indicators can be modified to suit the municipality's existing organisational and operational structures. They can be added to the development plans such as the Integrated Development Plan and the Integrated Transport Plan. They can be reviewed over a time period decided on by the municipality, so that progress can be gauged and plans of action devised. Sustainability Indicators generally provide a summarised statement of a specific condition, and from this remedial or improvement action can be taken.

Municipal employees should familiarise themselves with the concept of sustainability indicators, as they gauge the organisation's key performance. It is imperative that the municipality operates in a manner that supports sustainable development through the preservation of the environment and the efficient use of resources. The municipality should also serve the people by providing basic services such as water and refuse collection in all parts of the city, without segregating the poor and marginalised communities. Municipalities in developing countries must adopt new ways of operation to replace some of the rigid frameworks currently in place. This also applies to their governance and urban planning procedures. The municipality must educate its employees, from

those in management to technical and maintenance workers. Sustainability must begin in the municipal offices, from energy to water saving, and having a basic knowledge of the indicators may help as they summarise the city's entire development plan. The city can begin with simple implementation plans such as waste separation in the offices, which is a practical way to educate its employees. This can also be extended to schools, as children are more open to new concepts in comparison to adults. This can then be extended to the general community, enabling the citizens of Durban to actively participate in the development of their city.

The information provided in Chapter 4.2.4 consisted of data dated back to 2012, and conditions are now different than when it was first collected. The framework for this research was, therefore, based on the conditions that were prevalent in 2012. Up to date data will ensure that the framework outlines the current conditions in the city. In essence, the framework of indicators gives a holistic compilation of the conditions in the city based on available data. It is easy to read and interpret, and opens a platform of communication between the city's authorities and the citizens. The framework can also aid the municipality in taking remedial action before a negative event takes place. It can also be used to hold authorities accountable in terms of their efforts towards achieving sustainability. This can be used at community meetings, in which there must be a basic understanding of the framework by citizens. The indicators also give a clear indication of how the municipality is running the city so that citizens may express their concerns and suggestions. They also give a clear indication of thresholds and future targets for the city.

Since the indicators were based on research obtained from literature and case studies, they did not cover all the aspects present in the city. This requires consultation with all the stakeholders in the city, from the authorities, businesses, and citizens. Citizens are the most important aspect of the city as every policy and strategy has a direct effect on them. Their opinions must therefore carry weight in the development of the city, and there must be an understanding between all the parties. Unless strict measures are put into place in terms of authority transparency, sustainability indicators risk not being implemented or made public. The framework must be approved by the public before implementation to ensure citizen contribution, fostering a sense of belonging. The programme can be extended to schools and kindergartens, where children can be taught about sustainable living and environmental preservation. If they are taught from grass roots level, it will encourage and weave a sustainable culture in the upcoming generations, which will benefit the city in the long run (Ranhagen and Groth, 2012).

The system of indicators needs to be updated in order to stay relevant to improving the quality of life for the citizens. This can be achieved through consistent data collection and stakeholder input. Citizens must also participate in the collection of data through personal devices such as phones, tablets, and computers. With the level of technological advancement in African cities, they can

also use census and community feedback. Citizen feedback is essential as it reflects the opinion of the citizens of Durban and how they perceive conditions in the city. Durban can also adopt developmental ideas from more developed cities that are classified as sustainable. The city of Trento, for example, has made great strides towards improving its transportation, energy, and waste management systems. Some of the concepts can be leap frogged, as developed cities have carried out extensive research in those aspects. Durban has the tools and resources in line with aspects such as waste separation and renewable energy. The beachfront has bins which enable users to put different classes of waste in different containers. The city has also carried out projects on generating energy using solar power, but they have not been extended through to the whole city. Durban experiences sunlight for long hours and with high intensity, therefore solar energy will generate more power that can be added to the conventional grid. With the availability of more resources, they can carry out sustainability projects to completion, thus improving the living and working conditions in the city.

Other aspects such as gamification give citizens the platform to interact with the system and its associated benefits. In Trento, gamification attracted citizen interest, particularly in transportation where walking, cycling and bus rides resulted in residents gaining points. When they reached a certain threshold, they would claim a reward. Gamification can be applied to Durban, but it will not penetrate to all the citizens as not everyone can afford a smartphone and the associated data costs. The city must also host workshops on sustainability so that the citizens are educated about the strategies and visions of the city. Trento involved the citizens in almost every aspect and any new concept they were planning to implement (Trento, 2014). However, the challenges and conditions in these two cities are different. As mentioned in Chapter 4, Durban faces more basic challenges with social consequences. The city must address the basic issues first before implementing the rest of the concepts. Indicators tailored towards smart cities may be incorporated into the Durban framework upon further development and modification to suit its environment. They can be adopted from cities that have a sustainability reputation. The framework depicted in this research was developed using the structure introduced in the literature review, which started with the root problems of urban challenges, followed by the effect of the root cause, and finally the effect it has on the citizens. The following diagram represents the way these challenges were presented, from the sectors to the individual indicator.

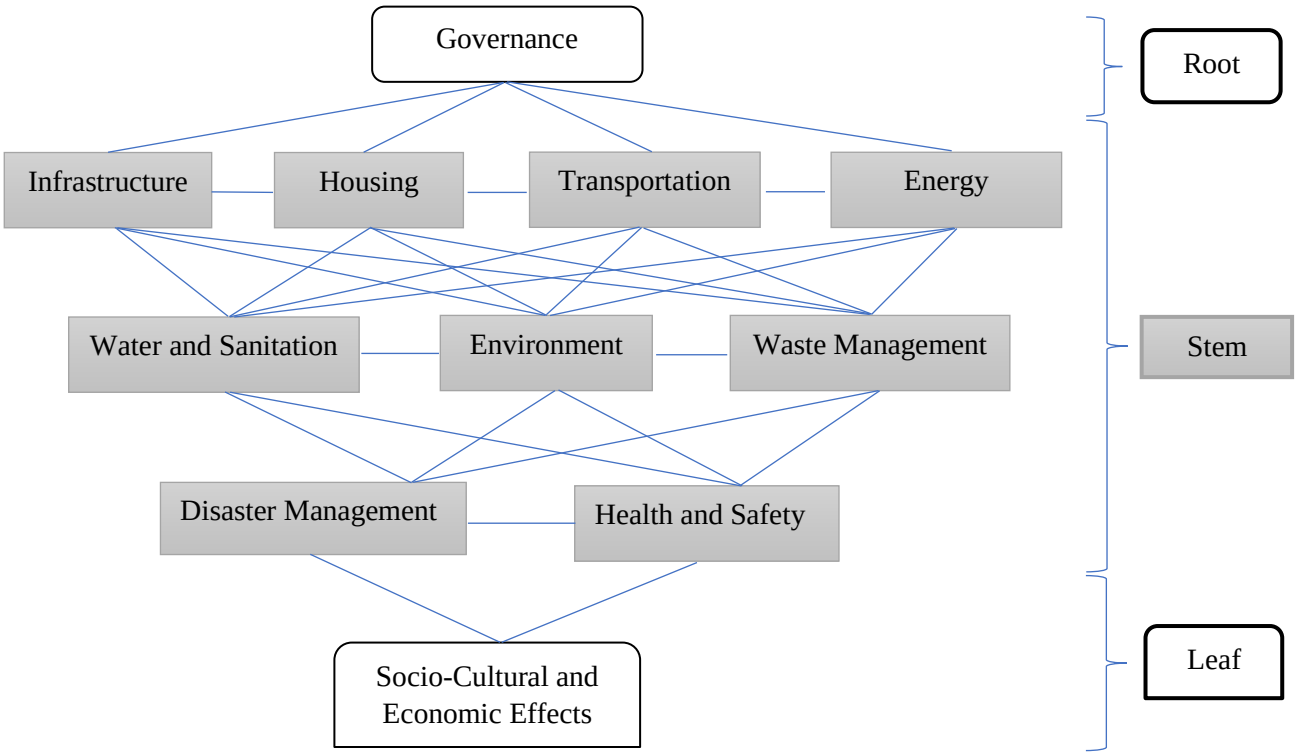

Figure 5-1. Tree Diagram for Synergy of Challenges

The tree diagram is reminiscent of the Symbio City concept in figure 2-11, whereby synergies and relationships are shown through interconnecting different aspects of a city. They also show the connections between sustainability indicators and for future research, benchmarks for each of the indicators must be created. This must involve all the stakeholders in the city, as they must cover all the aspects. Citizens must have a basic understanding of the functions of the indicators, so they can adopt them on a micro level. This will trigger a development on a meso level, and finally the macro level, which involves both the authorities and citizens of Durban. The city still has much to achieve towards sustainability. Crime, poverty, drugs, taxi wars, housing issues and rapid growth are still rampant in Durban, and the city must address these issues to ensure an improved quality of life. Overall, the city has high ranking in Africa in terms of the quality of life and liveability. It aims to be ranked among world class cities, and to achieve this, basic issues must be addressed, coupled with good governance procedures. This will provide a transparent government that shuns corruption and promotes fairness and equality. This will also help to address disparities that exist between the poor and wealthy communities, which has been the source of social instability in the city (eThekwini, 2017).

The framework of indicators for the city of Durban is more suited towards the Symbio City approach towards sustainability. This is because the Symbio City approach focusses on providing basic needs and services, which is a priority in Durban's development plans. The approach is also in line with the Sustainable Development Goals outlined in Chapter 2.3, which were developed on a worldwide scale to improve living conditions in cities. Synergy between the departments is important as development must occur in unison to allow for easy integration of sectors. Mixed land use development is an essential aspect as it integrates different people, cultures, businesses, and industries. Cornubia development is an example of mixed land use development area that combines low and high cost housing, industries, malls, and offices. The city has also implemented projects to improve and integrate the current transport system. These areas can use sustainability indicators, from inception to completion. They can also be used to monitor the city's systems in terms of functionality and how they benefit citizens and the municipality at large (eThekwini, 2017).

In contrast to the Symbio City approach, the Smart City approach is more focussed on improving services, as most of the cities in developed countries can already provide basic services. Their aim is to improve already existing services, hence the city of Durban cannot fully adopt this concept. The development of Durban deviates from the smart city concept as it adopts a more back to basics approach, while developed cities like Trento are now using technology as the main driver of development. While Durban sometimes lacks resources to see development projects through, developed cities have skills, resources, and manpower to improve services and conditions in their cities. Durban must therefore take an approach which involves the provision

of the basics coupled with harnessing technology to create a sustainable city. This will ensure that the city keeps up with current technological trends. The installation of fibre cable aimed to improve the connectivity of the city. At the same time, Durban is striving to provide low cost houses for those living in informal settlements so they can have decent accommodation. This minimises citizen dissatisfaction as they have to cater for communities with contrasting lifestyles and economic conditions. Sustainability Indicators for Durban are therefore focussed towards the provision of these services. Indicators for service improvement may be adopted from cities in developed countries, and they can be added as the city develops. Sustainability Indicators are a cheaper and more effective way to guide the city's development. The data used to inform the indicators may be collected using local resources and people, as they have better knowledge of the city and are familiar with the languages. The framework is aimed to foster change in the city, from operational methods to the way citizens live and how companies conduct their business.

The framework of indicators for the city of Durban was developed in line with the main pillars of sustainability. These were first mentioned in the introduction and referred to in various sections of the Literature Review. These pillars were derived from the Sustainable Development Goals, which were used to develop the current IDP approach being used by the city of Durban. The IDP includes the concept of Sustainable development whereby no city is left behind in terms of their development targets. Since the framework of indicators derived in this research was banked on the Literature Review and the IDP, they tie in with the Sustainable Development Goals. The most particular interest is in Goal 11 which emphasises the importance of "making cities and human settlements safe, resilient and sustainable." The indicators are expected to provide a platform to indulge the municipality and its citizens to all participate effectively in the development of the city. It is imperative that new information is consistently gathered so that the indicators are up to date and stay relevant with the prevailing conditions in Durban. The citizens must also have their input included in the evaluation of these indicators so they can be of value in the city's aim to be the most sustainable and liveable city in Africa. The following Section 5.2 outlines summarised methods of application, from identifying the city's challenges and evaluating its performance (Ranhagen and Groth, 2012).

5.5 Implementation

One of the main requirements for creating a framework for a sustainable city is a unified political vision. Governments and municipalities need to understand the issue of sustainability since they are sorely responsible for decision making processes. These can only be made after consulting all stakeholders, which include the poor and marginalised communities. The Symbio City approach that is recommended for the city of Durban entails the following steps for its working procedure:

i. Diagnosis of current conditions

ii. Outlining specific key issues and objectives
iii. Development of alternative proposals
iv. An analysis of the anticipated impacts as a result of these procedures
v. Choosing a strategy for implementing, monitoring, and following up on the model

Proper documentation should be used in the development of the framework, inclusive of maps, notes, sketches, and photos. Powerful tools such as Geographical Information Systems (GIS) and Computer Aided Design are essential for more advanced development scenarios. The working procedure has different planning levels which entail neighbourhoods, districts, the city, and the surrounding region. The review of these levels should occur simultaneously in towns and cities and should be adapted to suit local content and the environment (UN-Habitat, 2016a).

5.5.1 Step 1. Diagnosis of present situation

The first step involves an analysis of the current prevailing situation in a city to identify projects or propose future improvements. This also helps to create a clear vision and purpose of projects to be carried out, where different departments must come together in the review process to widen various opinions and observations. The structure for development projects must include a governing group responsible for decision making, the involvement of local stakeholders and a multidisciplinary review team. The review team should consist of experts in different fields of design and planning. This encourages a more integrated approach over sequential problem solving techniques. Sequential approaches usually result in comprehensive fact finding, but might lose focus on sustainability issues and the early identification of critical areas (Bolis et al., 2017). Once planning and review are complete, a time schedule is devised to order activities. It will allow financial and human resources to be allocated at various stages of the projects. It is also imperative that challenges in cities are fully mapped and analysed to identify conditions, problems, and possible opportunities. The sources of these challenges must be identified as a basis for devising effective and integrated solutions. The positives that exist in cities may be conveyed to citizens and municipalities to motivate participation. The following sub steps can be implemented in the working procedure:

a) Graphic Documentation and Mapping

This involves the using graphic depictions of different aspects and functions of the city. Currently, major South African cities have dashboards which are an example of graphic documentation. The aspects considered include land use patterns, green areas, forestry, infrastructure, the location of industries and neighbourhoods, transport patterns and cultural heritage sites. Maps for the city may be developed manually, but technology has introduced the use of Computer Design software. Maps can either be existent or developed to identify possible synergies and conflicts of different aspects. The city of Durban has some of its data in map form, showing different aspects such as

infrastructure and green areas. These are grouped according to wards and are made available on the city's website. Plans are the main starting point for proposals and reviews, which can serve as a good reference to transport patterns and rural-urban linkages (Ranhagen and Groth, 2012).

b) Documentation of positives and negatives

The positives and negatives in the city must undergo a thorough analysis through strengths and weaknesses. The positives and negatives can be specific areas, as well as threats and opportunities. Threats and opportunities can, however, be external or internal. At this stage, concepts that need to be changed can be put to light, which will help in creating a clear roadmap towards achieving sustainability.

c) Urban Topology Analysis

The analysis of the functional structures in an urban area is important in order to discover and understand a pattern, including past and modern environments. They can express a society's vision and particular needs, often associated with a specific age or movement. These typologies can be used in conjunction with a SWOT analysis to get a clear picture of current challenges and prevailing conditions of cities (Ranhagen and Groth, 2012).

d) Detailed analysis of environmental conditions

This can be based on a SWOT Analysis, detailing an overview of problems such as emissions and pollution against sustainability goals. Rating scales can be used to prioritise resources, activities, efforts and giving feedback to concerned stakeholders. A rating scale enables easy comparison of all factors influencing current conditions (Ranhagen and Groth, 2012).

e) Analysis of causes, sources and consequences of problems

Identification of sources and causes for environmental problems is very critical in that it allows verification of how these challenges have risen. They are often caused by various factors compounded together, and they are difficult to measure and categorise into specific problems. Air pollution can be as a result of emissions from industries, cars and power stations that use fossil fuels. The effects of these emissions may be catapulted by the lack of green areas and vegetation that can absorb gases. It is therefore imperative that linkages between problems are identified at early stages, and this can be presented in a problem tree diagram such as that outlined in Chapter 5.3. This can be devised by working in conjunction with the local people who usually have a good first-hand idea of the sources of some of the problems. A good approach would be to identify these problems on the interfaces between different systems, for example linking waste management and heating. This can also be applied to the diagnosis of a situation where challenges and available assets are interlinked to different sources.

An analysis of the environmental situation should be linked to a wider context which includes regional, national, and global perspectives. For example, data on climate change can be linked to population and Gross National Product (GNP) per capita. Institutional involvement enhances the capacity to develop solutions. Weak environmental regulation results in non-investment in environmentally friendly technology. The effects of opportunities and threats to the environment as a result of institutional factors needs to be analysed. Environmental problems can be influenced by internal or external sources, and they should be clearly defined so that correct intervention measures can be taken (Ranhagen and Groth, 2012).

5.5.2 Step 2. Specification of Indicators, Objectives and Targets

These objectives are developed as corrective measures based on what has been defined in Step 1. They create a benchmark for future short, medium, and long-term performance, which should focus on the planned intervention. In this research, these benchmarks were the Sustainability Indicators introduced in the Literature Review. These indicators must complement the existing policies, with any changes discussed and fully analysed. They can be quantitative or qualitative and should be based on the preliminary diagnosis and the area's definition of sustainability. The four main steps include:

a) Definition of Sustainability in Local Context

Different local stakeholders should discuss their own definitions of sustainability, which can be compounded to one main concept. This should be in relation to the overall vision of a city, with an understanding of how the local context relates to the global view.

b) Identification of Key Issues for further Planning and Review

Challenges and issues should be identified in relation to the overall vision, together with the definition of sustainability for a city. This will aid in further planning and enable structured brainstorming. The results can be clustered in the SWOT Analysis to strengthen the positives and address weaknesses and threats.

c) Formulation of Main Objectives

These objectives are based on the above two steps, and they should be inclined towards the overall vision and state how sustainability in a specific area can be improved.

d) Formulation of indicators and Targets

These are developed for the main and sub objectives, making them specific, measurable, time based, agreed and realistic. This research derived sustainability indicators to gauge progress of sustainability in the city. These indicators are a technical way of expressing certain conditions in a compact manner. Planning Indicators are a subset of Sustainability Indicators, and describe

future conditions in the same manner, serving as a benchmark scenario. This will enable future plans to be devised and effectively implemented (Ranhagen and Groth, 2012).

5.5.3 Step 3. Developing Alternative Proposals

Diagnosis of the current situation serves as a platform to formulate solutions to the current problems being faced by cities. The complexity of cities makes alternative solutions relevant to consider as they offer different ways in which targets and objectives can be met. Flexible solutions allow adaptability to rapidly changing scenarios. Much focus must be placed on the prevention of problems rather than eventually solving them. Mitigation is seen as less costly and more realistic in the short to medium term. However, it might delay solutions and development in the long term, as focus will be on preventing problems. Alternative scenarios can be developed in the following ways:

- Selection of key issues and define positions for the development of one-sided alternatives.
- The scenario matrix which entails plotting of extreme positions along two axes in a four-field matrix.

Synergies can enhance optimisation in situations where a solution solves two or more problems, which may be cost beneficial. A multidisciplinary approach promotes knowledge sharing and collaboration, resulting in a smooth and efficient process. Backcasting is also a tool that can be used as it facilitates the development of integrated optimum solutions (Ranhagen and Groth, 2012).

5.5.4 Step 4. Impact Analysis

This is examining if objectives and targets for increased sustainability have been included at both strategic and project levels. Environmental, social, economic, and institutional impacts have to be evaluated as a basis for informed decision making. Assessments are carried out in line with legal frameworks and policies in different countries and cities. Various tools can be used to evaluate the impacts, namely Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). Limiting these tools to a project level decreases opportunity to identify strategies that bring more sustainable outcomes. The assessments occur in a predetermined policy environment. A SEA should evaluate how the choices made in a proposal affect the environment and whether they achieve the environmental objectives. Assessment should include different stakeholders and done while the proposed solutions can still be modified. The SEA can help increase awareness and promote involvement in issues that concern the environment, generating new insights and solutions. It should also question established theories and ideas that are unsustainable. Various tools can be used to assess the environmental impacts of the planning proposals, such as the following:

a) Spider diagram where indicators are placed on the axis of a circle. They are graded depending on how far away from the centre they are, with optimum near the outer circumference and minimum being at the centre.
b) Effect profile diagram which consists of vertical columns, with each alternative represented by a different colour.
c) Multi Criteria Analysis which is a systematic procedure to weigh the effects of different alternatives. It is often used for complex situations whereby indicators are weighted and graded. These two factors are used to arrive at a score, which is then totalled for each alternative (Ranhagen and Groth, 2012).

5.5.5 Step 5. Implementation and Follow Up Strategy

A thorough follow up is essential for the implementation of a final proposed solution. It also ensures that adequate trade-offs are implemented for optimal efficiency. All four pillars of sustainability must be incorporated into all phases of implementation. Sub projects are essential in order to describe each aspect of the main project in detail. For large scale projects, implementation phases should be clearly defined as they are spread over a long timeframe. It is best to test solutions on a small scale in a pilot phase to gauge their applicability. The built environment has to be continuously assessed to gauge the outcome of the planning process. Maintenance ensures that finances and resources are allocated so that infrastructure does not degrade, shortening its life span and rendering the project unsustainable. Follow ups can be done using systems like sustainability indicators. Decision and tree Diagrams are useful for clarifying future choices and decisions. The Logical Framework Approach is a useful tool for planning, monitoring, and evaluating the projects (Ranhagen and Groth, 2012).

These methods can be used to implement the Symbio City approach to the city of Durban. It is imperative that all stakeholders are consulted at every stage, so that the development of Durban meets the needs of citizens and authorities alike. This will ensure that most of the policies to be applied benefit both current and future generations to come. The following chapter concludes the research, which evaluates whether these indicators address the problems defined in the research question and in answering the research question.

6 Conclusion

The issue of sustainability is now more imperative, as most cities, particularly in Africa, struggle to provide essential services to their citizens. There is need for cities to rethink and strategize their operations, with the support of citizens' changes in lifestyle. If these measures are not adhered to, the concept of sustainable cities might die as a whole. Success of the sustainability concept requires coordinated efforts between different stakeholders which include municipalities, small and large scale businesses, industries, academia, politicians and the citizens. Citizens are the most important components of a city's ecosystem, as they are the recipients of policies and services rendered by municipalities. Education and knowledge sharing are key stones to evoking citizen interest to allow them to contribute to the sustainable development of a city. Cities must also operate in ways that are not threatening to the environment and biodiversity. Resources must be used sparingly in order to leave enough for the next generation, thereby tying in with the definition of sustainability.

The main focus of this research was on the issue of sustainability in African cities, with Durban identified as one of the cities striving towards this goal. Africa faces more profound and complex challenges as compared to those in developed countries. This requires a different, more creative, and adaptive approach to resolving challenges as they do not have adequate resources, skills, and manpower. However, there is an opportunity to leapfrog some processes as developed countries have conducted extensive research and implementation in some areas. Infusing technology in the transportation sector is one of the many examples that can be adopted from developed countries. The use of smartphones may help in the implementation of this concept. The city already has in place technologies such as cameras for traffic monitoring. The city also has education programs and online platforms for citizen engagement. Durban is also trying to make strides towards the use of renewable energy sources, as evidenced by the provision of solar water geysers in the high density communities. However, there are more pressing challenges such as poverty reduction and provision of basic services. These issues need to be addressed before technological advancements. Addressing these basic issues will ensure social and economic stability in the city, while resolving most of the issues peculiar to cities on the African continent.

Main Pillars of Sustainability

The concept of sustainability revolves around four main pillars which are Institutional, Economic, Environmental and Social sustainability. It is important that cities aim to be sustainable in all four pillars so they can achieve overall sustainability. If cities are not sustainable in any of these pillars, it may affect other areas, sometimes with dire consequences. The Institutional aspect is the most important aspect as major decisions are made at this level. These decisions have effect on other pillars, hence aspects such as effective governance must be prioritised. Municipalities are the

main decision makers in cities, and it is imperative that they are run in a sustainable manner. The city's employees must spearhead the move towards sustainability by educating the people around them and actively participate in the process. Different agencies and authorities around the world have put forward frameworks and guidelines to engage in activities to improve conditions in cities and attain a sustainable status. It is now up to municipalities and their governing bodies to follow up on these guidelines and pledges. Development must now fall within the confines of these four pillars to improve service delivery and living conditions in the cities.

Smart City v Symbio City

This research looked at different approaches towards attaining sustainability. With most cities that are struggling being in Africa, it was imperative that methods of solving issues peculiar to this environment were devised. The Symbio City approach was more suited to the environments in African cities, involving more physical methods with focus towards different departments working together to achieve a common goal. The Smart City concept puts technology at the centre of its development. The African continent has basic issues which do not necessarily require technological involvement. Technology, however, may be used in some areas to improve the way the city operates. Technology cannot be ignored and is now part of humanity's everyday life. It would therefore make sense for municipalities to use technology to their advantage, but the main focus must be on the root problems that affect the urban poor. Symbiosis entails synergies within municipal departments, whereby they must coordinate and work in conjunction with each other to avoid overlaps and redundancies. The synergies will improve effectiveness and communication between essential services within these municipalities. The concept can then be further developed to incorporate technology, which will evolve it into a Smart City. This must be carried out while ensuring minimum harm to the surrounding environment and preserving biodiversity.

Sustainability Indicators

The importance of Sustainability Indicators cannot be overstated, as they provide a measurable benchmark towards being sustainable. They enabled a framework to be devised in this research, as they enable the simplification of complex issues into something understandable. Since they can also be used to hold cities accountable on their endeavours, they are critical in the creation of a framework for a future African city. Accountability has been a major issue with most governments around the globe, particularly in Africa. with strong will from political leaders, industries and citizens, the indicators can open communication channels for effective development. Indicators derived in this research are merely an indication of some areas of concern. It is important that the indicators cover all aspects of a city. This will entail multidisciplinary contributions from all facets within the city. The more areas the indicators cover, the more information they can relay to the authorities and citizens alike.

Case Studies

Since there is no defined framework in cities in developing countries, a comparative case study highlighted the difference in the way cities operate. The city of Trento offered a good example of a city in a developed country which is making great strides in attaining sustainability. Since most cities in developed countries have researched and devised methods to become sustainable, it was imperative that their methods be observed and assessed. This was done to determine some of the methods that could directly be developed on the African continent with little adaptation. Some of the concepts such as waste separation, integration of transport hubs and the use of applications in areas such as mobility, energy, and governance. A comparison between the cities of Durban and Trento further reinforced the need to address basic issues prevalent in most African cities. The city of Durban has large economic and social disparities which need to be addressed. The Case Study allowed for the derivation of indicators suited to a typical African city in Chapter 5.

Durban Sustainability Indicators

The indicators derived for the city of Durban are not final, as the research did not cover every aspect within the city. This framework was derived as a guide to a methodology to determine the framework for an African sustainable city. The framework allows new indicators to be added and some can be taken out, depending on the context and operating environment. This means that they can be used in different countries where they can be adapted to the prevailing environment and operating conditions. Sustainability indicators that cover every aspect will require the consultation of all stakeholders in the city, allowing for a multidisciplinary approach in the creation of such a city. Indicators are also a suitable guide for the development of the city, as they entail holding the municipality accountable as well as assessing progress.

This research was conducted as a methodology for municipalities so they can develop their own frameworks, outlining how they can resolve urban challenges in a sustainable way. The creation of a sustainable city using basic and non-technological based approaches resolves issues that are on the ground and affecting the average citizen. The Symbio City concept will prompt a change in the way people think, their cultures and lifestyles. The willingness of governments and their respective citizens will ensure development aligned with the main pillars of sustainability. This is critical as Sustainable Development Goals are to be realised by the year 2030.

6.1 Findings

From the framework of indicators derived in Chapter 5, it is possible for the Symbio City approach and the framework of indicators to be used in the development of Durban to become a sustainable city. The data in Chapter 3.3.1 shows some of the critical considerations for the city of Durban, which were used to derive a framework of indicators for eThekwini Municipality. Current policies

will need to be reworked and revised in order for a framework of indicators to be implemented effectively. This will involve divorcing older methods of operations and not just adopt concepts that were devised in the colonial era and those from cities in developed countries. Frameworks obtained from global platforms such as the Kyoto Protocol, Millennium Development Goals, and most recently, the Sustainable Development Goals, must be tailored to suit a specific goal within a country. The proposed framework in this research can be tested in a new development covering a small geographical area in relation to the city. The framework has the potential to be tested in the city's development areas such as Cornubia. Since the main aim of the Symbio City concept is to identify and apply synergies between different aspects, the mixed land use development can be used as a testing area. This will be a pilot program using the indicators determined by eThekwini, and successful implementation will see concept rolled out to the city of Durban.

The indicators developed for Durban can be changed, removed and new ones added. This depends on the prevailing conditions, environment, resource availability, citizen and official education levels, citizen participation and commitment. In this regard, all stakeholders must be involved in the city's development to improve conditions and the quality of life for Durban's residents. The measures outlined in Chapter 5 enable the current situation on the ground to be analysed. The city of Trento also gave insight on the policies that cities can adopt to become sustainable. Policies such as waste separation before refuse collection could be adopted by the city of Durban. This will require citizen education, which can be challenging as most of the adult population already have a set lifestyle.

In order to avoid blindly replicating methods being used by cities in developed countries, Durban can follow the steps outlined in Chapter 5.2. Diagnoses of current situation enables the development of solutions specific to those challenges, which are suited to the environment in Durban. Involvement of stakeholders will ensure collaboration in the implementation of these indicators. If these steps are implemented properly, it will enable the city to create a map of where it aims to be in improving on sustainability and quality of life for the citizens. The Symbio City approach which was developed mainly for cities in developing countries is the most feasible, and it can be merged with the IDP and the Sustainability Development Goals. The city must, however, educate its citizens on the measures that can be taken to improve sustainability on a micro level. Since South Africa has a background of historical segregation, Durban must aim integrate communities, thus enabling interaction between the poor and marginalised communities.

The provision of interim services in informal settlements is a positive development as the urban spatial pattern of Durban is not conventional. Since most of the population is concentrated on the outskirts of the city, decentralising would be beneficial to ensure more efficient management of resources and infrastructure in those areas. Currently, the city has made substantial progress in

managing uncontrolled urban growth by demarcating a development line. The use of Indicators is expected to help the city to track their progress in different aspects, as well as synergise the city's operations, which can improve efficiency. Modification of these indicators can be carried out by the municipality, with the input of all stakeholders through meetings. Currently, Durban ranks high in African cities striving towards being sustainable. Implementation of these measures will ensure that the city improves on their status and achieve on of their main goals, which is to be "the most liveable city in Africa."

6.2 Recommendations

This research focussed on the derivation of a framework of the sustainable African City of the Future. This was done using information from literature and case studies, which were used in the final framework for the city of Durban. However, the research was conducted using information mainly from literature. The literature was derived from various sources, which allowed different perspectives in defining challenges and solutions. The problems would have been better defined through engaging with municipal experts, who would provide more first-hand information in line with the city's development plans. Moreover, challenges could have been defined from various perspectives. A top down approach was used in deriving the framework, hence it excluded citizen engagement and input. Future research must include citizen engagement and input in the final framework. This will ensure that citizens approve the development plans before they are adopted by the city. Future research must also consider multidisciplinary input to improve the synergy between different departments.

The data collected for the city of Durban was from 2012, hence some of the data might have changed. The data also did not cover all the aspects mentioned in the challenges in the literature review, therefore some information might not have been used in the derivation of the framework. Methods for assessing sustainability indicators were complex, and with inconsistent data, it was difficult to implement. Future research must ensure the collection of data that is consistent with the indicator weighting assessment methods. This will ensure that the indicators that have a qualitative and quantitative backing to create a more efficient and functional framework. Up to date literature must be sourced as some of the some of the literature used might not be applicable to date. A Multi Criteria Decision Analysis can be done to ensure proper evaluation of sustainability indicators using available local information. These measures will ensure that the research has more scientific backing to the selection and use of sustainability indicators, which will be beneficial in the creation of a sustainable framework for the city of Durban. Successful implementation of this framework will see it being expanded to other cities in South Africa, and to other African cities.

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Appendix 1 – Data for Durban

Ward	Population	Households			# Male	# Female	# Disabled	Employed	Unemployed	Pensioners	Not Active
		Formal	Informal	Traditional							
1	39044	2507	75	4764	18350	20694	1178	7044	14052	1562	17948
2	39003	2684	480	4350	17989	21015	1946	6875	11857	1560	20271
3	55182	4919	421	4909	26486	28697	1659	11596	18212	2207	25375
4	44960	5543	324	4572	21132	23828	2691	12132	16192	1796	16636
5	42430	5785	1223	973	19856	22575	2034	10768	16461	1274	15201
6	30397	5729	387	303	14271	16125	1222	7293	12963	1198	10140
7	30504	3939	508	1318	14482	16022	1066	10779	9018	1375	10707
8	40924	6331	754	2652	19644	21281	1940	13030	13468	2054	14427
9	45559	10269	368	1321	21864	23695	1824	19530	9611	3629	16418
10	27226	8105	180	442	12798	14428	818	18194	593	2984	8439
11	41347	6751	3219	243	19331	22016	1194	15899	12243	1195	13205
12	32088	5993	755	831	15152	16936	1104	8638	11899	645	11551
13	43517	8457	1143	1452	20700	22817	1306	13049	14723	1225	15745
14	40579	8021	1338	1684	19379	21200	1830	11783	14189	814	14607
15	67435	14017	2574	1841	32369	35067	2030	21638	27557	1360	18240
16	36987	8867	889	395	17753	19233	1431	17626	8079	1706	11282
17	39965	8636	899	406	19182	20784	1203	14025	11178	1206	14762
18	27531	9099	188	126	12970	14560	842	18294	1555	2648	7682
19	48754	9117	3921	840	23402	25353	1950	16105	17052	978	15598
20	19500	3413	451	93	10097	9402	780	6627	7748	392	5125
21	23004	6228	960	148	10814	12190	919	11942	5076	1148	5986
22	23918	3899	2729	271	11764	12154	510	7244	10232	479	6442
23	24046	5294	1983	75	11954	12092	752	10858	4015	1402	9173
24	34850	7599	1249	138	20327	14522	1389	15442	4168	1566	15240
25	30684	8069	1437	97	14170	16515	987	15639	4225	2354	10821

Ward	Population	Households			# Male	# Female	# Disabled	Employed	Unemployed	Pensioners	Not Active
		Formal	Informal	Traditional							
26	25560	9789	101	202	11502	14058	1425	14153	3259	2696	8148
27	22260	9986	103	170	9870	12391	1039	14096	1412	3115	6751
28	12643	4766	73	76	5946	6697	757	6008	2081	949	4554
29	33681	5893	2608	311	15983	17697	1048	12363	11046	702	10272
30	37680	5962	4355	293	17977	19703	906	14613	12272	1014	10795
31	28313	8994	1076	102	12861	15451	920	15891	2936	2920	9486
32	13740	4039	361	45	6731	7009	602	7211	1976	962	4554
33	24753	9588	218	99	11467	13287	1019	14383	2068	2395	8301
34	30685	7019	1574	88	14893	15791	846	14721	6278	1144	9686
35	36658	12287	529	129	17598	19061	1237	21583	2967	2718	12109
36	29195	9370	120	99	13482	15713	893	19089	1268	2981	8838
37	35000	8434	491	96	16799	18201	1039	13948	8453	930	12599
38	50895	3458	8835	1036	24399	26496	2437	13077	18093	1019	19725
39	15024	1625	2624	1	9593	5431	303	5260	7638	154	2125
40	72258	3478	2043	65	40833	31425	2169	22458	34212	2190	15588
41	32819	6190	1140	97	15684	17135	1562	9764	11390	1271	11665
42	55366	9104	4266	1321	26022	29344	2215	14395	21049	1109	19921
43	32863	3974	3554	488	15446	17417	989	9196	11508	658	12159
44	52293	8354	2719	1194	24167	28127	2557	13491	18005	1581	20797
45	39715	6183	144	498	19056	20659	1202	11493	14310	1185	13913
46	22609	4353	317	55	11068	11541	686	6123	9022	1027	7465
47	33487	6555	952	554	15741	17746	1079	8896	12390	1261	12201
48	25976	5794	83	124	12212	13763	786	11647	3466	1031	10862
49	33760	7635	4	81	16513	17246	1335	15515	3748	1026	14497
50	27134	6546	67	69	13296	13839	814	12988	3021	805	11125

Ward	Population	Households			# Male	# Female	# Disabled	Employed	Unemployed	Pensioners	Not Active
		Formal	Informal	Traditional							
51	26545	8663	95	180	17906	18639	1098	16077	5849	733	14979
52	32760	7207	299	169	15724	17036	1311	14001	5346	951	13413
53	34946	4982	3348	1147	16774	18172	1398	10839	13263	699	10844
54	42140	7825	2530	762	19814	22326	2101	12863	15641	846	13636
55	62485	7900	7049	1206	29368	33118	2557	15795	27701	1816	18989
56	59317	5889	6994	2269	27981	31336	2965	14459	23692	1779	21166
57	40934	3905	6013	1242	19270	21664	2016	11581	15505	821	13848
58	41261	10895	1519	269	19948	21314	1919	19986	7716	1918	13559
59	46226	6727	3658	1710	22190	24037	2309	14338	13860	1386	18029
60	41210	7783	2671	957	20164	21047	2059	17012	8895	1621	15303
61	33598	7627	1022	517	16241	17357	1328	15663	5724	1301	12212
62	27641	5036	2202	629	13820	13821	829	11334	7462	829	8846
63	32522	9147	340	144	15612	16910	1300	18873	3086	2102	10563
64	27420	7733	157	155	12925	14495	823	15894	2801	1664	8725
65	37605	9907	751	112	18040	19565	1133	20641	4189	2249	12775
66	27506	7479	513	81	13297	14209	825	14859	3757	1743	8890
67	56174	7665	328	2424	26274	29900	1794	14628	21568	2123	19978
68	30087	15431	14656	1100	6353	252	73	13466	5968	1755	10653
69	29638	6646	759	84	14056	15582	905	12693	5592	1868	11353
70	25974	6518	301	29	12211	13763	1047	11656	3319	1582	10999
71	37500	6789	2807	345	17995	19505	1500	16355	7942	1511	13203
72	44441	6329	3356	1216	21280	23161	1823	16416	11319	1873	16706
73	25540	3784	1889	187	11989	13451	986	9364	6635	1080	9441
74	19405	3322	1223	80	9735	9670	582	5950	7828	601	5626
75	20257	3135	718	20	9992	10266	704	6605	6671	1003	6982

Ward	Population	Households			# Male	# Female	# Disabled	Employed	Unemployed	Pensioners	Not Active
		Formal	Informal	Traditional							
76	27800	2926	775	64	16903	11897	834	8640	11070	648	8089
77	62498	7234	8452	902	29481	33017	1980	18847	22070	1980	21580
78	35934	4465	3571	803	17248	18686	1078	9702	13295	1078	12937
79	46048	4543	7108	119	22098	23950	1835	12192	17932	1380	15204
80	36120	4938	4038	457	16996	19124	1084	9056	14759	1099	12306
81	27256	3940	2624	70	13079	14177	819	7096	10359	1085	9801
82	36643	4379	4550	92	17224	19419	1100	11712	12832	735	12098
83	43422	6578	3500	426	20840	22582	1303	10442	16914	1302	16066
84	49194	6821	3141	1247	23169	26024	1520	14513	15596	1520	19084
85	33681	6118	1585	90	15833	17848	1013	10081	10828	1009	12772
86	36140	5623	3249	98	16986	19154	1086	10831	13371	730	11938
87	35391	4967	3535	263	16650	18741	1062	9565	14837	1059	10989
88	30921	4653	3035	112	15585	15335	928	8357	12446	926	10117
89	50351	3135	4397	258	25042	25309	1513	16978	16447	1200	16926
90	21061	4417	921	136	10918	10143	636	8292	5048	655	7721
91	42612	7641	543	778	19639	22973	1704	9841	16373	1315	16398
92	24055	4817	1711	623	11799	12256	954	9398	8560	732	6097
93	48995	8726	1047	3148	23033	25963	2231	14370	16201	2065	18424
94	46602	6261	746	2084	21903	24699	1893	12566	16343	1642	17692
95	47272	7103	483	2409	22218	25054	1697	10435	20204	1225	16633
96	47879	5594	233	3961	22179	25700	1436	8282	22017	1606	17581
97	31257	8881	397	1072	14691	16566	1160	13896	6233	2326	11128
98	51685	8844	1037	1543	24292	27393	1605	17525	13814	3673	20346
99	44507	7575	828	1687	21319	23188	1736	15445	10056	2314	19006
100	39699	4079	427	2907	18387	21313	1192	7223	12905	1465	19572

Ward	Population	Households			# Male	# Female	# Disabled	Employed	Unemployed	Pensioners	Not Active
		Formal	Informal	Traditional							
101	23836	5775	1499	110	11111	12725	675	12093	4387	1799	7356
102	37630	9220	1198	113	18348	19283	1227	17702	6244	1253	13684
103	30437	3526	602	2545	14522	15916	1454	8491	10949	1104	10998

Ward	Hospitals	Clinics	Parks	Pools	Community Halls	Sports Fields	Fire Stations	Police Stations	Schools	Library	Literacy	Area km²
1	0	5	2	0	2	9	0	0	16	1	14456	88,70
2	0	12	0	0	0	1	0	0	20	0	13880	168,14
3	0	7	0	0	0	5	0	1	30	0	23183	92,17
4	0	7	1	0	7	2	1	0	11	0	19333	63,15
5	0	2	0	0	1	4	0	0	8	0	19604	44,01
6	0	3	2	0	4	2	0	0	15	0	15688	10,67
7	0	2	0	0	6	6	1	1	9	1	14158	111,87
8	0	3	2	0	8	2	0	0	12	1	19665	71,60
9	0	4	2	0	4	8	1	1	12	1	25934	54,58
10	1	3	3	0	0	0	1	2	10	2	18764	42,68
11	1	3	25	1	0	4	0	1	10	2	23291	10,85
12	0	1	4	0	5	3	0	1	9	0	14227	7,02
13	0	3	3	2	7	3	1	1	9	2	21367	11,90
14	0	2	0	0	6	3	0	0	3	0	19292	6,58
15	1	2	0	0	2	2	0	0	8	2	35083	23,94
16	0	1	6	0	2	2	0	1	7	0	21490	16,67
17	0	1	8	0	3	8	0	0	10	2	22364	13,01
18	2	1	6	0	3	4	2	2	17	1	19385	26,74
19	0	2	1	0	4	1	0	1	2	1	25849	11,62
20	0	1	0	0	3	1	0	0	7	1	11462	4,21
21	0	2	10	0	1	3	0	0	6	2	14944	8,20
22	0	0	0	0	3	1	0	0	3	0	13890	2,27
23	0	0	17	0	0	3	0	1	12	1	15942	13,86
24	1	1	13	2	4	2	0	0	15	1	23352	19,17
25	1	1	13	1	1	2	0	0	10	1	20159	8,35

Ward	Hospitals	Clinics	Parks	Pools	Community Halls	Sports Fields	Fire Stations	Police Stations	Schools	Library	Literacy	Area km²
26	2	2	11	1	0	0	0	2	5	0	19240	7,05
27	0	0	20	2	0	0	0	0	15	0	16770	11,09
28	1	2	12	0	0	0	0	5	14	3	9226	3,34
29	1	0	15	0	2	2	0	1	4	1	19584	6,91
30	0	0	15	0	0	2	0	1	6	0	22246	6,21
31	4	2	22	1	0	3	1	0	23	1	19672	5,77
32	0	0	5	0	0	2	2	2	8	0	9597	25,47
33	2	0	28	2	0	0	0	1	20	2	17773	7,36
34	0	0	18	0	0	9	0	0	16	0	18961	17,08
35	1	2	27	0	0	1	0	1	6	1	24734	26,01
36	0	1	36	0	0	3	0	0	19	2	20209	16,03
37	0	2	22	1	0	5	0	0	7	0	20189	10,00
38	0	0	1	0	1	3	1	0	8	0	24242	5,65
39	0	0	0	0	0	3	0	0	0	0	9607	0,90
40	0	1	1	0	1	2	0	0	5	0	43213	2,12
41	0	0	3	0	2	1	0	0	8	0	18601	3,31
42	0	2	1	0	0	2	0	0	7	1	27682	3,94
43	0	0	4	1	0	3	0	0	11	0	17082	4,97
44	0	2	4	0	0	1	0	0	12	0	25512	17,39
45	0	3	2	0	2	2	0	1	10	0	19086	5,86
46	1	1	4	0	1	4	0	1	11	1	12996	2,91
47	0	1	4	0	0	3	0	0	8	0	17402	3,15
48	2	1	15	0	2	7	0	0	13	2	15309	7,41
49	0	1	23	0	0	7	1	1	13	0	20248	6,69
50	0	2	18	1	0	5	0	0	11	1	17076	4,19

Ward	Hospitals	Clinics	Parks	Pools	Community Halls	Sports Fields	Fire Stations	Police Stations	Schools	Library	Literacy	Area km²
51	0	1	17	0	2	4	0	0	13	2	22286	7,31
52	0	1	22	0	0	9	0	0	14	1	19541	4,75
53	0	2	4	0	1	4	0	1	5	0	16434	5,63
54	0	1	7	0	3	4	0	1	6	1	21574	4,21
55	0	1	5	0	1	3	0	1	5	0	30505	5,54
56	0	3	2	0	1	3	0	1	4	0	28571	24,72
57	0	1	0	0	0	2	0	0	6	1	19270	4,62
58	0	9	13	0	2	6	0	0	11	2	24669	93,28
59	1	3	2	0	1	2	0	0	10	0	22657	50,07
60	0	6	10	0	1	2	0	1	11	0	21741	42,86
61	0	10	20	0	0	12	0	1	14	1	19711	46,59
62	0	4	10	1	3	4	0	1	9	1	14927	34,83
63	0	2	28	0	1	3	1	1	9	1	21334	20,00
64	0	3	15	1	2	4	0	2	13	1	18132	15,00
65	0	1	22	1	1	4	0	1	14	1	24801	19,72
66	1	1	19	0	0	5	0	2	18	2	17434	18,11
67	0	1	3	0	5	7	0	0	14	1	28628	27,39
68	0	2	16	2	0	3	0	1	19	2	18972	5,94
69	0	0	12	0	2	8	0	0	15	1	18246	8,01
70	2	2	20	1	0	7	0	1	17	2	16307	7,51
71	0	0	9	1	3	3	0	0	12	0	22711	6,15
72	0	0	3	0	1	4	0	0	9	0	23643	13,83
73	0	1	10	2	1	4	1	1	17	0	14301	8,92
74	0	0	2	0	0	3	0	1	4	1	11444	3,56
75	1	1	5	1	1	0	1	2	6	0	11693	7,06

Ward	Hospitals	Clinics	Parks	Pools	Community Halls	Sports Fields	Fire Stations	Police Stations	Schools	Library	Literacy	Area km²
76	1	1	0	0	0	0	0	2	4	0	17332	3,21
77	0	1	0	0	0	1	0	0	5	0	31467	7,20
78	0	1	0	0	1	0	0	0	6	0	19402	2,48
79	0	1	1	1	1	1	0	0	7	1	23965	3,48
80	0	0	0	0	0	2	0	0	6	0	19501	3,34
81	0	0	0	0	0	0	0	0	7	0	14451	2,08
82	0	2	0	0	1	2	1	0	4	1	20514	3,23
83	0	2	1	0	1	1	0	0	10	0	23446	3,21
84	0	0	2	1	1	1	0	1	12	0	24258	27,40
85	0	0	2	0	0	3	0	0	9	0	18171	4,58
86	0	0	6	0	1	0	0	1	5	0	18792	4,12
87	0	2	3	2	3	0	0	0	7	0	18082	2,80
88	0	0	2	2	0	0	0	0	10	0	17622	3,67
89	1	1	0	0	0	2	0	2	5	0	27939	5,91
90	0	1	10	2	2	4	1	2	11	2	12923	21,34
91	0	1	0	0	1	0	0	0	12	0	20206	13,62
92	0	2	4	0	3	1	0	0	8	1	14690	12,53
93	2	2	5	1	3	4	1	0	11	0	24785	18,20
94	0	2	3	0	2	2	0	1	10	0	23058	9,90
95	0	1	0	0	2	2	0	0	8	0	23163	9,40
96	0	1	0	0	1	5	0	1	17	0	22162	60,45
97	0	2	10	0	3	2	0	1	7	1	18724	17,39
98	0	4	3	1	2	8	0	1	7	1	27941	43,44
99	0	4	10	0	5	8	0	0	11	1	22787	90,48
100	0	7	0	0	8	6	1	0	28	1	14963	155,76

Ward	Hospitals	Clinics	Parks	Pools	Community Halls	Sports Fields	Fire Stations	Police Stations	Schools	Library	Literacy	Area km²
101	1	1	8	0	1	2	0	1	14	1	15875	6,65
102	0	2	10	1	1	0	0	0	7	0	23265	39,13
103	0	5	0	0	0	0	1	0	17	0	12946	87,96

Appendix 2 – IAHS Conference Paper

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DEVELOPING A FRAMEWORK FOR THE SUSTAINABLE AFRICAN CITY OF THE FUTURE

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Abstract *Population in modern day cities is increasing rapidly, particularly in Africa, Asia and South America. This has forced cities to expand beyond serviceable boundaries, raising the demand for resources and services, straining local authorities and service providers. The demand for energy and transport has led to an increase in air and noise pollution, as well as toxic emissions. Informal settlements are springing due to inadequate housing, resulting in hazardous living conditions for the poor. These areas have rapid disease spread rates, environmental degradation and increased crime.*

Models of sustainable and smart cities have been developed in the context of developed countries to guide the development of future cities. However, a more articulated and specific approach is required in the developing world due to the above-mentioned challenges for contemporary cities. This approach should involve methods better suited for the context of developing countries and sustainability indicators inclined towards their environment.

The research presented in this paper seeks to develop a framework that African cities can adopt to incorporate sustainable infrastructural designs and decision-making processes, improving the quality of life for citizens and inflicting minimal environmental damage. Sustainability Indicators were identified and used to gauge the level of sustainability in cities, and their importance weighed by a rating scale. The indicators were developed after consulting experts in contemporary African city management and planning, together with available literature. The score of each indicator on the rating scale determined the relevance of the indicator to the creation of a sustainable African city. Different aspects, including the African culture and heritage, had to be considered in the creation of the framework. There were many common factors which emphasized the provision of basic needs and services. The indicators for the final framework were pivoted around the four pillars of sustainability (environmental, social, economic and institutional). The proposed framework is oriented to provide an instrument to assist in decision making that local authorities in African countries could adopt according to their localities to create a sustainable city.

1. INTRODUCTION

The migration of citizens in search of better life opportunities has led to a rapid population increase in modern day cities. This influx has caused spatial growth and a rise in demand for basic needs and services, as cities must accommodate the increasing number of inhabitants. In developing countries, an average of 70 000 people migrate to cities every day. These people end up living in slums in informal settlements due to a shortage of housing and difficulties in securing formal employment [1]. These areas harbour inhospitable and life-threatening conditions as they are located on marginal land such as steep slopes and flood plains. They are also vulnerable as they lack infrastructure and resources to combat, prevent or recover from disasters. Inadequate water, sanitation facilities and their proximity to rubbish dumps pollutes the land and accelerates the rate of spread of diseases. High unemployment levels, coupled with low levels of education has led to increased crime rates. This is predominant in Africa, where 62% of the urban population resides in slums [2]. It is also the least urbanised continent, with 40% of the population living in urban areas as compared to Asia's 42% and Latin America's 80% [3]. More rapid urban transition is expected to occur in developing countries as compared to developed countries in Europe. Cities in these areas must, therefore, find ways to curb the effects of urbanisation and adapt to the changes in population [3].

One of the main challenges of urban growth is that most of it is occurring in countries that lack the financial resources and infrastructure to adapt to these changes. This has aggravated poverty and unemployment, resulting in various socio-economic challenges. Increased demand for services such as energy and transportation require the combustion of more fossil fuels. This increases the emission of greenhouse gases into the atmosphere, resulting in climate change. Smoke from electricity production and inefficient vehicles pollutes the air, increasing the risk of citizens contracting respiratory diseases [4]. The destruction of ecosystems and the environment due to overconsumption of natural resources has made modern day cities unsustainable. Waste produced from the metabolism of cities is poorly managed, with illegal dumping by citizens and industries polluting the environment, particularly water bodies. This increases the risk of water borne diseases in areas where inhabitants have no access to potable water sources. Continued operation in this manner will have negative long-term consequences that will impact the environment and citizens. Climate change, which is currently a global concern, will result in extreme weather events such as prolonged droughts and cyclones. This will threaten the ecosystems of cities, which need to devise ways to operate sustainably to ensure environmental preservation and improvement in the quality of life for citizens [2].

Cities in developing countries have not evolved in their approach to solve urbanization challenges in a sustainable manner [5]. Urban growth is occurring despite low rates of industrialization and economic growth. Informal settlements on the periphery of cities are compounding to form large continuous settlements, leading to uncontrolled spatial expansion that has created megacities [4]. Most governments in African countries are struggling to address most of these challenges, as they lack manpower and financial resources to devise and implement viable solutions [1]. It is, therefore, imperative that an appropriate framework for development is proposed, aimed at equipping cities in developing countries to deal with these challenges sustainably. This paper discusses the results of the first stages of a larger research aimed at developing a methodology to derive a sustainable framework for African cities. The

framework will be derived from a set of Sustainability Indicators pivoted around the four pillars of sustainability. These pillars consist of the environmental, institutional, social and economic dimensions [4].

The paper portrays a sustainable city as a solution to urban challenges faced by cities around the world. Although cities employ different methods to solve urban challenges, they have one main goal, which is to be sustainable. The overarching concept of Sustainable cities will be outlined in Section 2, with Smart cities and Symbio cities being the different approaches applicable to the developed and developing countries respectively. Section 2.1 will elaborate the concept of smart cities, with a corresponding case study of the city of Trento as a typical example. Section 2.2 will expand on the concept of symbio cities, and a case study on the city of Durban will be considered as a typical example in the context of a developing country. A comparative analysis will be carried out to highlight similarities and differences between the approaches used by the two cities. This will be backed by available literature and the authors' interaction with systems, citizens and experts in the cities of Durban and Trento. The case studies were analysed based on field research and direct observation in which residents, stakeholders, municipal employees and academia were engaged. Section 3 will outline the significance and the use of Sustainability Indicators in developing the framework, with an outline of the methodology to be followed to conduct this research to derive the final framework for a sustainable African city.

2. SUSTAINABLE CITIES

Rapid urbanization, population increase, congestion, waste management and air pollution must be carefully controlled to ensure effective long-term operation of cities. This will prevent the overexploitation of natural resources, improve the surrounding environment and the quality of life. A sustainable city aims to manage natural resources effectively, extracting optimal value with the least environmental degradation [6]. There is strong focus on citizen welfare and obtaining a balance between the consumption and replenishment of natural resources. A multi-disciplinary approach to solving current urban problems ensures that all stakeholders are involved and contribute to the decision-making process. The increased use of alternative, clean and renewable resources for production of energy and transportation reduces greenhouse gas emissions and pollution. This contributes to improved health and provides cleaner air for the citizens, with long term positive effects of curbing climate change. The preservation of biodiversity and natural ecosystems is a priority, with stiff penalties issued to people or organisations who breach environmental laws. Construction and renovation of infrastructure is carried out, taking into account the limitations of the surrounding ecosystem. Effective management of solid waste and waste water ensures pollution from rubbish dumps and toxic effluents do not damage the environment [3].

Continuous engagement between authorities and citizens is necessary as inhabitants have good knowledge about the challenges they face and can offer viable solutions. The integration of migrants into the city and the provision of cheap urban housing reduces the creation of informal settlements [1]. Safe, efficient and environmentally friendly public transport is provided to enhance mobility within and around the city. To facilitate the interaction of people from diverse backgrounds, ethnicities and races, cities provide open public spaces. These should be closely

monitored to ensure the safety of the public, as some of these areas become criminal hotspots [3]. Use of information platforms improves safety in impending disaster situations by alerting relevant authorities. The development a sustainable city can be carried out by either retrofitting existing infrastructure or building from the ground up. This depends on the locality, resources and availability of land. Developed countries prefer to refurbish and retrofit as they argue that current cities are already too large and complex to create new ones. Developing countries, however, opt to create new cities, incorporating green and sustainable measures in the planning process [7]. The development can be implemented using either a top-down or bottom-up approach. The top-down approach comprises of a design by experts, based on their skills and knowledge with minimal public involvement. The bottom-up approach entails the input of citizens being the basis upon which the city is designed.

The design must not only consider physical aspects such as infrastructure, but should also include services, health, and citizen welfare. There must be a strong interconnection between the citizens and their areas of interest, complimented by recreational facilities. Water and energy efficient buildings will help to improve indoor comfort with minimal damage to the environment [2]. A sustainable city should be flexible enough to adapt to changes in technology, citizen lifestyle and increase in population. It should be a city whereby residents receive important information in real time, with open communication channels between citizens and the authorities [5]. As outlined in Section 1, cities use different approaches to achieve sustainability, dependent on the locality and availability of resources. The following Section introduces the concept of smart cities, which entails the extensive use of technology as a major facilitator to attain sustainability. This approach is more favourable in the developed world as they have better resources than their developing counterparts, with most of their challenges focussed on improving services and infrastructure rather than addressing basic needs. These challenges are better solved using high tech solutions, thus the use of technology helps to address them more efficiently [8]. A wider and more holistic approach to the problem of sustainability is discussed in section 2.2, analysing the concept of Symbio Cities, which seem more appropriate to address the issues of urbanisation and cities in developing countries.

2.1 Smart Cities

A smart city is a city that enhances its systems, services, operation, environmental sustainability, and citizen welfare through an integrated approach, using Information and Communication Technology (ICT) [9]. Many definitions of smart cities exist, which are highly dependent on the context of application and the identity of a city. There has been no agreed definition or a single template to define a smart city. It was discovered that the concept, hence the definition, were developed in three main areas; namely academic, government and industry. The main underlying concept, however, is the use of technology to facilitate the integration and improvement of existing systems in cities. Consideration of human capital is crucial as technology alone cannot create a smart city [9]. Cities provide their citizens with detailed information, facilitating human-infrastructure interaction using personalised services. Physical infrastructure is monitored by sensors, meters, cameras and mobile devices that gather critical data which can be used to optimise daily operations. This forms an interconnected and intelligent network where data can be exchanged and sourced between organisations and

individual citizens. However, the smart city network can only be functional in an environment where citizens are willing to embrace and use technology to their benefit. Citizens can also act as sources of information and help in the crowdsourcing of data by relevant authorities. This enables services to be improved, promoting a bottom-up approach to the design and operation of a city [7].

Smart cities are also known as high capacity learning and innovative centres, where creative and knowledge intensive strategies enhance the competitiveness of a city. They attract highly skilled workers to live there and they retain the best talent available, increasing human capital. Resources are managed through effective participatory policies which involve citizens and organisations in decision making processes. Social media and websites are used to convey real time information and receiving citizen feedback [10]. ICT networks and digitalisation enable citizens to access services and real-time information on any device. Data obtained from the use of these services is used to generate informed suggestions, targeting specific needs. Large processing capabilities are essential to give citizens useful information based on the collected data. Real time monitoring capabilities also allow cities to monitor critical areas such as energy consumption, pollution and traffic, enabling personnel to respond to situations with minimal delay. Open data policies allow free flow of information between citizens, organisations and businesses. Big Data, which constitutes of large and complex processing capabilities, can be used to predict events to enable planning ahead in case of disasters and undesirable situations such as traffic congestion. Knowledge sharing between the society and the digital dimension enables technology to change and shape the way citizens live and work. Constant connection to services is facilitated by providing Wi-Fi hotspots around the city [11].

The success of technology in a smart city ecosystem is largely dependent on the number of regular users to ensure the efficiency of the system. More usage creates more data collection opportunities, resulting in an intelligent and citizen focussed system [12]. Incompatible information systems, coupled with outdated infrastructure, complicate the implementation of smart plans oriented towards the citizens. In order to offer efficient service delivery, the authorities must acknowledge citizens' preferences. There must be clear coordination between the services offered and usage by the citizens. The Vienna University of Technology came up with six dimensions that constitute a smart city, whose model was adopted by the European Union. They comprise of smart governance, smart environment, smart people, smart living, smart mobility and smart economy [9]. These six aspects reveal the sectors that entail a smart city. There is a common use of ICT in each of the sectors, hence revealing the extensive use of technology to improve the quality of life for the citizens and preserving the environment. The following section presents a case study of a typical smart city in which technology is a facilitator for sustainability and effective operation of the city. It follows the outline of the six dimensions that constitute a smart city, but adjusted to suit its conditions and locality.

2.1.1 Case Study: City of Trento, Italy

This case study presents the city of Trento, in the province of Trentino-Alto Adige, in the north of Italy. A field research was conducted in this city, which included direct observation of systems and operations, as well as engagement with the citizens, municipal employees and

academia at the University of Trento. Consultation with the Smart City Office at the Municipality of Trento provided useful information in how various systems such as transportation, recycling and health were being improved by using technology. Trento is ranked as the city with the highest quality of life in Italy, with high smart rankings within Europe. This is largely attributed to its attention in the inclusion of various stakeholders, particularly the University which increases the potential for a creative innovation ecosystem. Trento is one of the leading cities in terms of smart buildings, grids and lighting. The city has a population of approximately 120,000 inhabitants, and is expected to increase steadily due to migration, like other cities around the world [13]. The use of technology is viewed as a major facilitator of change, and ways in which it is applied must be transparent to all stakeholders within the city. It is expected to be user friendly to every type of citizen, including the elderly, children and the 'technologically illiterate.' The smartness of the city, however, does not entail a complete takeover by technology, as this would make services more complicated. The city of Trento initiated this process by registering as a candidate smart city to the European Union in 2014. Afterwards, a workshop in which six papers concerning the different dimensions of the city were drafted. A dedicated smart city office was opened to manage and accelerate the process of improving the city of Trento [12].

The city has made great strides in the use of environmentally friendly systems in the provision of energy, transportation and waste management. The use of solar energy by households and buildings within the city is now more popular, with residents now becoming producers of electricity that can be fed into the grid. The main challenge encountered is the dispersion of domestically produced electricity into the grid due to the variable loads that result from changing weather systems [14]. The use of a smart grid created a real-time demand/response system to curb the effects of fluctuating production and consumption of power in the grid. Retrofitting existing buildings has also seen a reduction in energy consumption. Educating municipal staff about sustainability has also seen a marked improvement in the reduction of energy usage within municipality buildings. Other sustainable practices such as waste separation and recycling have seen citizens participating in the development of an environmentally friendly and clean city [14]. Waste separation has fostered a culture of recycling among citizens, with every building and household provided with different bins for every type of waste. The municipality collects different types of waste on certain days, making it easier to manage and separate that which is easily recyclable and that which can be deposited into landfills.

The provision of mobile applications has improved mobility within the city, encouraging the use of public transport, bicycle and ride sharing. Cleaner forms of mobility are prioritised in the city as evidenced by traffic lights system, which gives priority to pedestrians, bicycles and buses. Dedicated bus lanes, wide coverage of cycling lanes and pedestrian crossings further reinforce the prioritisation of these modes of transport [15]. Online platforms such as websites and social media are being used to provide information and feedback capabilities for citizens. They have also enhanced public participation by allowing citizens to post their own ideas on how the city can improve its services. Gamification of sustainable means of mobility have resulted in more citizens using public transport, cycling and walking. The city is also using technology to create integrated health systems and effective governance systems. Big data and

open data policies are being implemented to ensure that useful and beneficial information is provided for the citizens [12]. Implementation of these systems shows how Trento is using ICT to solve urban challenges and improving services within the city in a sustainable manner. However, not all cities would make use of ICT as a facilitator for attaining sustainability. In developing countries, the challenges differ and require less high-tech solutions. Instead, clear collaboration between different sectors of the city would help address issues such as the provision of basic needs and services, poverty and pollution [3]. The following section outlines the Symbio city concept, which entails these synergies to achieve sustainability, and are better suited for cities in developing countries.

2.2 Symbio City

A Symbio City model utilises multidisciplinary and synergic approaches to solve urban challenges. Technology is not at the forefront of development as compared to smart cities, but instead focus is on the provision of basic needs and services for the citizens [3]. Participation of different stakeholders is encouraged, taking into consideration the needs of the poor and marginalised communities. This encourages an efficient bottom up approach to design and implementation, with special attention given to the most vulnerable which include women, children, the elderly and disabled. It is expected that an improvement in the living conditions with respect to the social, economic, environmental and institutional aspect can alleviate poverty. Poverty in this context is described as the deprivation of basic needs and services. Sharing of knowledge and experiences between entities increases the capacity to solve challenges, developing a system that compliments existing policies. Open exchange of information at different levels of management, such as local municipalities and governments, allows for efficient methods of operation that do not clash [3].

All the synergies and collaborations mentioned are aimed at creating a self-sustaining city in terms of resource consumption. Environmental preservation overseen by governments and municipalities will help to maintain natural ecosystems and local biodiversity. Authorities can be held accountable for their use of resources and management by engaging all stakeholders in the city, including slum dwellers. This can be done through workshops, forums and community meetings. The distribution of resources and services should be equal to ensure that every citizen is afforded an opportunity to improve their life and address inequality issues [16]. It is imperative that sustainable business practices and industrial regulations are enforced to minimise pollution. The poor are most affected by these practices and must, therefore, be protected. Cities also aim to address socio-economic issues such as unemployment to reduce criminal activities, particularly in slums. Controlling spatial growth will help to effectively manage the creation of informal settlements, reducing pressure in terms of providing services to these areas [4]. Cleaner forms of energy are prioritised for both industrial and domestic use. Decentralised and cleaner electricity production systems would be feasible in areas that are not connected to the current grid. Some cities in Africa have high levels of sun intensity, hence they would be ideal for implementing a photovoltaic grid. Though developing countries contribute less pollution than their developed counterparts, they must still strive to reduce greenhouse gas emissions [3].

The city of Durban is one of the cities in Africa that is implementing a multi-disciplinary and

synergic approach to addressing urban challenges. The city faces rapid urbanisation, with limited resources to address most of these challenges [17]. The following section presents a case study of a typical large city in the developing world, which has a more variety of challenges as compared to cities in developed countries. Its approach to solving these issues differs from those taken by cities in developed countries. Analysis of this case study is based on the author's engagement with various systems within the city as a resident, consultation of academia and literature about the city.

2.2.1 Case Study: City of Durban, South Africa

Durban is located on the eastern coast of South Africa, in the province of KwaZulu-Natal. It had a population of approximately 3.6 million inhabitants in 2016, and is the third largest city in the country, with universities and colleges within its precinct [18]. The city faces a high rate of urbanisation that has been difficult to project due to rural-urban migration. It is estimated that the population will grow to 4.4 million by the year 2030, and most of these citizens will reside in informal settlements. It also has segregated spatial planning pattern due to history, hence this must be taken into consideration in planning for growth and development. The city has put in place a plan to address all the challenges encountered in its Integrated Development Plan (IDP). Successful implementation of these plans will improve the lives of citizens and conditions in the city. The provision of low cost housing seeks to reduce homelessness and alleviate the number of residents in informal settlements. Poor households are given rate rebates as they cannot afford to pay for services. The city is facing backlogs in service delivery, but the municipality is putting most of its resources to provide adequate infrastructure. Short term infrastructure in the form of ablution facilities, drainage channels, fire breaks and emergency access channels are being provided to improve the quality of life in informal settlements [17].

Environmental preservation measures to protect ecosystems and prevent pollution were first implemented in 2004, under the Municipality Climate Protection Programme. Environmental laws have been put into place to control illegal waste dumping and pollution in the city [17]. Waste is being collected in most areas, including informal settlements, and is deposited in properly managed sanitary landfills around the city. Further steps to curb climate change have been implemented by the installation of solar water heaters as alternative renewable energy household appliances. To enhance mobility within the city, more municipal buses and trains have been commissioned, with efforts to make pick up and drop off points much safer. Encouraging the use of public transport will reduce congestion levels in Durban. However, there is stiff competition between different modes of public transport, rendering some routes inefficient and unprofitable. The provision of law enforcement agents, police and disaster management centres has increased safety in the city, enabling it to effectively respond to emergency situations. In order to identify and address areas of concern, citizens are being constantly engaged and educated about sustainability to encourage active participation in the development of the city [17].

The city of Durban is aiming to provide adequate housing and services for all its citizens, hence some models in infrastructural development are being tested. A project which seeks to implement a mixed land use model is being developed in an area called Cornubia, in the north of the city [17]. Development levels in African cities means that there is availability of land to

build green areas and settlements from the ground up. The model has allowed the mixture of businesses and residential areas, providing the much-needed job opportunities for new residents in the area. Successful implementation of sustainable practices in this area will enable the model to be carried out to the rest of the city, and other cities in the region. This will complement the plans outlined in the IDP which are as follows:

- To create a city where people enjoy sustainable livelihoods in all aspects
- To empower citizens to participate in the development of their own city
- To preserve culture, history and heritage

The development of the city is in line with their vision for 2030, to be "the most liveable city in Africa." The city has made progress with their back to basics approach, which aims to meet the citizens' demands in terms of service delivery [17].

2.3. Comparative Analysis of sustainable city approaches between Durban and Trento

A review of these two cities has shown that they have the same underlying goal of becoming sustainable. They are highly ranked in their own countries as cities with the highest quality of life. The cities contain academic institutions that are held in high regard for their research capabilities. Both cities have made good progress in ensuring sustainable operation and environmental preservation. They also share common challenges such as pollution, traffic congestion and the influx of migrants. However, due to the localities of the two cities, different development levels, size and the availability of resources, there is a difference in the challenges they face. Durban has more basic challenges such as service delivery, higher rates of migration and spatial segregation. The city of Trento has managed to address most of its challenges through constant engagement with different stakeholders and citizen participation using ICT platforms. Waste management has improved through fostering a culture of recycling and separation of waste from a household level. This is not the case in Durban, where the problem of waste is persistent, particularly in informal settlements and city streets. This is due inadequate knowledge about waste management on the citizens' part, as well as inconsistent waste collection methods by the municipality around the city.

The city of Trento has managed to get more citizens to use alternative modes of transport such as buses and bicycles. Lack of safety and efficiency in public transport routes is hindering the creation of a sustainable public transport system in Durban, even though the majority of citizens use it for economic reasons. There are more modes of public transport in Durban, with minibus taxis in direct competition with local municipal transport. These taxis are making it difficult for public transport to become favourable to citizens as it is generally perceived as unsafe. The city of Durban also has to deal with higher rates of rural-urban migration, with an increase in the number of slum dwellers. The provision of government subsidised low-cost housing is expected to reduce the number of slum dwellers. The city of Trento operates closely with educational institutions for research and innovative ideas on sustainability and improvement of services, coupled with ICT as a major facilitator. Durban, on the other hand, employs more basic and physical methods to provide services and improve existing ones. Technology is also employed, but to a much lesser extent as compared to Trento.

As mentioned in section 1.1, the main goal of modern day cities is to operate in a sustainable

manner to improve the quality of life for the citizens. Analysis of the two case studies shows that the cities of Durban and Trento employ different approaches to attain sustainability. It also shows that there is no single template to solve urban challenges, but different methods can be applied, dependent on the context, locality and the availability of resources. In some cases, however, ideas such as encouraging the separation of waste can be directly borrowed and assessed for feasibility before implementation in such a city as Durban. In order to measure progress towards implementation, as well as assessing the strengths and weaknesses of most cities in their aim to become sustainable, the use of sustainability indicators has become common. In a world in which the need for sustainable cities is now a reality, sustainability indicators help to create strategic plans and reflect on progress towards specific conditions. Section 3 outlines how sustainability indicators will be used in this research to derive a methodology to create a framework for a sustainable African city.

3. SUSTAINABILITY INDICATORS FOR CITIES

Since this paper entails the first stage in developing a framework for a suitable African city, the analysis of sustainability city models and relevant case studies highlighted the importance of defining and using clear sustainability indicators on which such a framework must be based upon. Application of these indicators will be outlined in the following stages of the research. Sustainability indicators are used as supporting tools for the crafting of policies for cities, taking diverse information and condensing it to knowledge towards a specific aspect. They are mainly used for three purposes which are as explanatory tools, conducting pilot projects or assessing the performance of a city [19]. They must be well defined, easily interpretable and easy to collect. Data used to formulate these indicators must be easily understood by the public and policy makers. Proper implementation of sustainability indicators will result in more communication between different stakeholders, thereby holding relevant authorities accountable in terms of progress. Their reliability is often affected by lack of data from municipalities and government institutions, particularly in developing countries [18].

Indicator systems used to obtain and evaluate sustainability indicators have already been developed in other research, mainly targeted for European cities. These frameworks depend on the scale of application and the type of indicators chosen. Some of the indicator systems in use are the European Green Capital Award (EGCA), Global City Indicators (GCI) and the European Environmental Agency Urban Metabolism Framework [19]. Since these are suited for cities in Europe, it is imperative that an indicator assessment system be devised for cities in developing countries. This system should consider the wider variety of challenges faced, such as rapid urbanisation and the availability of resources. For these indicators to be implemented, a method of evaluation must also be formulated, which will determine the most important and critical areas by assigning weightings to each individual indicator. This will enable authorities to respond effectively in resolving pressing issues within the city. In this research, the formulation of the framework for the sustainable African city of the future will be based on obtaining indicators suited to the Symbio city concept. The city of Durban will be the starting point of collecting sustainability indicators. This will be backed by available literature on the city, as well as the consultation of different stakeholders, including residents, academia and experts in the industry in municipalities.

Once these indicators are obtained, they will be grouped into different sectors which show the different aspects that make up a city. Indicators common to these sectors will highlight some relations and synergies between the different aspects in a city. Once the indicators have been grouped, a method to evaluate these indicators will be devised. Fuzzy Logic, Multi-Criteria Decision Analysis, Smartainability Methods and Life Cycle Assessment are some of the various methods being used to evaluate sustainability indicators [20]. Further research will enable the selection of an appropriate method to evaluate the indicators obtained. Evaluation of these indicators will identify the ones with the most weighting as the critical areas of concern. A combination of these critical indicators will create the proposed framework for the sustainable city, which will guide in the decision-making process for the allocation of resources. A SWOT Analysis will be carried out to assess the strengths and weaknesses of the framework. The applicability of the proposed framework will be tested on a pilot area, with successful implementation seeing the method being repeated in a city-wide context. Figure 1 shows the process to be followed; from defining the appropriate context in terms of either a symbio or smart city, to how the indicators will be evaluated in order to derive a proposed framework.

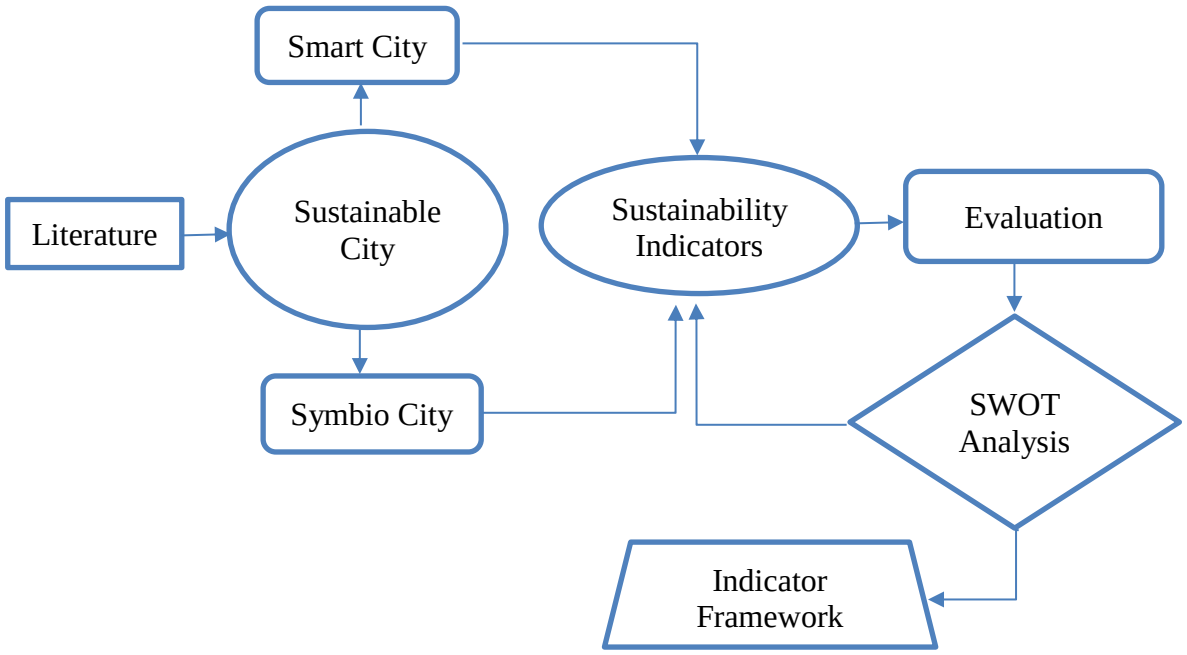

Figure 1. Flowchart of the proposed methodology to derive the framework of indicators

4. CONCLUSIONS AND RECOMMENDATIONS

The concept of sustainable cities has become very popular, with the ever increasing need to prevent pollution, preserve biodiversity and improve the quality of life for citizens. It is imperative that cities in developing countries aim to achieve sustainability, as they face a wider variety of challenges that have a large impact on the citizens and existing systems. This paper has analysed different approaches to the sustainable city concept, namely smart city and symbio

city approach, also through the lens of case studies from the developed and developing world. The symbio city concept focusses on a more holistic approach towards solving urban challenges, hence is more inclined towards a developing country's context. The use of sustainability indicators will be pivotal to the support and creation of a symbio city model in the African context. They will help in the identification of crucial areas, as well as measuring the performance of cities. The next stages of this research will result in the derivation of a framework of sustainability indicators that will help in the creation of a symbio city in the African context, where synergies between different sectors are outlined and utilised to improve sustainability in cities.

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