Assessing changes in residential densities in the City of Tshwane between 2010 and 2018

By

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ABSTRACT

An estimated 55% of the world's population currently lives in cities. It is further predicted that the urban population will increase to 68% by the year 2050. One of the main drivers of this rapid increase is urbanization that has mainly affected African and Asian Cities. As population increases, so does the demand for accommodation in cities, which if not monitored can result in urban sprawl. With the unprecedented population growth, many cities across the world have adopted the compact city ideal as a way of dealing with urban sprawl. In South Africa, the nature of the current urban form, which was as a result of the segregation era, seems to persist as growth continues on the periphery of cities. In an effort to deal with low-density urban expansion, the City of Tshwane in 2005 came up with its Compaction and Densification Strategy that focused on densifying the current built-up areas. The aim of the strategy was to densify and promote land use mix in the municipality, thereby increasing the City's sustainability. This study thus sought to assess the residential density changes that have occurred in the City's Metropolitan area between 2010 and 2018 and then assess the impact the CDS has had on these densities. The assessment of the impact of policy is important because it allows policy makers and planners to make informed spatial planning decisions and make necessary adjustments to the policies. To achieve this, residential densities were quantified for the study period and population densities were also quantified for a comparable period. Then regression analysis was undertaken between residential densities and the CDS to assess the impact the CDS has had on the observed residential densities between 2010 and 2018. From the density quantification results of both residential and population densities, it was observed that the highest density in the city occur in township areas such as Soshanguve, Mamelodi and Atteridgeville. The regression analysis produced an output of $R^2 = 0.006$ and $R^2 = 0.005$ for 2010 and 2018 respectively. These results gave an indication that there was a weak positive influence of the CDS on density in the City of Tshwane. A correlation between 2011 population and 2010 residential density produced a correlation coefficient of $r = 0.692$ which indicated that there was a strong positive relationship between the two variables. A second correlation between 2018 population and 2018 residential densities with $r = 0.492$ indicated that there was an average positive relationship between the two variables.

Keywords: Densification, Compaction, Urban Sprawl

OPSOMMING

‘n Beraamde 55% van die wereldbevolking woon tans in stede. Voorts word voorspel dat die stedelike populasie tot 68% sal toeneem teen die jaar 2050. Een van die hoof redes vir die drastiese toename is verstedeliking wat hoofsaaklik Afrika en Asiatiese stede affekteer. Soos wat bevolking toeneem, neem die vraag na verblyf in stede ook toe, en indien dit nie gemonitor word nie kan dit aanleiding gee tot stedelike uitbreiding. Vanwee die onge-ewenaarde toename in bevolking, het baie stede wereldwyd ideale van kompakte stede aangeneem as ‘n manier om stedelike verspreiding te hanteer. In Suid Afrika is die aard van die huidige stedelike vorm ‘n gevolg van die vorige era van segregasie, en dit blyk voort te duur soos wat groei aanhou plaasvind op die stedelike rand. In ‘n poging om lae-digtheid stedelike uitbreiding te bekamp, het die Stad Tshwane in 2005 ‘n Kompaktering en Verdigting Strategie (KVS) saamgestel wat klem plaas op die verdigting van bestaande beboude gebiede. Die doel van die strategie was om verdigting en gemengde grondgebruike aan te moedig binne die munisipaliteit, om sodoende die volhoubaarheid van die Stad te verbeter. Hierdie studie beoog om die residensiële digtheidsveranderinge te evalueer wat tussen 2010 en 2018 plaasgevind het, en ook om die impak van die KVS op sodanige digthede te ondersoek. Die evaluering van die impak van beleid is belangrik omdat dit beleidmakers en beplanners instaat stel om meer ingeligte ruimtelike beplanningsbesluite te neem, en om die nodige aanpassings aan beleid te maak. Om hierin te slaag, is residensiële digthede gekwantifiseer vir die studieperiode en bevolkingsdigthede is ook gekwantifiseer oor ‘n vergelykbare periode. Regressie analise is toegepas tussen residensiële digthede en die KVS om die impak van die KVS op die waargeneemde residensiële digthede te bepaal. Vanuit die digtheids resultate van beide residensieel en bevolking is bevind dat die hoogste digthede in die stad plaasvind in nedersettings soos Sohanguve, Mamelodi en Atteridgeville. Die regressie analise het ‘n uitset van $R^2 = 0.006$ en $R^2 = 0.005$ vir 2010 en 2018 getoon. Hierdie resultate gee ‘n indikasie van ‘n swak positiewe invloed van die KVS op residensiële digtheid in die Stad Tshwane. ‘n Korrelasie tussen 2011 bevolking en 2010 residensiële digtheid het ‘n korrelasie koëffisiënt van $r = 0.692$ opgelewer wat aandui dat daar ‘n sterk positiewe verwantskap tussen die twee veranderlikes bestaan. ‘n Tweede korrelasie tussen die 2018 bevolking en 2018 residensiële digthede met $r = 0.492$ dui aan dat daar ‘n gemiddelde positiewe verwantskap tussen die twee veranderlikes bestaan.

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1. INTRODUCTION

The United Nation in 2018 estimated that 55% of the earth's population currently lives in urban areas. This is a result of increased urbanization combined with the overall growth of the world's population, which mainly affects Asia and Africa (United Nations, 2018). The rapid growth in urban population has put much pressure on urban land and resources as people move into the city in search for better opportunities. Based on the current population growth rate, the United Nations (2018) estimated that urban population would increase by 68% by the year 2050. As population increases rapidly, planners and policy makers have the responsibility of finding ways to accommodate the growing population in a sustainable way that does not affect the environment or the population's quality of life.

The planning domain has over the years seen an increasing emphasis on developing a more sustainable urban form, which has predominantly favoured policies that focus on creating more compact urban areas and increasing residential densities (Howley, 2009). Creating a sustainable urban form has widely been accepted as a challenge that faces researchers, planners and policy makers (Dave, 2010). One of the fundamental building blocks of sustainability is urban form, in the sense that the form of your city will determine how sustainable it is. In an effort to deal with challenges that face the current urban form, the United Nations (2011) developed a set of Sustainable Development Goals (SDGs), which are a call of action to end poverty, protect the planet and make certain that people live peacefully and are prosperous in the environment they live in. These Sustainable Development Goals have been used to guide the urban planning of South Africa, as the country attempts to align its planning to that which is outlined in the SDGs. At the local Government level, each municipality has to outline on their spatial plans various ways in which they aim to achieve sustainable development aligned to the Sustainable Development Goals as well as the National Spatial Development Plan. The major focus amongst South African municipalities has been on achieving sustainability through urban compaction and residential densification.

One major challenge of unprecedented urban population growth in developing countries is the resultant urban sprawl, which is often accompanied by problems such as inefficient land use and lower densities (United Nations, 2014). In response to this challenge, the urban planning domain around the world has shifted towards compact cities and increasing city densities. Density is a commonly used term for predicting and controlling land use in the planning domain

(Sivam *et al*., 2012). There are two contrasting views in compaction and densification, with those advocating for lower densities arguing that in low density urban form people have a choice of locality, access to affordable housing and there is enough space for them to have privacy (Roberts, 2007). In contrast to this, those who are against low densities argue that low densities create inefficiencies in the sense that it limits the viability of public transportation and increases the city's ecological footprint (Roberts, 2007). Urban planning policies in developed cities of the north have largely focused on the reduction of sprawl and promoting a more compact urban form by increasing densities. These cities have been successful in their efforts to reduce sprawl due to their well-designed and well-maintained public realm (Wang & Shaw, 2018). However, the picture is not the same for cities of the global south, due to poor planning of infrastructure such as roads and the provision of public transportation, which are critical in creating compact cities. In the South African context, there is a national drive towards densification, hence its inclusion in most municipal strategies. The City of Tshwane, in 2005 came up with its Compaction and Densification Strategy (CDS) in an effort to reduce urban sprawl by densifying existing built-up areas. In light of the above mentioned, this research seeks to analyse the change in residential densities in the City of Tshwane (CoT) between 2010 and 2018, thereby evaluating the impact of the City's CDS on the observed changes.

1.1 RESEARCH PROBLEM

Urban areas have been growing rapidly over the years. According to Le Roux *et al*. (2019), South African Urban populations are expected to increase from 38 million in 2018 to 85 million people by the year 2050, which is a proportional increase from 66% to 80% over the 32-year period. The impact of this rapid population growth is significant in terms of economic, social and environmental terms and has implications on city policy. Like many other metros in South Africa, the CoT has experienced a population growth of approximately 12% between 2011 and 2016. As the population increases, so does the demand for accommodation, which often results in sprawling cities as urbanization and development continues to occur.

In an effort to reduce urban sprawl in the its metropolitan area, in 2005 the city put forward its CDS which was aimed at the structural composition of the metropolitan in accordance with directives from National and Provincial Legislation advocating for more compact urban development. The Compaction and Densification Strategy sought to minimise unmanaged urban growth and to create opportunities for densification in areas that have low densities. Furthermore, CDS wanted to focus residential densification around areas where people will

have access to employment opportunities, transport opportunities and access to other services (City of Tshwane, 2005). As the population continues to increase it is therefore important to assess the changes that have occurred in residential densities and assess the potential impact the City's CDS has had on the observed changes. Assessing the changes as well as the impact of strategies is important because it allows policy makers to make the necessary changes in their approach towards reaching the ultimate goal of creating more efficient and sustainable cities.

1.2 RESEARCH AIM

The aim of this research was to assess changes in residential and population densities in the City of Tshwane, thereby assessing the impact of the City's 2005 CDS on the observed changes.

1.3 RESEARCH OBJECTIVES

- To quantify and map 2010 and 2018 residential densities in CoT at Enumeration Area (EA) level
- To quantify and map 2011 and 2018 population densities at EA level in CoT
- Determine the changes that have occurred in both population and residential densities
- Compare population vs residential densities
- Assess the potential impact of the City's CDS on residential densities

1.4 KEY RESEARCH QUESTIONS

- How has residential density changed between 2010 and 2018?
- How has population density changed over a comparable time period?
- How does the changes in density correspond to the objectives put forward by the CoT CDS?
- What impact does the CoT CDS have on the observed residential density changes?
- What is the relationship between residential density and population density?

1.5 HYPOTHESIS

H_0: There is no relationship between the CoT CDS and observed changes in residential density.

H_A: The CoT CDS had a significant impact on the changes in residential density that occurred between 2010 and 2018.

1.6 RESEARCH METHODOLOGY

1.6.1 Data

The secondary data be used in this study was a set of two Geoterra Image buildings datasets, which are a set of points that represent buildings across the CoT Metropolitan. The chosen years for the study were 2010 and 2018 due to the availability of data for the two years. The datasets were classified into different types of buildings as illustrated in Table 1 below.

Table 1. GTI buildings classification

Class Number	**Class Name**	**Class description**
7.1	Formal	Free hold formal houses
7.2	Informal	Informal structures
7.3	Clusters/complexes	Clusters/complexes
7.4	Estates	Small holdings
7.5	Security Villages	Security Estates
7.6	Smallholdings/Agriculture	Small holdings/Agriculture
7.7	Rural workers housing	Includes all rural workers housing on smallholdings, farms, forestry areas, etc.
7.8	Villages	Villages is found mainly in KwaZulu-Natal and the Eastern Cape Provinces

The second set of secondary data used in this study was population data for the year 2011 from Statistics South Africa and 2018 population estimates from GTI, which is modelled population based on mid-year estimates. These population datasets came from different sources because during the time of the study there was no other census data that could used for the analysis. These mid-year estimates were calculated from the census data, which should be a good estimate of the population. The StatsSA Enumeration Area (EA) boundary was used as a base for the analysis to calculate the changes that occur in both population and residential densities at the EA level. Lastly, this study also used a shapefile from the City of Tshwane, which outlined areas where densification should be occurring based on their 2005 Compaction and Densification Strategy.

1.6.2 Data Pre-Processing

All the spatial layers were reprojected to ensure that they were all within the same Projected Coordinate System. This was done in ArcMap using the '*Reproject*' tool in the ArcToolbox. This step was important in ensuring that there is proper spatial alignment between the datasets in terms of the coordinates that represent features.

1.6.3 Data Analysis

Residential densities for both 2010 and 2018 were quantified in ArcGIS at the EA level. Thereafter the two years were compared to assess the changes that have occurred during the 8-year period. Population densities were also quantified for 2011 and 2018, also at EA level, to assess the changes that have occurred between the two years. Thereafter statistical analysis was undertaken to assess the relationship between residential density changes and areas where densification is prioritised in the city in order to assess whether the implementation of the 2005 Compaction and Densification Strategy has had an impact on the changes that have occurred in residential densities.

1.7 DELINEATION OF STUDY

Although the City of Tshwane's CDS focuses on both compaction and densification, which is more than just increasing densities but also land use mix, this study will only focus on quantifying residential density changes and not on identifying areas where there is land use mix. The study also focuses on the gross rather than net density

1.8 STUDY AREA

The city of Tshwane Metropolitan Municipality is located in the northern part of Gauteng Province, South Africa (Figure 1). The Metro was established in 2000 with the previous Metsweding District Municipality being incorporated into the municipality in 2011. With a total land area of 6 298 km^2 the metro is home to an estimated population of 2 921 488 people (StatsSA, 2011). The municipal area is further divided into seven planning regions, each with its own unique characteristics. These regions came about as a result of the adoption of the city's Integrated Development Plan in 2011. This allowed for the regionalization of service delivery in the effort to decentralise certain operational and maintenance functions while strategic planning remained the responsibility of the departments within the city.

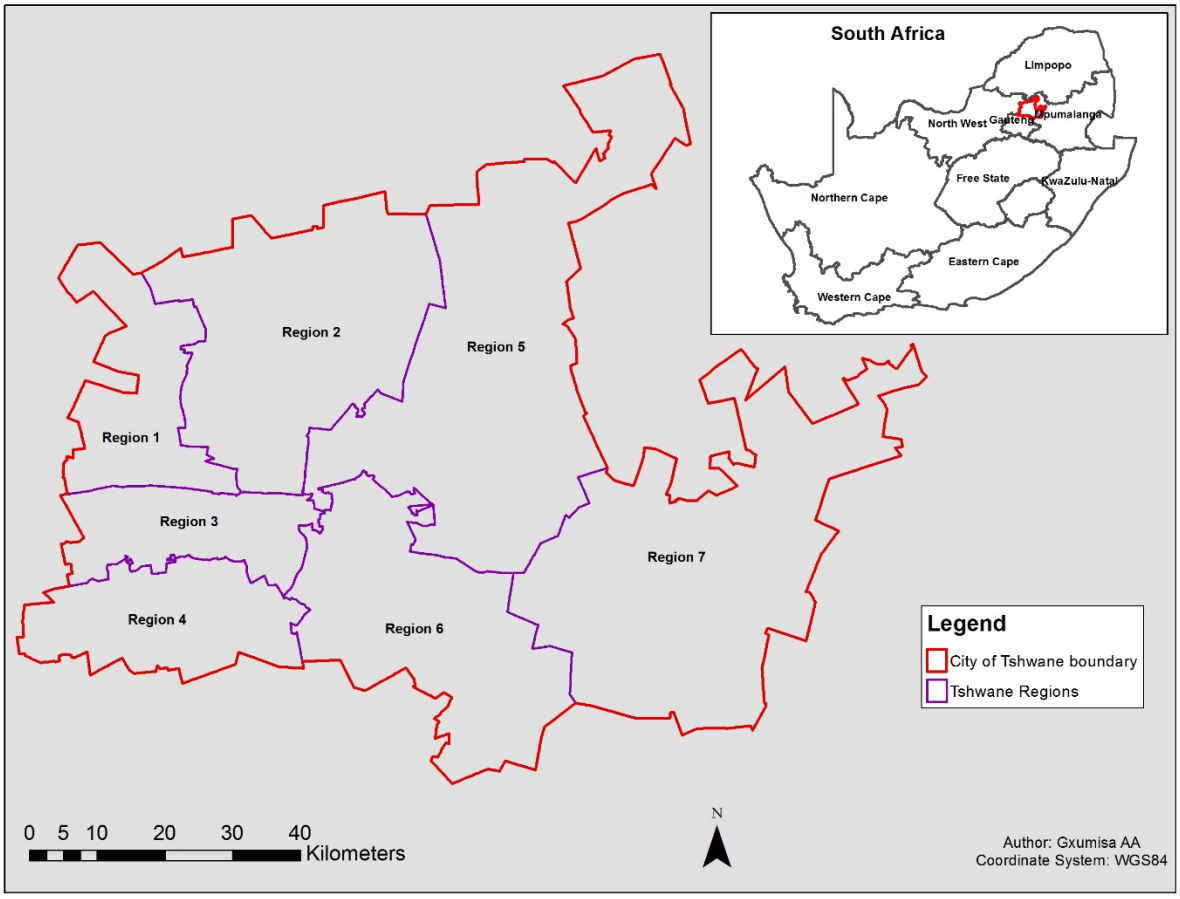

Figure1. Study Area

1.9 STUDY SIGNIFICANCE

Studies of this nature are important to carry out because they give sound knowledge of the changes that have occurred in both residential and population densities and also the prediction of future trends. It is hoped that this study will assist policy makers in assessing the success of their densification strategies and adjust them accordingly. Furthermore, a study of this nature hopes to add onto existing literature on densification and the impact planning policies have on densities. The comparison between residential density and areas that the City specify for densification will assist in assessing whether the densification strategy has had an impact on the changes observed in the metropolitan area.

Chapters

This research study is made up of the following Chapters that follow the introduction:

Chapter 2: Focuses on the Literature Review

Chapter 3: Focuses on the methodology used to obtain the objectives of the study

Chapter 4: Focuses on the analysis outputs and their description

Chapter 5: Discusses the results obtained

Chapter 6: Focuses on the study conclusion and recommendations

2. LITERATURE REVIEW

Before analysing changes in density, it is important to review literature relating to densification and gain an understanding of the topic as well as some concepts linked to densification. It is also important to look at previous studies that have been conducted on densification in an effort to compare and contrast previous results with that of this study. As a result, this chapter focuses on literature on densification in a broader view.

2.1 POPULATION GROWTH AND URBANISATION

Urbanization is viewed as one of the contributing factors that have resulted in the rapid increases in urban population seen today (Buhaug & Urdal, 2013). Pacione (2009) defines urbanization as a contemporary and ongoing process where there is an increase in the proportion of people residing in urban areas. According to the United Nations, the human population increased from 2.5 to 6.9 billion people between 1950 and 2010. Based on the current growth rate, the UN (2018) indicates that the population is expected to reach 9.8 billion people by the year 2050, and 68% of this is expected to be found in urban areas. Leeson (2018) further indicates that approximately 3.4 billion people reside in rural areas and this number is expected to decline to 3.2 by the mid-21st century, with Africa and Asia making up 90% of this population. This decline results from people shifting from rural into an urban society.

Population growth affects urban areas in various ways, from infrastructure requirements and their environmental impacts to social interaction patterns, as well as regional economy changes. Urban growth in the developing world occurs for two main reasons; firstly as a response to economic growth in cities and secondly as consequence of rural-to-urban migration (Marshall, 2007). According to De Brauw *et al.* (2014), rural-to-urban migration is an important component of the economic development process witnessed as labour migrates out of agricultural areas into manufacturing and service sectors. However, as people migrate into urban areas there is no guarantee that they will secure an income. Research has shown that one out of three household members who have migrated in search for employment find it difficult to secure employment (Devereux, 2000). As a result, the migrants' inability to secure an income puts strain on the planning and management of urban areas, which then results in the creation of informal settlements usually found at the city's periphery (Robson, 2005). As informal settlements continue to grow, planners in developing countries are faced with the challenge of not having the necessary financial means to provide services to the fullest extent

in these settlements, which then leads to unfavourable land use patterns and conditions that are neither environmentally, socially nor economically acceptable.

The migration of people into urban areas has had researchers concerned for both rural and urban areas. In urban areas, the concern is largely on the increase in unemployment rates, service provision to the new migrants as well as the associated political unrests that people engage in when they are dissatisfied with the provided services (De Brauw *et al*., 2014). In rural areas, the concern is that rural outmigration leads to labour shortages as the economically active labour moves out of these areas (Ajaero & Onokala, 2013).

Pawan (2016) states that urbanisation is normally triggered by four primary reasons, namely: industrial growth, social factors, employment opportunities, and modernization. Firstly, people are attracted to urban areas because of industrial growth, which is often associated with expanded employment opportunities. Urbanization occurs as rural people migrate into urban areas in search of better employment opportunities. Secondly, people are attracted to the city by social factors such as better standards of living, better education facilities, better access to basic services and the idea that cities have better social benefits compared to rural areas. Thirdly, people migrate to urban areas due to the diversity of employment that exists in the city. In the rural parts of the world, people are predominantly dependent on agriculture as their source of employment; people thus migrate to urban areas for better paying jobs and diversified employment opportunities. Finally, urbanization is triggered by modernization due to advancements in technology, better infrastructure and improved communication. Thus, being in urban areas is often viewed as an efficient form of living, which simplifies people's lives.

2.2 URBAN SPRAWL

As urban populations increase, so does the demand for land to accommodate the growing population, which has resulted in sprawling cities. Urban systems are expanding at an accelerated rate all over the world, with forecasts suggesting that these rates have dramatically increased the size of cities (Artmann *et al*., 2019). The phenomenon of urban sprawl is not new in the urban planning domain as it has been of major concern in both North America and Europe since the 20th Century (Kruger, 2017). The focus on urban sprawl came with the realization that the phenomenon contributes to climate change and has significant impacts on land, water and air (Banai & DePriest, 2014). To tackle these issues, one needs to define what urban sprawl is. Like many terms in the urban planning domain, there is ambiguity on the precise definition of what urban sprawl is and how to best measure it. However, leapfrog and scattered pattern of

development, commercial strip development and large expanses of low-density occupation is the consensus by many researchers on the attributes that characterise the phenomenon (Burchell & Mukherji, 2003; Musakwa & van Niekerk, 2014; Chobokoane & Horn, 2015).

2.2.1 Causes of Urban Sprawl

Factors causing urban sprawl vary across the world depending on the level of development of a country or the structure of the society in that particular country (Karakayaci, 2016). In Europe, urban residential sprawl is responsible for more than 45% of the land transformation that occurs on the coastal zones due to tourism and leisure. Furthermore, sprawl in Europe is caused by macro-economic factors, demographic factors, housing preferences, and transportation (Habibi & Asadi, 2011). In America, the cause of urban sprawl is the large demand for detached housing with gardens (Kruger, 2017). Thus, urban sprawl in America is characterised by an increasing growth in suburbanization that results in people having to commute longer distances (Cobbinah & Amoaka, 2012). According to Habibi & Asadi (2011), urban land consumption in the United States increased from approximately 417 square kilometres (km^2) per 1000 inhabitants in 1950 to 759 km^2 in 1990. Hosseini & Hajilou (2018) conducted a study in Iran on the drivers of urban sprawl in the urban areas of Iran whose results indicated that there were eight main factors causing sprawl, namely, population growth; land value; exterior pressure; land speculation; transportation policies; management system; political fragmentation; and land use systems.

2.2.2 Consequences of Urban Sprawl

Urban sprawl results in the consumption of valuable land as people continue to transform land from its natural state into built up, which then has significant impacts on the city's ecological environment. In addition, sprawling cities result in costly and inefficient public transportation thus having massive implications for the poor in these cities. The further people have to travel outside the city the more expensive it becomes to travel. Urban sprawl also results in an increase in air pollution because the further people move away from city; the more unreliable public transportation becomes, which results in people having to use private vehicles to commute into the city. This increased private vehicle usage also cause traffic congestion on the road infrastructure. Chemicals emitted by these vehicles settle on land surfaces, which eventually is washed into rivers thus affecting the water ecosystem (Kruger, 2017). The more a city sprawls, the larger the quantities of water and energy required for consumption (Yusuf

& Allopi, 2010). This then puts a strain on the city's resources. Urban sprawl results in ineffective land use that leads to the over consumption of valuable land minerals, and wetlands. The sprawling nature of cities usually means that there is more quantities of water and resources consumed than in compact cities (Dewar, 2000).

2.3 DENSITY & DENSIFICATION

The term density is a complex one to define because of the multitude of contexts in which it is used for in various disciplines (Cheng, 2010). This essentially means that there is no single overall definition for the concept. What further makes the concept complex is the way it calculated which often results in confusion of what density really is. Although the concept is often misunderstood, it can be easily defined as a ratio between two entities. In the Urban Planning domain, density is usually measured as the number of people, jobs, or housing units per land unit area (Litman, 2016). Residential density is often defined as the number of dwellings per hectare, which is usually measured as net or gross density. Net density is calculated by the number of dwellings on land use zones that are solely reserved for residential development (Flannery *et al*., 2015). This calculation takes into consideration private driveways but excludes public roads. In contrast, gross density can be referred to as the number of dwellings in a given area, which takes into consideration all other land-use types within the area (Flannery *et al*., 2015). It essentially includes land for non-residential in its calculation.

The way in which density is calculated determines the level of accuracy of the results. For instance, using gross density to calculate residential density can result in unrepresentative outcomes, especially in areas that are not designated for residential purposes. Net is often chosen to calculate residential density because it gives a more accurate snapshot of residential densities in residential areas. However, there are cases where the zone would be allocated for mixed land use, which often obscures the results. Another challenge with net residential density is the issue of informal settlements that pop up in zones not designated for residential use and these can easily be miscalculated. Furthermore, the accuracy of the net residential density would obviously depend on the accuracy of the delineation of the residential zones within the unit area. If the data is not accurate then the results will also be inaccurate.

2.4 DENSIFICATION AND COMPACTION

The densification and compaction concepts are not new in the planning field. The idea of containing urban sprawl through compaction and densification dates as far back as the

industrial age. The suburban parts of cities during the industrial age began to sprawl as a result of unhealthy and crowded city centres and also due to the increase in car ownership (Westerink *et al*., 2013). Urban sprawl during the time was contained in order to curb the rapid growth of the suburban areas. With challenges brought by sprawling cities, urban densification and compaction is often viewed as a solution for creating a more sustainable, inclusive and resilient urban form (Todes *et al*., 2018). Compaction and densification has become popular over the years among many international agencies and cities across the world, especially in Europe. The compact city concept is more than just densification of urban neighbourhoods. It also includes things such as urban containment, efficient land use, viable public transportation, lower car dependency, mixed land use, affordable travel costs, protection of the urban edge and the transitional land that separates urban from rural and the protection of the environment in general (Burgess, 2000).

Densifying urban areas through compaction unfortunately does not come without its debates. There are researchers that support the compact city idea and those that are against it. Those that support compaction and high density do so with the belief that it creates a more sustainable urban form with reduced energy consumption, reduced car emissions, less land consumption while still creating more liveable cities (Jabareen, 2006). Critics of compaction counter argue that the re-use of urban land may result in the decline of green spaces within the city and overcrowding as densities increase (Burton, 2000). Furthermore, compact cities are criticized for having undesirable social costs such as a poor quality of life, and are unlikely to have any environmental benefits (Westerink *et al*., 2013 and Anabtawi *et al*., 2016). Both sides of the argument are however, based on people's beliefs and not empirical evidence that would support any of these arguments. One of the major reasons for this is the variation in cities across the world, which makes it difficult to use a blanket approach for planning, as city settings are unique, and so should the policies that guide planning from these individual cities.

2.5 CITIES OF THE DEVELOPED WORLD

European and North American cities have been growing at an alarming rate, which has led to the growing awareness of urban sprawl (Dieleman & Wegener, 2004). Urban sprawl, which consists of low densities, outward expansion, spatially segregated land use and leapfrog type development is regarded as not conducive for the attainment of good quality of life (Burchell *et al*., 2000). As a result, since the 1990s the Commission of European Communities has been encouraging its member countries to adopt policies that promote compact cities in their spatial

development in order to reduce urban sprawl and its negative effects (Anabtawi *et al*., 2016). Randstad in Holland is one of the known examples of compact cities in Europe. It is known as the densely populated part of the Netherland. Elements of densification in the Randstad region were seen as early as the 1960s with formulation of the National Spatial Planning, which was included in the second report on Physical Planning for the Netherlands (Van der Burg & Dieleman, 2004). The focus of this policy was mainly on channelling urban growth into areas originally designated to accommodate this growth and to prohibit further growth in small rural settlements. The policy was successful in moving people into designated growth centres as about 500 000 people moved into these areas, which the saw a halt in urban sprawl between 1970s and early 1980s (Dieleman & Wegener, 2004). One of the attributing factors for the success of the policy was that urban growth focused on the redevelopment of brownfield sites and new greenfield sites that were located adjacent to built-up areas of the larger cities in the Randstad region. Cities in the developed world have been able to implement compact city policies with success because of their advancements in infrastructure, which often found to be lacking in the developing cities of the global south.

Hong Kong is another example of a city that adopted the compact city ideal. The move towards high-rise high-density development in the city was influenced by rapid population growth coupled with limited land resources (Zhang, 2000). Today, Hong Kong is known as one of the world's most compact city that is characterised by high development and population densities, mixed land uses and an efficient public transport system (Mahtab-uz-Zamam *et al*., 2000). To increase densities in the city, public housing has taken the form of high-rise, high-density development (Zhang, 2000). Compaction and densification in Hong Kong has been considered successful because it has not been accompanied by challenges such as societal dysfunction and physical deterioration that is often witnessed in high-rise estates in western cities (Mahtab-uz-Zamam *et al*., 2000). This has thus led to policy makers and urban planners continuing to produce high-rise and high-density development. Densification in Hong Kong has been successful because of its instrumental role in meeting urgent housing needs, in order to accommodate the growing population. Although high-density development is often associated with problems such as tensions, lack of privacy, identity problems and isolation, in Hong Kong these problems do not appear to have much impact on the resident's quality of life (Zhang, 2000).

In Germany, Munich being the third largest city is known for its high population density of about 4500 inhabitants per Km^2 (Thierstein & Schmidt, 2008).In terms of compaction and densification urban planning approach, Munich has been dubbed to as one Germany's success stories. The success of densification in the city can be attributed to urban development policies that have been aimed at addressing urban sprawl (Anabtawi, 2018). The city has been able to reduce the ratio of built-up area per inhabitant, thereby reducing the rate at which urban sprawl occurs. Findings from a study conducted by the European Commission (2014), which looked at land use change in a number of European cities, revealed that Munich has become more compact and more sustainable over the years.

Some studies in literature have sought to explore both the negative and positive sides of compaction in developed cities. An example of such a study is that of Burton (2002), which was aimed at examining the validity of pro-compact city claims that densification promotes social equity in the city. The study whose focus was on compact English cities, revealed that densification had the potential of influencing social equity in both positive and negative ways. Furthermore, compact cities had the benefit of improved public transportation, reduced segregation and people had better access to facilities. However, the negative side of compaction included the likelihood of high-density development reducing living space and the lack of affordable housing in the studied compact English cities.

2.6 CITIES OF THE DEVELOPING WORLD

Research has shown that although cities of the developing world have higher densities compared to those of the developed world, in the developing world cities have not become less compact with the observed decelerating population growth and the beginning of decentralisation (Richardson *et al*., 2000). Cities in the developing world are faced with the challenge of the lack of empirical data on the current density levels and trends in densification as well as the confusion that comes with how this densification is measured in order to inform policy (Dewar, 2000). High density development in many Asian and China cities is seen as a solution to the challenges of rapid population growth, however, there is growing concern that densification in China results in unintended social consequences (Wang & Shaw, 2018). This is evidence that there is no blanket approach for creating a sustainable urban form, thus each city should be dealt with uniquely.

In the case of India, land and housing are scarce resources, especially in cities such as Mumbai. The built-up density of Mumbai is approximately 43 570 people per square kilometre (UN Habitat, 2014). Urban development policies in Mumbai between 1960 and 1970 in Mumbai focused on reducing built-up densities in order to avoid overcrowding (Dave, 2010). Although this type of development increased sprawl, it was deemed necessary in order to avoid the potential effects of having an overcrowded city. The decision to promote low-density development was a questionable one due to the associated urban environmental problems. Today, Mumbai has population densities that are higher than built-up densities. Nallathiga (2007) argues that compaction in Mumbai is needed in order to address past policies that encouraged low-density development. Having the right policies in place is essential in encouraging smart growth and compaction in Mumbai. Although the compact city ideal is being encouraged globally, it is important that it is not at the expense of the environment nor should it compromise the quality of life of urban residents. With developing countries already facing high levels of density in their cities, it is important that Compaction is not used as a blueprint for development but rather to guide densification in a way that takes into consideration the local context. According to Nallatiga (2007), the containment of suburban sprawl by means of growth control would not be the way to go, but instead Mumbai should emphasise on having more responsive planning systems and flexible regulatory policies that will meet the city's needs.

With the global drive towards densification, there are cities that have needed deconcentration overtime. Egyptian cities are examples of this situation. According to Acioly (2000), Egyptian cities have had high levels of compactness. The inner cities were characterised by narrow roads and alleys, mixed land uses, compact buildings, which resulted in a very dense urban form. The type of development that occurred in these cities produced little to no space for amenities and open public spaces. It was not uncommon to find areas that have 100% coverage of the plot by high-rise informal buildings, which had negative effects on the health of residents. Arguably, the narrow roads within the city contributed to high levels of traffic congestion and inaccessibility of the city. This then led to the accumulation of garbage in the streets. To address these challenges, the government of Egypt embarked on a programme of urban restructuring in the city of Cairo and Giza where they began pursuing policies that focused on decentralisation and population deconcentration due to adverse effects of compaction. However, Acioly (2000) states that the plan failed due to government being unable to attract investment and people to the new areas of development.

Cities in the developing world are often built in areas that are prone to natural disasters or areas that are of high relief (Dewar, 2000). Densifying the already vulnerable cities thus pose a challenge to urban planners. Dave (2010) indicates that developing cities are faced with higher growth rates and are already highly populated. The argument made by researchers is that compact cities can thus be in no way transferable from developed cities into the developing world cities (Dave, 2010; Barger, 2016; Wang & Shaw, 2018). This is due to variations in in economic and social development that exists between developed and developing countries, which includes but not limited to low economic growth levels, high income inequalities, shortages of environmental infrastructure and basic service delivery (Dewar, 2000). All of these issues have significant impacts on the implementation success of the desired densification. Increasing densities that are already high in developing world cities means that the infrastructure is overloaded and there are more environmental problems such as an increase in pollution, which affects the residents' quality of life.

However, there are cities in the developing world that have had success in the implementation of compaction. An example of this is Curitiba in Brazil, which is known across the world as an environmentally friendly city with an urban area that is highly densified (Macedo, 2013). Densification policies in Curitiba began as far back as 1965 when the city put in place its first Master Plan whose focus was on encouraging decongestion and revitalization of the inner city (Acioly, 2000). The focus of the master plan was also on shifting from radial concentric to a more linear growth pattern, which allowed the city to expand further. Subsequently, government was able to implement one of the World's most successful and efficient public transportation system in the form of buses. Acioly (2000) further indicates that there was a promotion of mixed land use and higher population densities along various structural axes of the city. The success of Curitiba was built upon the maximisation and optimization of land, infrastructure and public investments in the city's policies.

2.7 DENSIFICATION IN SOUTH AFRICA

Densification in South Africa is often accompanied by questions about the viability of making SA cities compact and sustainable (Dewar, 2000). Although South Africa faces challenges in terms of the creation of a more sustainable urban form, like many cities in the developing world, South Africa's situation is unique due to the past apartheid legislations that formed the spatial structures seen today. The Apartheid legacy in SA contributed to the complexities that are seen in terms of densification patterns (Chobokoane & Horn, 2015). During the apartheid

era, all non-white racial groups were systematically moved to the edge of the settlements, which could be as far as 60km away from the city (Dewar, 2000). These areas at the edge began to grow, sprawling outwards due to patterns of immigration, and because of cheaper land prices found on the periphery. Coupled with segregation policies, modernist planning approaches in the country also encouraged low built up densities as well as the separation of land uses within SA cities (Todes *et al*., 2018). This then resulted in cities that were characterised by low densities, fragmentation and separation, with high densities mainly concentrated at urban edge in townships. At the edge of these townships, both formal and informal settlements existed. These types of settlements are often characterised by extremely high densities and a lack of basic services such as sanitation.

2.7.1 Informality and Densification

Informal settlements are not uniquely a South African but a global phenomenon. According to Marutleulle (2017), between 75% and 99% of the urban population in many African cities are found in what is known as slums/informal settlements. StatsSA (2011) reported that on average, 12% of South Africa's urban households lived in informal housing, with Gauteng having the highest proportion of 20%. These settlements are usually found in hazard prone areas such as floodplains, and tend to grow at an accelerated rate. Planners in the developing world are thus often faced with the challenge of providing for these growing informal settlements, with limited success due to the lack of funding. Failure to accommodate and cater for these informal settlements results in bad land use patterns and conditions that are neither socially, economically nor environmentally favourable (Campbell, 1983).

2.7.2 The Sprawled Nature of South African Suburbs

Much of the growth that has been witnessed in African and international cities over the years has been occurring on the periphery of the city (Todes, 2014). Prior to 1994, South African cities were structured in a segregated manner in order to prevent any form of movement of other racial groups into the white areas. This resulted in the settlement of the marginalised population on the city's periphery in high densities. The end of the apartheid era brought democratic transition that led to the unprecedented growth of SA cities, which was associated with major implications on spatial planning, thus affecting social service delivery, infrastructure development and environmental degradation (Odindi *et al*., 2012. Since the end of the apartheid era, the SA government has been on a mission to transform social segregation,

injustice and inequality (South African Cities Network, 2016). Although there have been some successes with implementation of redress strategies, the public sector investment has not been able to result in a more equitable, inclusive and integrated city. The current urban form is regarded as unsustainable because of its intensive consumption of resources, infrastructure backlogs, urban safety challenges, and youth unemployment in cities. The sprawling nature of SA suburbs has posed a challenge for the provision of efficient and inclusive public network and the reduction of emissions (South African Cities Network, 2016). The freestanding housing type that seems to be a trend in SA suburbs has resulted in low-density development and longer travelling distances as people continue to move away from the city centre. Being far away from the city and having low densities means that people are faced with public transport accessibility problems (Pernegger and Godehart, 2007).

South African suburbs are known for their low average residential densities. The population distribution in SA cities is also highly uneven with higher densities in townships and informal settlements than in the suburbs. For example, in Cape Town, the average population density is 39 inhabitants per hectare but it varies between 100 and 150 in informal settlements and 4 to 12 inhabitants per hectare in the former white suburbs (City of Cape Town, 2009). This enormous imbalance poses a challenge in economic, efficiency and social justice because it hinders labour and housing market interactions, transport networks and economic service delivery in the densified areas (SACN, 2016). The low density living in suburbs are costly to the provision of public transportation and other infrastructure resulting in a city that is more car-based. One of the contributing factors to the sprawling nature of suburbs in SA was the construction of major highways between the 1960s and 1980s (SACN, 2016).

2.7.3 South African Legislative Framework on Densification

South Africa began focusing on creating a more compact urban form almost 30 years ago when Government formally committed itself to compaction policies that were aimed at discouraging urban sprawl and promoting a more compact urban form (Chobokoane & Horn, 2015). The argument for compaction and densification in South Africa was that there was a need to reduce movement, reduce air pollution and create walkable cities. Dewar (2000) suggests that policies on densification and compaction were necessitated by three interrelated factors, namely: employment creation, walkable cities and public transportation. Compaction was required for employment generation due to relatively high unemployment rates in cities, which resulted in people relying on self-generated income from small businesses. The ability for these businesses

to thrive depended on how agglomerated and intensive the market was if very intensive, low-income households could outsource many of their functions at a much cheaper rates rather than letting the household doing every function. This would thus create employment opportunities for the rest of the residents. The second factor was creating walkable cities where people would be able to walk to places of interest. Thirdly, compaction came because of the need to resolve problems that were facing the cities' public transportation systems. The current sprawling nature of SA cities creates a situation where there is high movements of people during peak hours and then these numbers fall drastically during off-peak, thus rendering the provision of larger capacity public transport such as trains non-viable (Dewar, 2000). Thus, appropriate policies need to be implemented in order to achieve the desired sustainable urban form in SA cities.

Compaction and densification are crucial elements of urban policy in the post-apartheid era. The focus of these policies has been on infilling and densification around transport corridors and important urban nodes (Todes *et al*., 2018). There have been numerous policy guidelines that have been put in place to promote a more compact and densified urban form in South Africa. These policies date as far back as 1995 where the then new government committed itself to compaction policies with the publication of the Development Facilitation Act no 63 of 1995 (Republic of South Africa, 1995). Other plans and policies include Growth, Employment and Redistribution of 1996; the National Growth and Development Strategy; the draft National Spatial Development Perspective; the Green Paper on Spatial Planning which served as the foundation for the production of the Spatial Planning and Land-use Management Act 16 of 2013; the Urban Development Strategy and the Urban Development Framework (Chobokoane and Horn 2015).

Amongst the many policies, the White Paper on Local government was significant as it paved the way for the country's Municipal Systems Act. This Act requires that all municipalities in SA have an Integrated Development Plan (IDP), which guides all planning budgeting, management and decision making in municipalities (Chobokoane & Horn, 2015). Part if the requirements of this Act is that every IDP needs to include a Spatial Development Framework, which sets out guidelines for land use management. According to Dewar (2000), the first systematic attempts to deal with compaction and spatial structural readjustment in the republic were those found in the City of Cape Town's draft Municipal Spatial Development Framework

(MSDF) in 1999. This plan recognised that the concept of accessibility was key to making a more compact, equitable and integrated city (City of Cape Town, 1999).

Currently, the number of legislative and institutional frameworks, Acts and policies that come from both National and Provincial Government set out guidelines for the restructuring of SA cities. One of these is the National Spatial Development Perspective (NSDP), which came as a realisation that national investment and development programs were not only misaligned between the different spheres of government but also the inability of these programs to address past apartheid spatial economies. Thus, the aim of the NSDP was to address these two challenges.

2.8 DENSIFICATION IN THE CITY OF TSHWANE

The City of Tshwane has over the years shown a sprawling developing pattern, especially along the east and south of Pretoria. This has been a result of the decentralization of the private sector from the Central Business District (CBD) into suburbs, thereby creating basic office nodes in the Metro's municipal area. The movement of the private sector from the CBD was a result of poor public transportation in the city, which lead to an increase in the use of private vehicles. As the number of private vehicles into the city increase, so did congestion due to limited parking space available in the CBD. Furthermore, the cost of renting space in the CBD was higher than at the periphery, which made sense for businesses to move to the east and South of the city where land was cheaper. Pretoria East as an economic node has grown at an accelerated rate compared to the CBD's relative decline (Badenhorst, 2002). This resulted in more development occurring in the eastern part of the city. The availability of cheaper land and a vibrant property market that occurred between the 1970s and 1980s fuelled the movement and development in the east (Badenhorst, 2002). The development of the Menlyn Shopping Centre also saw the migration of retail, office and other development from the CBD to areas around the mall. Badenhorst (2009) claims that in fact Menlyn has replaced the CBD as a retail centre for those who reside in the Pretoria East. However, the type of development that continues to occur in the east is that of low-density which encourages sprawl. According to Badenhorst (2002), Pretoria East is characterised by mostly single detached housing with stands ranging from 800m^2 upwards.

The cost of urban sprawl in the Metro and its associated low densities need urgent attention. According to City of Tshwane (2018), due to the limitations in the provision of new bulk

infrastructure, it is critical that the use of existing infrastructure is maximised. In order to do this, the city needs to focus on intensification and densification of the current urban land use through compaction strategies that promote infill. Although densification through infill is a sound development principle, the city itself has noted that most of the existing developed areas were previously developed in a way that did not plan for higher densities. Therefore, the current bulk and road infrastructure cannot accommodate additional population (City of Tshwane, 2018). This then requires the City to have a holistic approach that seeks to support a better public transport system and the provision of urban services. Ideally, densification should be as close as possible to the CDB; close to municipal core areas and services; and closer to areas where people can access jobs and facilities (City of Tshwane, 2018). One tool that has been used to control urban sprawl in the city is the urban edge. The implementation of the urban edge is hoped to assist in protecting valuable environmental areas and promote the use of existing infrastructure through redevelopment and densification through infill. Having the urban edge in place also has the advantage of allowing for agglomeration of businesses to form one primary node.

2.8.1 City of Tshwane 2005 Compaction and Densification Strategy

In 2004, the City of Tshwane (CoT) began a multiple phased project that was aimed at densifying the city's municipal areas. The first part of the project was aimed at giving the city information on local and international trends on residential densification. The second phase of the project was what is today known as the city's Compaction and Densification Strategy (CDS) of the year 2005, which was aimed at addressing the need for densification and compaction in the Municipal areas. CDS is guided by both national and provincial legislative frameworks, which set out the guidelines on the objectives of CDS. At provincial level, the Gauteng Planning Development Act of 2003 guides CDS with many principles, which one of them is to promote a more compact development of urban areas and to limit sprawl, thereby protecting agricultural resources and further optimising the use of existing land. The CoT's strategy came in to effect due to the need to address questions that arose concerning development in the municipal area. The aim of CDS was to address how residential development can be attended to in order to create a more efficient, equitable and sustainable city (City of Tshwane, 2005). The rationale behind densification in CoT stems from the need to manage spatial growth in a way that creates a sustainable form, increases efficiency and creates cost effectiveness. Furthermore, this densification seeks to increase convenience and a better quality of life for all CoT citizens. There was the need to increase population thresholds

in order to allow for economic growth and create an environment for business to grow in specific areas within the municipal areas.

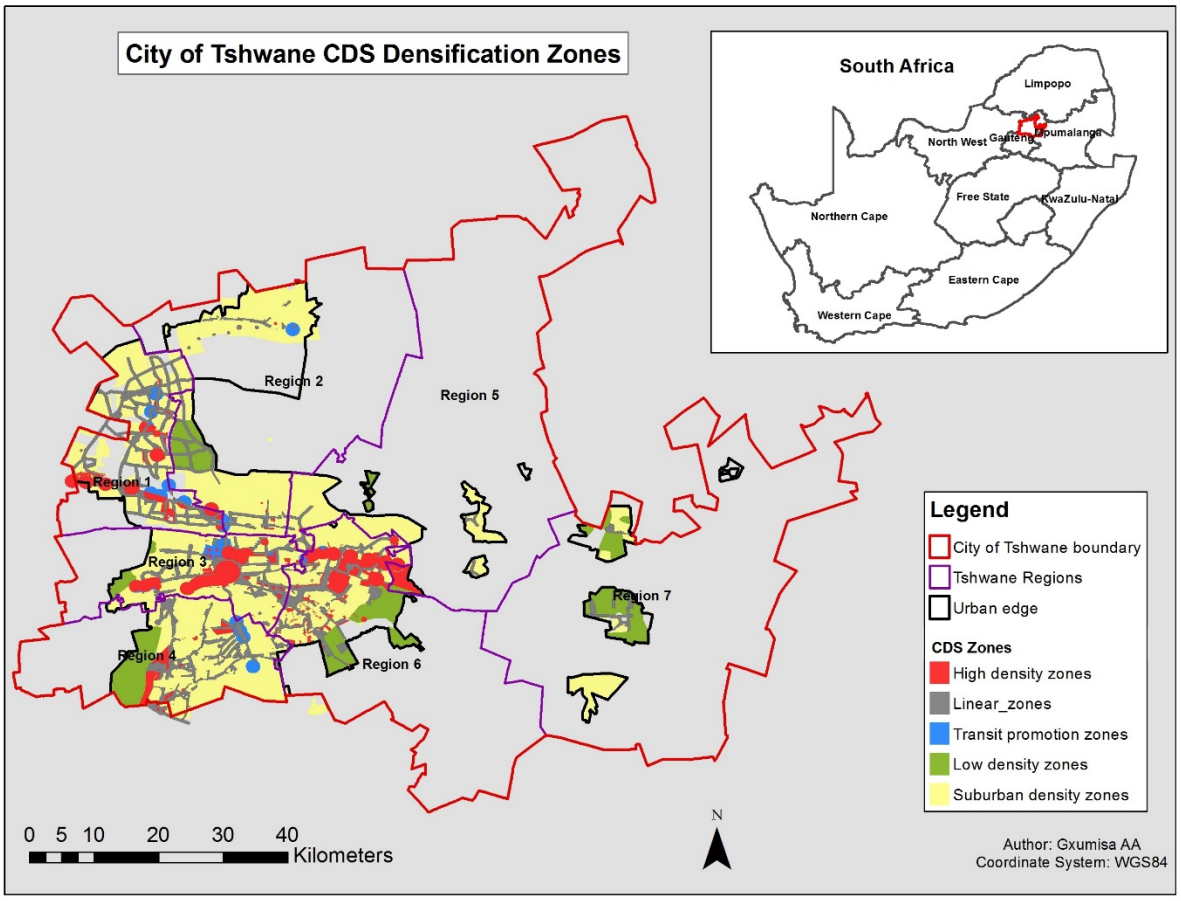

Figure 2: City of Tshwane CDS densification zones.

Amongst many outcomes, densifying the city is expected to reduce the ecological footprint of the city, prevent urban sprawl that destructs agricultural land. Moreover, increasing densities would not only increase public transport use but also create a walkable city where there would be less private vehicle usage. CDS outlines four key density zones: concentration zones, linear zones, suburban densification zones and low-density zones (Figure 2). No zone should be looked in isolation but all as one because they speak to each other (City of Tshwane, 2005). Concentration zones are characterised by high-density zones and transit promotion zones. High density zones in the metro are the primary areas of focus of the city's CDS, which is characterised by medium to high residential density developments centred at nodes deemed important for the city. The densification would thus be centred around major urban areas with a wide variety of activities including economic, entertainment and other services. Transit promotion zones are zones found around transport nodes such as train station and major

highway interchanges. Increasing densities around transit nodes would not only bring services closer to the people but also increase public transport feasibility. Linear zones in CDS refers to areas next to major transport routes that usually accommodate large volumes of traffic to concentration zones. Suburban densification zones are those currently with low densities but have potential to be mildly densified through methods such as subdivisions and cluster housing. These need to be located closer to employment, transport routes and major shopping centres. Finally, Low density zones that exist within the municipal area which are typically characterised by high-income earners that have houses with large stands and single dwelling houses. In these zones, there is limited access to public transportation. These zones are considered an exception to densification because low densities are actually more desired in these areas either due to spatial location or *due to bona fide* (City of Tshwane, 2018). The maximum densities per zone are illustrated on Table 2.

Table 2. Allowed densities for each zone and distances (City of Tshwane, 2018).

Zone	**Density**	**Distance**
1. Concentration zones: a). High density	> 200 units/hectare	< 500m walking distance
b). Transit promotion zones	>120 units/hectare	between 500m and 800m to public transport
2. Linear	80units/hectare	± 200m walking distance from public transport
3. Suburban densification zones	< 25 units/hectare	25km radius of CBD
4. Low density	< 10 units/hectare	-

2.8.2 Densification and the Cost of Infrastructure in City of Tshwane

Many development policies in South Africa promote densification and compaction in an effort to discourage the sprawling nature of SA urban areas. Many researchers have argued that increasing densities over a smaller land area does not only help limit sprawl but it also lowers the cost of public service provision due to shorter distances and economies of scales due to agglomeration (Biermann, 2000). However, the challenge with the compact city ideal that has persisted over the years is that both arguments that are pro and against compaction seldom include service-engineering cost. The cost of engineering infrastructure should be a critical component in aiding the decision of the urban form that would best suite a location but this is often disregarded. Policies will stipulate their densification targets without considering the capacity of things like bulk service and road infrastructure.

Biermann (2000) conducted a study a study in what previously known as the Greater Pretoria Metropolitan Council area, which comprised of Centurion, Pretoria and the Northern Pretoria. The aim of the study was to illustrate what happens when infrastructure costs are included in densification. The study incorporated water, electricity and sanitation infrastructure in high, medium and low-density scenarios. From the results of the study, it was evident that compact development in the form of infill in areas that were closer to the city centre was not necessarily a sustainable option in terms of cost efficiency compared to peripheral areas. Furthermore, increasing densities in the metro did not necessarily reduce the per capita cost of infrastructure. In terms of water distribution, the results indicated that at low densities the cost per capita of infrastructure in some peripheral areas was higher. Keeping density constant resulted in the cost for sewer networks being higher on the periphery in some areas but relatively low in the eastern part of the Metropolitan area. In essence, Biermann (2000) proved that increasing the number of people would require additional infrastructure, hence the total cost of infrastructure increased with higher population densities for all types of infrastructure. According to the results of the study, the cost of infrastructure in the high-density scenario could potentially increase by 200% percent more than in low density, while low density to medium density scenario would increase by over 100 and medium to high density would increase by just over 50% (Beirmann, 2000). As argued by researchers (Glover & Simon, 1975, Siedentop & Fina, 2010 and Helcombe & Williams, 2008), the study concluded that bulk infrastructure costs do not simply decrease as density increases.

2.9 CHAPTER SUMMARY

The world's urban population has been growing at unprecedented rates. This growth is due to people migrating from rural to urban in search for better opportunities. The more the urban population grow, the greater the negative affects not just the environment but also the social aspect of urban areas. Thus, it becomes important that planners and policy makers put forward strategies that will deal with this growth and creating sustainable cities. Central to the sustainability urban form ideal, planners and policy makers have over the years opted for creating compact cities. Making cities compact requires that densities are increased but in a way that creates efficiency and improve the residents city of like. Like many cities in the developing world, South African cities have adopted compact city ideal and an example of this is the City of Tshwane's 2005 Compaction and Densification Strategy, which is aimed at increasing densities in the city in order to prevent urban sprawl. This chapter therefore elaborated on the need for densification and how the CoT plans to densify its municipal area.

3. METHODOLOGY

This chapter describes the materials used to achieve the objectives of the study. This study followed the policy evaluation approach. According to Mouton (2011), the aim of a policy evaluation study is to answer the question of whether an intervention implemented in the form of a policy or strategy has been successful in achieving its expected outcomes or not. Spatial planning policies or plans are usually based on a diagnosis of a problem that requires intervention. In the case of this particular study, the implementation of the City of Tshwane's 2005 CDS was through the realization that the city needed to limit urban sprawl by implementing policies that promote densification and compaction.

According to Segura & Pedregral (2017), spatial planning is a continuous process that requires evaluation, monitoring and review in order to ensure policy effectiveness. Continuous evaluation and monitoring is important because it allows policy makers to identify areas of improvement. One way of ensuring policy improvements is by measuring its effectiveness overtime. Segura & Pedradral (2017), further argue that it is often difficult to isolate the impact of spatial planning policies from other public policies because these are often interlinked and there is often the challenge of the lack of data in many cities. The measurement of policy effectiveness is also difficult to measure because there is no one standard way of doing so and planning activities are usually complex.

Faludi (2000) laments that the evaluation of spatial planning policy is not just a matter of measuring outcome, but also the type of evaluation required for each plan should depend on the assumptions made about the plan, its function and the purpose thereof. Rather than focusing on the policy's material outcomes, Faludi (2002) suggest that the focus should be more on the role policies play in assisting decision makers make sense of planning situations. The question then becomes; what is the best approach to evaluate spatial planning policies if not based on outcomes? The best way to measure the quality of a policy should rather be in terms of its performance in facilitating decision-making. Thus, the aim of this study was to first look at the residential density changes that have occurred in CoT between 2010 and 2018 and then evaluate the impact of CoT's 2005 CDS on the observed changes.

The data used for analysis, the pre-processing of the data and the analysis of the data are described in this chapter. The pre-processing stage involved reprojecting the data to ensure that it was within the same coordinate system. Thereafter the actual analysis could begin in ArcGIS.

The results obtained from the spatial analysis in ArcGIS were further taken into IBMS SPS statistics in order to answer questions that were set out in the beginning on the study using statistical analysis tools. The questions addressed by the analysis part of the study were: how has residential and population densities changed over the years; what was the relationship between changes in residential and population densities; and what impact had the CoT CDS had on the observed residential density changes. Figure 3 provides a summary of how the research objectives were met.

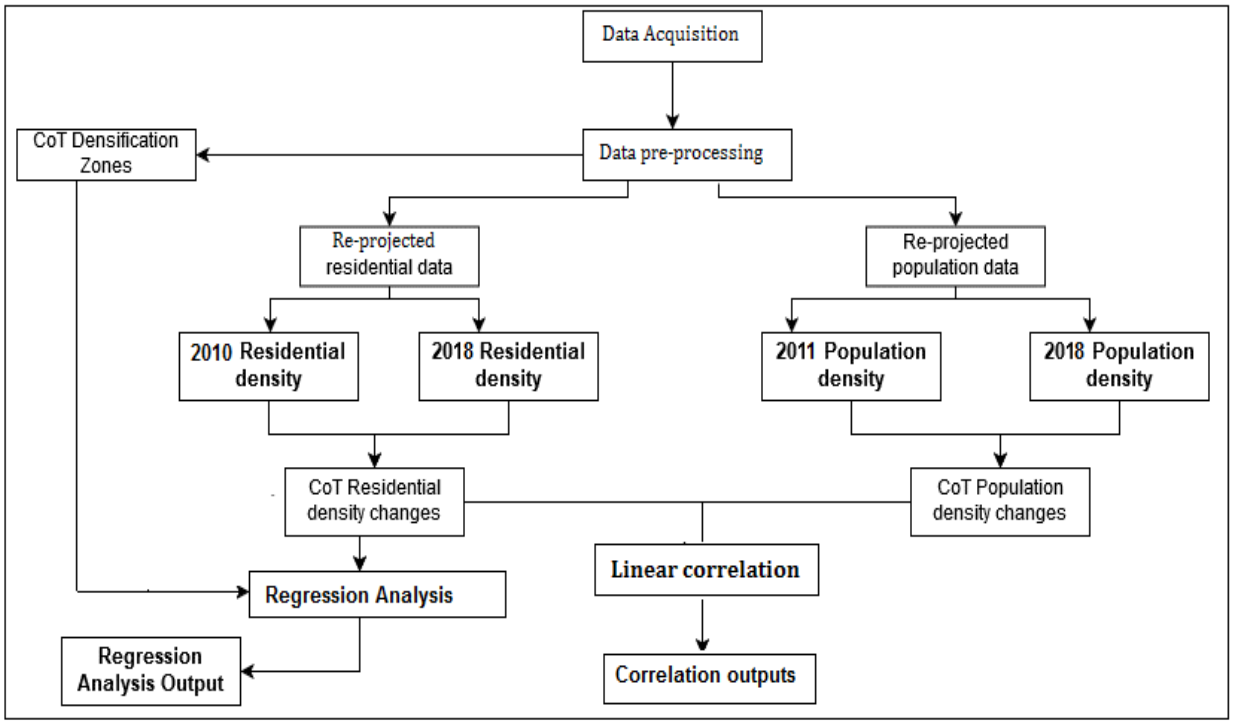

Figure 3.Methodology

3.1 DATA

The secondary data used in this study includes two sets of residential building points for the years 2010 and 2018 from GTI, population data at EA level for 2011 and 2018 from StatsSA and GTI, respectively. These years for both residential and population data were chosen due to the availability of data. The third secondary data set used was a shapefile of the municipality's EAs obtained from the 2011 StatsSA census. The fourth dataset used was a shapefile of all the areas specified by the CoT as their priority zones for the CDS.

3.2 DATA PRE-PROCESSING

When working with GIS data, it is important that all datasets are subjected to pre-processing before any form of analysis can be done on the data. The data was therefore reprojected into the World Geodetic System of 1984 (WGS84) before analysis could be undertaken. Reprojecting is important because it allows the data to be in the same coordinate system thus making it comparable with each other. The focus of this study was solely on the CoT municipal area therefore, only the EAs that fall within the city's boundary were selected for further processing. Based on the 2011 census data from StatsSA there was a total of 5233 EAs in CoT and this number was kept consistent in the processing of both residential and population data, in order to ensure comparability between datasets.

3.3 DATA PROCESSING

The first important step of the processing was to first calculate the area of the EAs in hectares. This area would be then used to calculate both residential and population densities in CoT at EA level

3.3.1 Residential and Population data

A spatial join was performed between the EAs shapefile and the residential points in order calculate how many residential buildings were in each EA. This was done for both 2010 and 2018 residential points. Thereafter gross density was calculated for both years using the following formula:

$$\text{Gross residential density} = \frac{No.of\ building\ in\ EA}{Area\ of\ EA\ (ha)}$$

The population data was also spatially joined to the EA data in order to calculate the population density for both 2011 and 2018. The gross density was calculated in people per hectare using the following formula:

$$\text{Gross population density} = \frac{No.of\ people\ in\ EA}{Area\ of\ EA\ (ha)}$$

Thereafter maps we created for each scenario with density values classified in geometric intervals.

The changes in residential densities between 2010 and 2018 were calculated using the following formula:

$$2018\ residential\ density - 2010\ residential\ density$$

From the output values, there were five types of areas identified: areas where there were increases in densities, areas where densities neither increased or decreased, areas there densities declined, areas that had zero densities for both years, and areas that previously had no buildings in 2010 but now had new building in 2018.

Population density changes were also calculated between 2011 and 2018 using the following formula:

$$2018\ population\ density - 2011\ population\ density$$

Similar to the residential density changes output, population changes were also classified into five different classes: increase density, no change in density, decline in density, no population and new population for 2018.

3.3.2 Statistical Analysis

A statistical analysis in the form of simple linear correlation was conducted to assess the type of relationship between population and residential density changes. Furthermore, a linear regression test was conducted between residential changes and the CoT strategy to assess the impact the CDS had on the observed residential densities. In this instance the CoT CDS was the independent variable and residential density changes was the depended variable that receives the influence. This analysis test was used to either reject or accept the study's null hypothesis.

4. RESULTS

4.1 INTRODUCTION

The main aim of this chapter is to describe residential and population density changes that took place between 2010 and 2018, and 2011 and 2018 respectively. This chapter presents the main findings of the research project and provides a description of these findings. The findings shall be discussed in Chapter 5.

4.2 RESIDENTIAL DENSITIES IN CoT

Table 3 gives a summary of the increases in different categories of residential buildings for the city of Tshwane in 2010 and 2018. Figure 3 graphically represents the percentage growth of each of these classes. The growth results from Table 3 indicate that the informal building type had the highest increase in the number of buildings (74.53%) between 2010 and 2018. The security villages and estates class followed the informal class with a growth of 41.01% and 26.71%, respectively. The results further show that the formal free-stand housing type also increased during the study period, at 11.98%, which is almost equal to the 11.24% growth seen in backyards over the same study period. Rural worker housing and small farm holdings had the lowest growth, with 3.46% and 0.61% respectively. The clusters/complexes class was the only one with a negative growth. The results showed that clusters/complexes declined by 7.25% during the study period.

Table 3: Summary of the different GTI building land uses in Tshwane

	Buildings 2010	Buildings 2018	Growth (%)
Formal	373302	418015	11.98
Clusters/complexes	4952	4593	-7.25
Estates	9359	11859	26.71
Security Villages	13632	19223	41.01
Smallholdings/Agriculture	15497	15591	0.61
Rural workers housing	5063	5238	3.46
Informal	166472	290545	74.53
Backyard	124780	138802	11.24

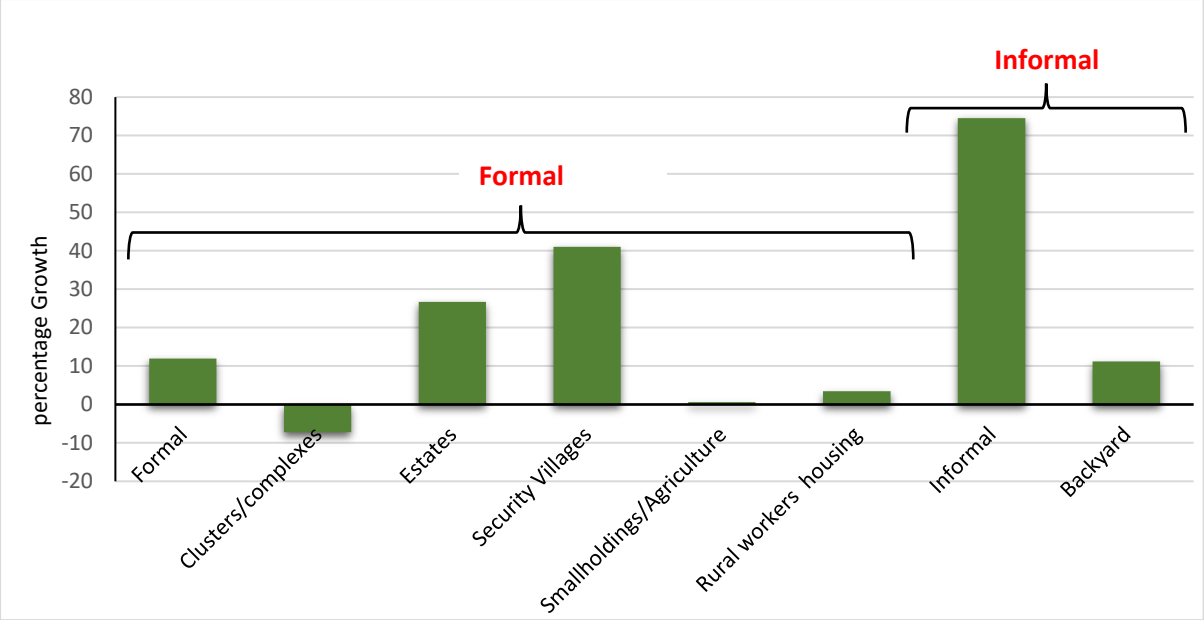

Figure 4: Growth in residential buildings between 2010 and 2018 in Tshwane.

The classes were further grouped into formal and informal classes as shown in Figure 4. The results of the absolute growth on Figure 5 for these two major classes indicates that the informal class had the highest growth between 2010 and 2018, growing from 291 252 buildings to 429 347, respectively, which is a growth of 47.4%. The formal class on the other hand grew from 421 805 residential buildings in 2010 to 474 519 in 2018, which is only a 12.5% growth.

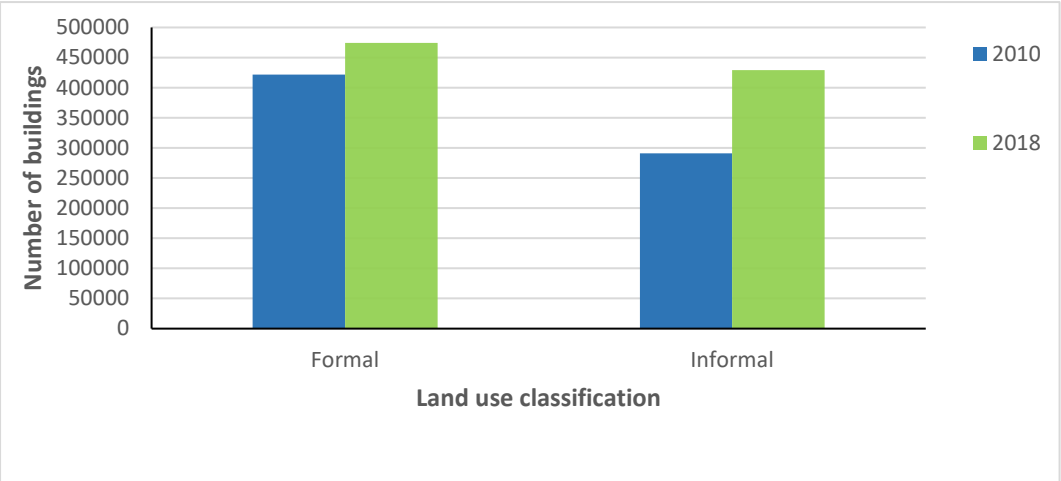

Figure 5: Absolute formal and informal residential building growth in Tshwane between 2010 and 2018

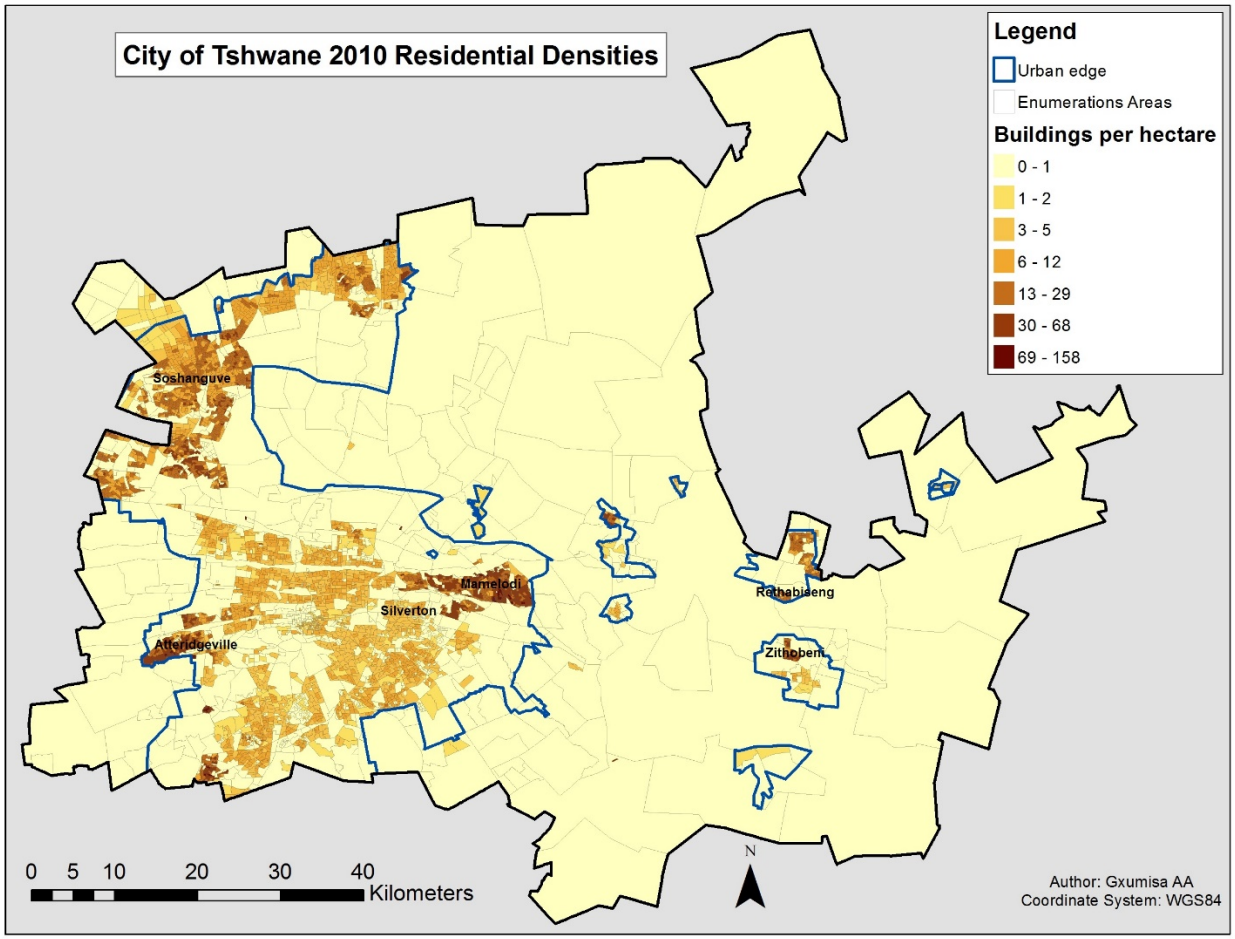

Figure 6: City of Tshwane 2010 residential density

Figure 6 graphically represents the residential densities in City of Tshwane for the year 2010 at EA level. The areas with the dark brown colour were those with the highest densities and those with the light yellow were low-density areas. From the map, it can be observed that the highest density (density between 68 and 158 buildings per hectare) areas were located in the eastern part of the map around the Mamelodi area, on the western part of the metro in areas like Saulsville and Atteridgeville, and on the north-western parts of the metro around the Soshanguve area. Medium densities areas with a density between 6 and 12 buildings per hectare were found around areas such as Garsfontein and Silverton in the east, Akasia in Pretoria north and townships such as Zithobeni and Rethabiseng in the far eastern parts of the metro. Low-density areas with densities between zero and one building per hectare showed a wide distribution throughout the metropolitan area. These low density areas were mostly located on the northern and eastern parts of the city's municipal area.

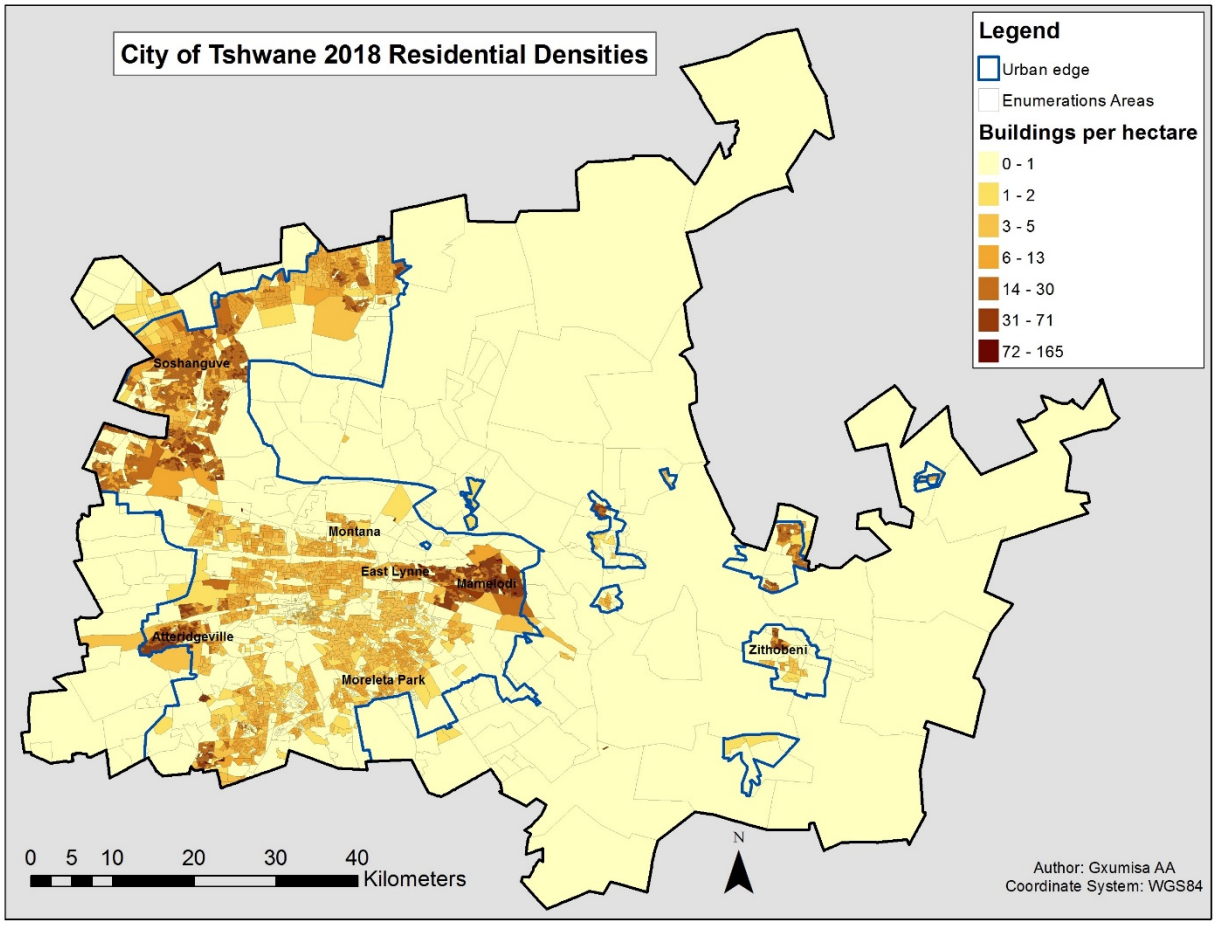

Figure 7: City of Tshwane 2018 residential density

Figure 7 gives a visual representation of the residential building densities in City of Tshwane for the year 2018. The darker brown colour represents high-density areas and the light yellow colour represents areas of low density. From the map, areas with the highest densities had density values between 72 and 165 buildings per hectare. These high-density areas included areas such as Mamelodi in the eastern part of the city, Atteridgeville in the western parts, and Soshanguve in the north-western part of the city. Medium densities ranged between 6 and 13 buildings per hectare and these included areas such as Soshanguve, Montana and Sinoville in the northern parts of the city, and Zithobeni, Moreleta Park and East Lynne in the eastern part of the city. The low-density areas ranged between zero and one building per hectare. These low residential density areas were distributed throughout the city, being most prominent in EAs around the northern and eastern parts of the city's metropolitan area.

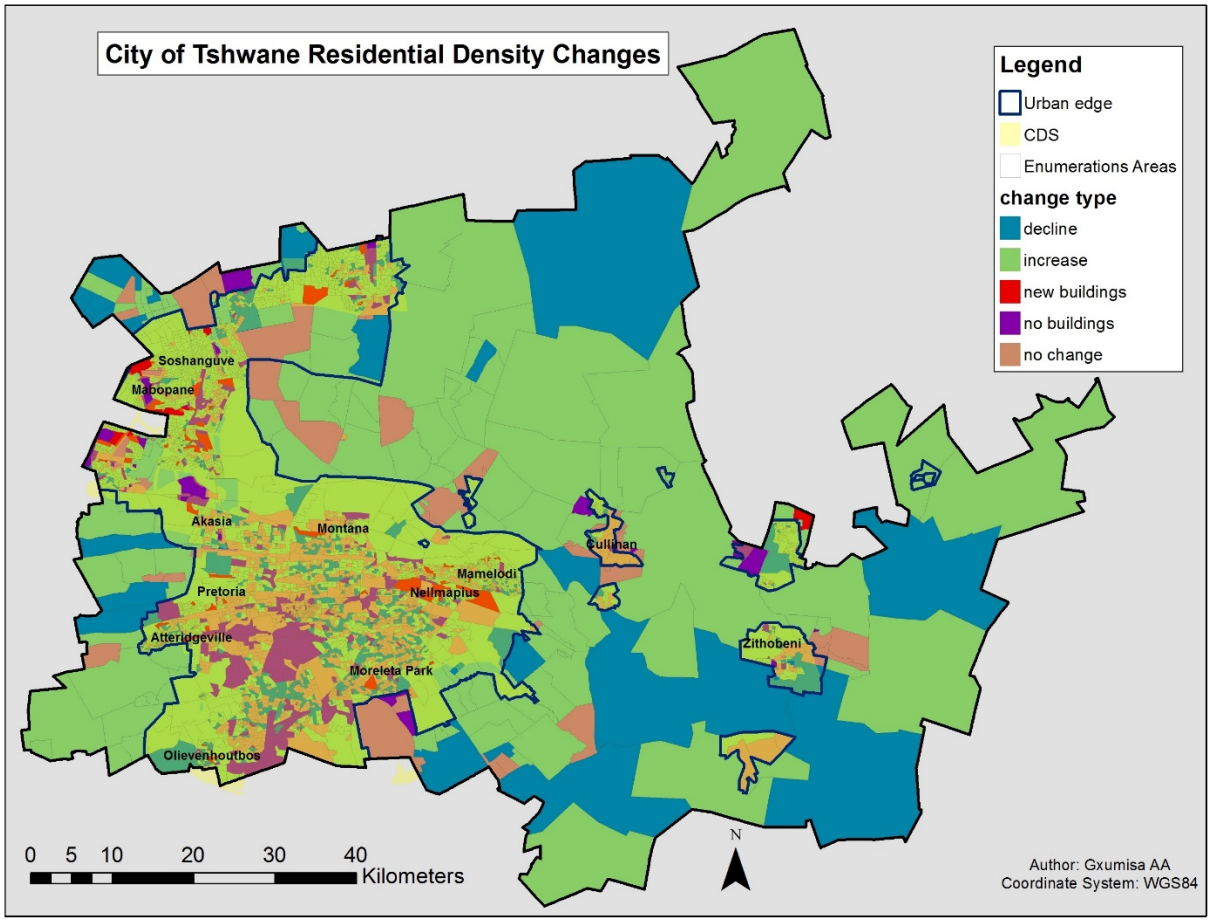

Figure 8: City of Tshwane residential Density changes between 2010 and 2018

The results from the change analysis are presented in Figure 8 above. From the results, there were five types of changes in EAs identified. The blue areas were EAs that had a decline in density between 2010 and 2018. The colour green represents EAs that have had an increase in residential densities during the study period. Significantly, the areas that showed an increase in densities are not necessarily those around the inner city. Areas that previously had a density of zero but gained a new density in 2018 are represented by the red colour on the map. The purple colour represents EAs that had no buildings in 2010 and 2018, thus a density of zero buildings per hectare for both years. Enumeration areas that had densities that remained constant between 2010 and 2018 are represented by the brown colour. The yellow colour shows the location of the densification zone.

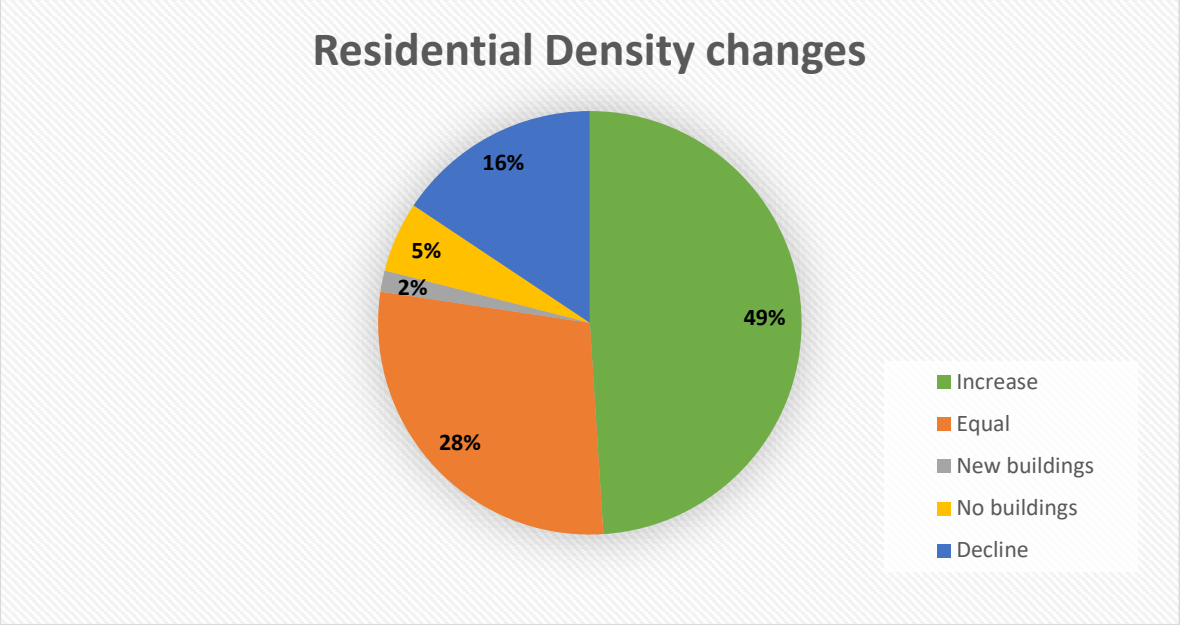

Figure 9: Percentage (%) of each residential density changes class

Figure 9 gives the percentages of each of the identified changes in the city. From the results, the proportion of EAs that had an increase in residential densities was 49% of the total EAs in the study areas. According to the map in Figure 8, these EAs were present for the most part of the city in both informal and formal residential areas. Those that had a decline in density accounted for 16% of the total. From the map, it can be observed that areas with a decline in density were located in the northern parts of the city and dominant around the Centurion area. The results further show that only 5% of the EAs had no residential buildings for both 2010 and 2018. These were EAs around Akasia, Soshanguve, and Mabopane in the north of Pretoria; Cullinan, Silverton and Scientia in the eastern part of the city; and around Pretoria central. The change class that had the lowers residential densities was that of EAs which previously had a density of zero in 2010 but this increased in 2018. This New Buildings class accounted for 2% of the total EAs in the city. These EAs were located in areas such as Mabopane, Ga-Rankuwa and Soshanguve in the north; Saulsville in the west; Mamelodi and Nellmapius in the east and Olievenhoutbos in the south of the city. The city also had EAs whose densities remind constant during the study area. These areas accounted for 28% of the metro EAs and were spread throughout the metro but mostly dominant in areas such as Faeri Glen and Garsfontein in the east, Sunnyside in Pretoria central, and around the Pretoria West area.

4.3 POPULATION DENSITIES IN CITY of TSHWANE

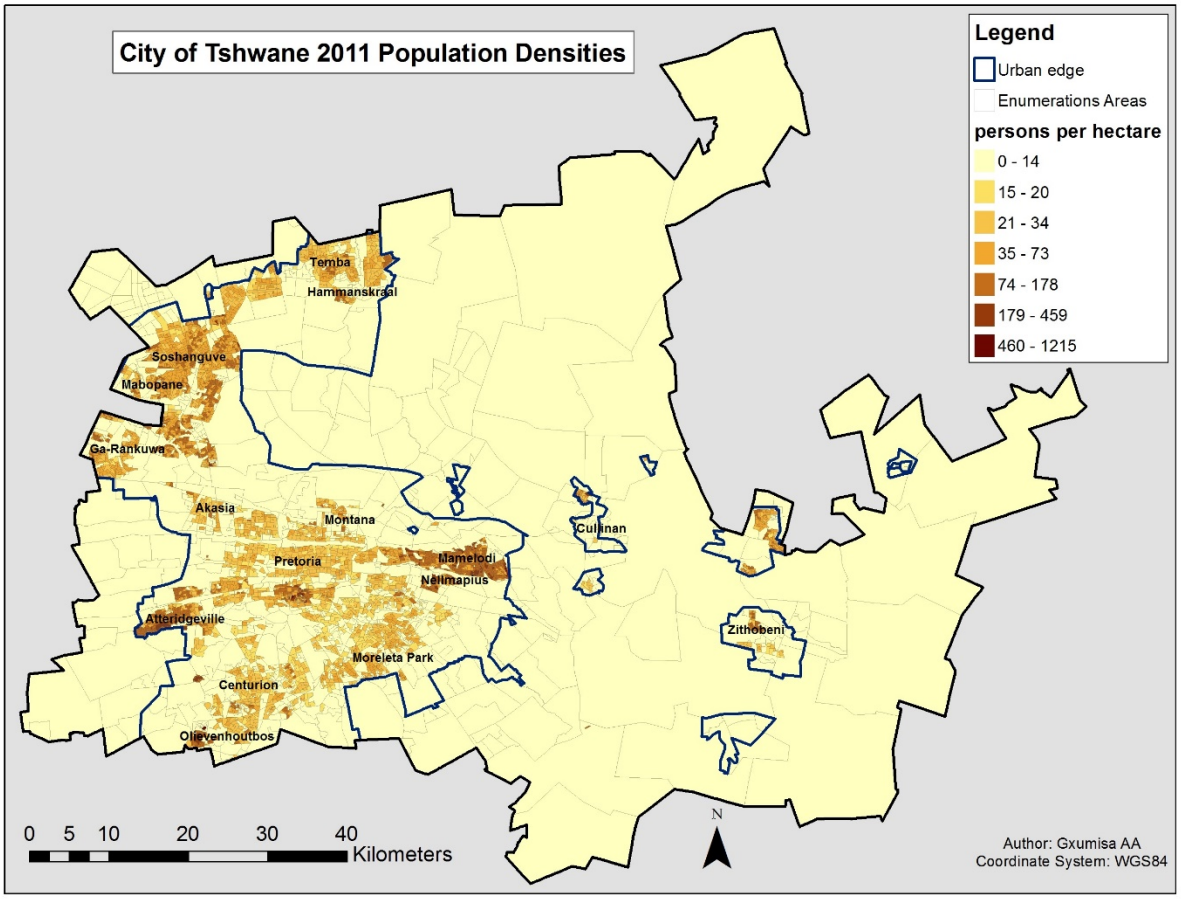

Figure 10: City of Tshwane 2011 population density

The map in Figure 10 gives a visual representation of the population densities in Tshwane for the year 2011. The dark brown colour represents EAs with the highest population density and the light yellow colour represents areas with low population densities. From the map, the high-density areas (density between 460 and 1215 people per hectare) were located around the Mamelodi, Sunnyside and Olievenhoutbos areas. Medium density areas were those that had a density range between 35 and 73 people per hectare. These medium density EAs were located around Winterveldt, Zithobeni, Ga-Rankuwa, parts of Mamelodi and Centurion. The map further shows that low density EAs, which had a density between 0 and 14 people per hectare, were widely distributed throughout the city.

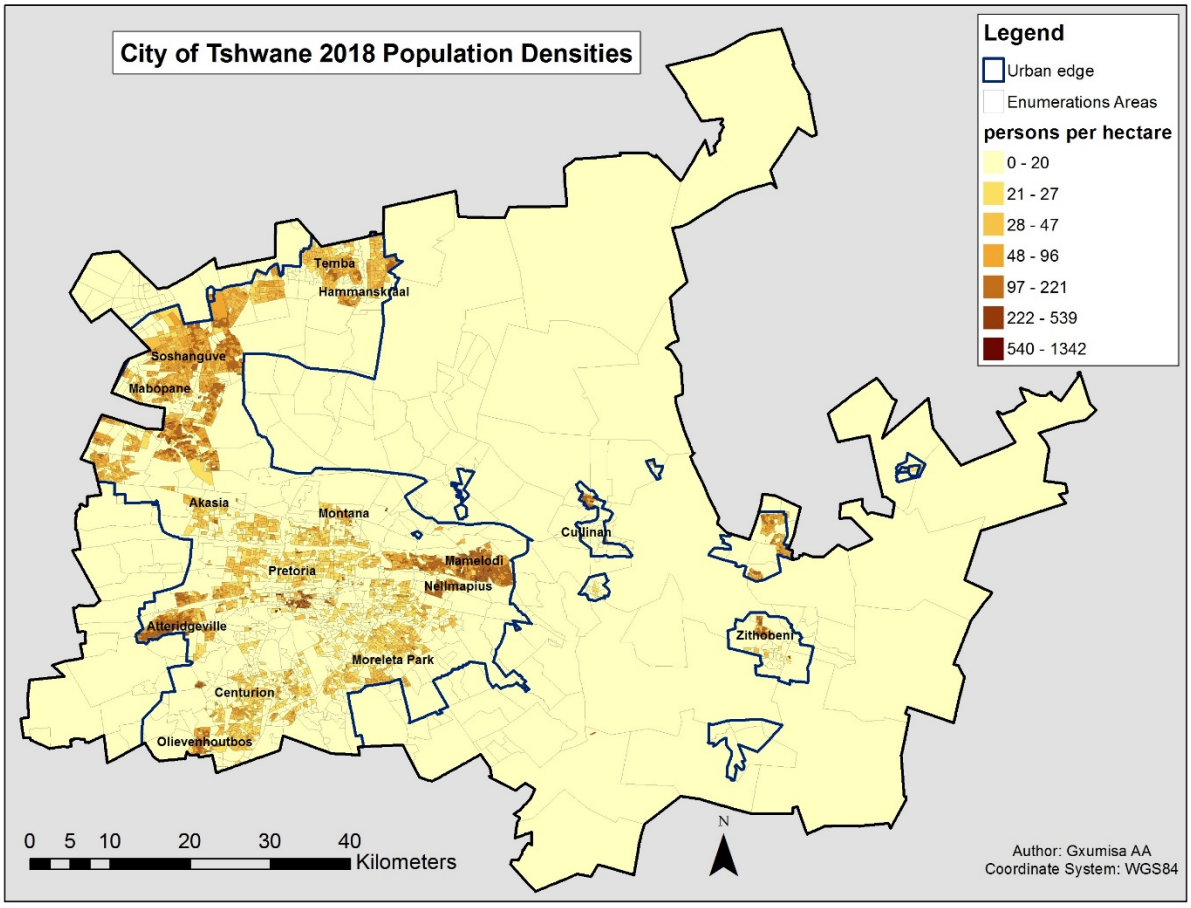

Figure 11: City of Tshwane 2018 population density

Figure 11 gives a visual representation of the 2018 population densities in CoT calculated at EA level. The highest densities ranged between 540 and 1342 people per hectare. The lowest densities in the city are represented by the light yellow colour with densities ranging between 0 and 20 people per hectare. From the results, the high-density areas were located around the Pretoria central in areas such as Arcadia and Sunnyside, in places like Soshanguve in the northern Pretoria, and Mamelodi in the eastern parts of the city. Medium density EAs had a range between 49 and 96 people per hectare and these were EAs around Akasia, Hammanskral, Soshanguve, Ga-Rankuwa in the north; Saulsville and Atteridgeville in the west; Mamelodi and Nellmapius in the east and Centurion in the south of the metropolitan area. The low-density areas were distributed throughout the city, with prominence in the eastern and northern parts of the city.

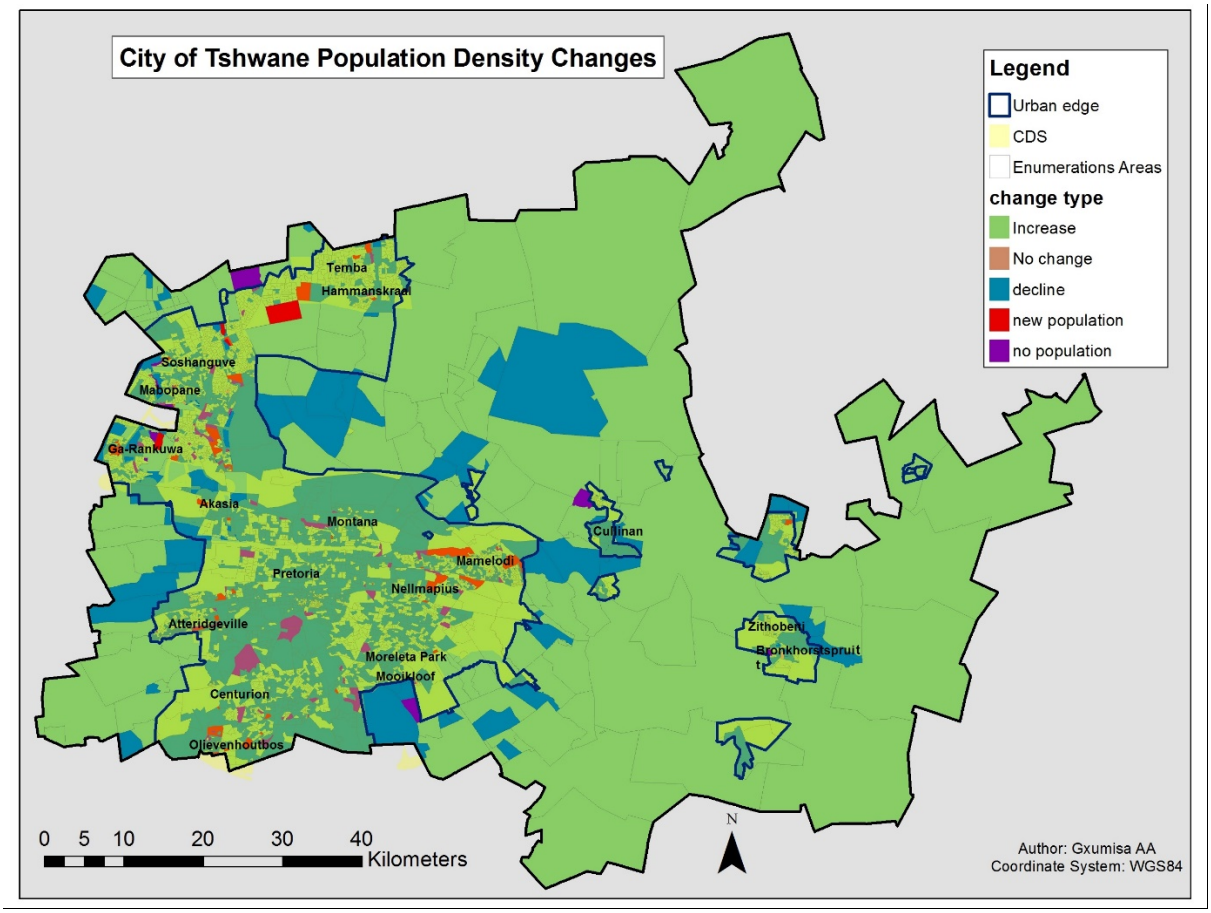

Figure 12: City of Tshwane population density changes between 2011 and 2018

Figure 12 gives a visual representation of the location of the five types of population density changes found in the city between 2011 and 2018. From the results of the classification, EAs that had an increase in population density are represented by green and those that has no changes in population densities are represented by the brown colour. EAs that had a decline in density, between 2011 and 2018 are represented by blue. EAs that had no population in 2011 but had a new population density in 2018 are represented by the red colour, and EAs that had zero population density for both 2011 and 2018 are represented by purple.

From the percentage results in Figure 13, EAs that had an increase in population density accounted for 52.23% of the total. From the results of the map in Figure 12, these EAs were spread throughout the city. The second highest percentage was that of EAs that had a decline in population density, which accounted for 41.41%. EAs with declining densities occurred in areas such as Akasia and Soshanguve in the north, Atteridgeville and Saulsville in the west, Bronkhorstspruit and Mamelodi in the east, Olievenhoutbos in the south, and areas around Pretoria central. The results from figure 13 also indicate that 4.30% of the EAs in the city had no population at all. These EAs with no population were located around the New Eersterus and

Soshanguve areas in the north and the southern parts of the city around Irene in Centurion. The smallest percentages were that of the New Population class and that of the No Change class, which accounted for 0.38% of the total EAs in the city. From Figure 12 areas with new population densities were around Soshanguve, Mamelodi, Olievenhoutbos, Ga-Rankuwa and Akasia. Areas with no population change were located around Soshanguve in the north, and Mooikloof Ridge and Bronkhorstspruit in the east of the metro.

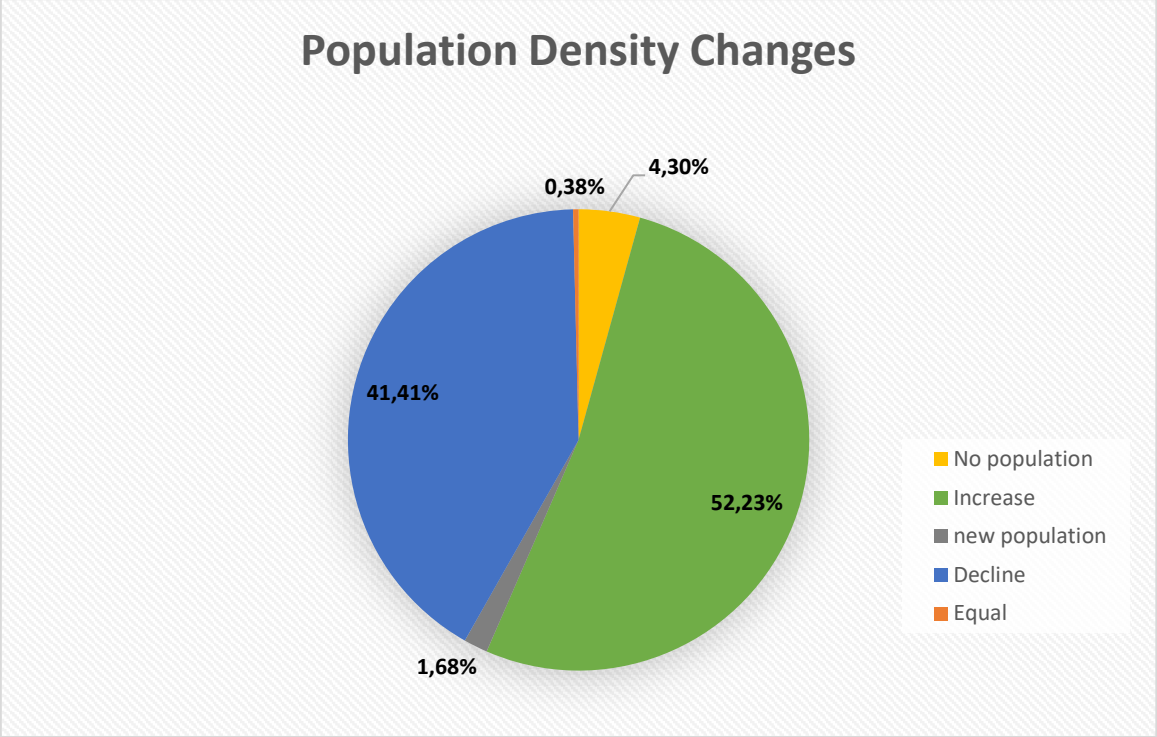

Figure 13: Percentage (%) of each population density changes class

4.3 STATISTICAL ANALYSIS

4.3.1 Descriptive Statistics

Table 4 gives the average residential densities per zone for 2010 and 2018 compared to the specified densities by the CDS (as represented in figure 2). From the results obtained high density zones increased from 16.49 to 16.52 building units per hectare. These densities were lower than the 200 plus units per hectare specified in the CDS. Transit promotion zones average densities increased from 8.36 to 8.75 units per hectare, which was also less than the specified 120 plus units per hectare. Linear zones also increased from 10.57 and 11.18 units per hectare but this was still less than the specified 80 units per hectare. The Suburban density however

showed to have met the minimum threshold as densities for 2010 and 2018 fell within the 10 to 25 units per hectare range with 15.28 and 16.27 units per hectare for 2010 and 2018 respectively. According to the CDS strategy, densities in the low-density zones should be less than 10 units per hectare, but those from the analysis indicated that these specified densities were exceeded, as it was 10.64 and 16.59 for 2010 and 2018 respectively.

Table 4. Average residential densities in the CDS Zones for 2010 and 2018

Density Zone	CDS specified Density (units/hectare)	2010 Average residential density (Building units/hectare)	2018 Average residential density (Building units/hectare)
1. Concentration zones: a). High density	> 200	16.49	16.52
b). Transit promotion zones	>120	8.36	8.75
2. Linear	80	10.57	11.18
3. Suburban densification zones	10- 25	15.28	16.27
4. Low density	< 10	10.64	16.59

4.3.2 Regression Analysis

Table 5 provides the output of the regression analysis undertaken to assess the impact of the City of Tshwane Compaction and Densification Strategy on the 2010 residential densities. The CSD was the independent variable and 2010 residential densities as the independent variables. The analysis produced a correlation coefficient (R) of 0.076, R squared value $R^2 = 0.006$ and Adjusted R Square of 0.005.

Table 5. 2010 Residential density regression analysis

R	R Square	Adjusted R Square
0.076	0.006	0.005

A second regression was conducted between the 2018 residential densities (dependent variable) and the CDS (independent variable), to assess the impact of the city's strategy on the 2018 residential densities. The results in Table 6 indicate that the correlation coefficient value was 0.073; whereas R squared was 0.005 and the Adjusted R Square was 0.005.

Table 6. 2018 Residential density regression analysis

R	R Square	Adjusted R Square
0.073	0.005	0.005

4.3.3 Correlation

A Spearman's bivariate correlation was conducted between population and residential densities to assess the type of relation that exists between the two variables. The results for the 2010 residential and 2011 population density correlation are presented in Table 7. The correlation coefficient for this analysis was r = 0.69. Another correlation was conducted between 2018 population and 2018 residential densities and the outputs of this analysis are also presented in Table 7. From the results, r = 0.49.

Table 7. Correlation between 2010 residential and 2011 population densities and 2018 residential and 2018 population densities.

	Residential density 2010	Population density 2011	Residential density 2018	Population density 2018
Residential density 2010	**1**	**0.692**		
Population density 2011	**0.692**	**1**		
Residential density 2018			**1**	**0.492**
Population density 2018			**0.492**	1

4.3.4 Hypothesis Testing

A Oneway Anova test was conducted between the CDS and residential density changes in to test the the null hypothesis which stated that there is no relationship between the CDS and the observed residential density changes. The results of this analysis are presented in Table 8, where the output p-value is 0.00 at 95% confidence interval.

Table 8. Oneway Anova test

	Sum of Squares	df	Mean Square	F	p-value
Between Groups	454.558	5	90.912	5.013	**0.000**
Within Groups	46372.594	2557	18.136		
Total	46827.152	2562			

4.4 CHAPTER SUMMARY

This chapter presents findings of research. It started by giving the growth in residential densities between 2010 and 2018. Then residential and population densities were quantified in order to assess the changes that have occurred in each case. The residential densities were assessed between 2010 and 2018 whereas population densities were assessed for the 2011 and 2018 period. Statistical analysis in the form of regression, correlation and an Anova test were conducted. The regression analysis was used to determine the influence of the CDS on residential densities; correlation was used to assess the type of relationship that exists between population and residential densities, and the Oneway Anova test as undertaken to test the null hypothesis.

5. DISCUSSION

5.1 INTRODUCTION

The aim of this chapter is to discuss the results obtained from the analysis, from the quantification of residential and population densities and how these have changed over years. This chapter will also discuss the statistical analysis on the regression between CDS and residential densities and the correlation between population and residential densities. Lastly, the chapter further describes the implication of these results in the urban and regional planning domain.

5.2 DENSIFICATION

From the graphical representation of 2010 residential densities and that of 2018 it can be observed that the highest residential densities in the municipality were found around townships such as Mamelodi, Soshanguve, Atteridgeville and Olievenhoutbos. The highest population densities in the municipalities were also found around the same areas for both 2011 and 2018. The townships are areas where one finds both the formal and informal type of settlement in and around the periphery of the township (Geyer *et al*., 2012). The densities being higher in townships in this study correspond to the observations made by South African researchers (Pernegger & Godehart, 2007 and Lategan & Cilliers, 2016) who have argued that townships in the country have the highest densities compared to any other area. According to Lategan and Cilliers (2016), South Africa's informal settlements have increased over the years. The results of the current study showed that informal settlements have increased by 74% between 2010 and 2018. One of the characteristics of informality is that these areas often lack basic services which the impacts on the resident's quality of life. As informal settlements continue to grow, it becomes imperative that planners and policy makers find a way of ensuring that growth in the urban areas is occurring in a sustainable manner.

The results from this study showed that backyards have also seen a substantial increase during the study period. Population density increases drive up the demand for housing space in order to accommodate the growing population. Backyard dwellings are not new in SA, as they date as far back as the apartheid era. This type of residential dwelling is a result of rapid population urbanisation that has made it difficult for the government to provide sufficient and decent housing for the growing population. One advantage of backyards is that they encourage infill within brownfields rather than greenfield development. Another advantage of backyards is that

the owners of the main house can rent out the backyards in order to generate income. This then forms part of the informal economy often seen in townships. However, Zweig (2015) argues that the significance of backyards as a form of accommodation in South African cities has generally been disregarded by housing policies. Policy makers would rather focus on delivering low-cost housing at a larger scale than deal with backyards. The current low-cost housing policy has largely been criticised for creating detached single-family housing with stands of a minimum 250m^2, which has resulted in lower densities. Furthermore, the policy has been criticised for the location of these low-cost houses, which is often at the periphery of the city meaning that people have to commute for longer distances to access jobs and other services. In a survey that was conducted in CoT to determine the densest low-cost housing areas in Mamelodi, the results indicated that almost 80% of residential lots in Mamelodi has backyards (Schoonraad, 2000). This has significant implications on bulk infrastructure as the as the number of people per lot increases. . Hatting and Horn (1991), state that on average each lot has about 40 people. According to Bank (2007), most municipalities in SA have not extended basic services to these backyards, hence the strain on the current infrastructure.

The results from the study further indicated that the city has seen a 41% increase in security villages and a 26.7% increase in security estates. This type of living has become popular among mid and high-income earners. Estate and security villages are often referred to as gated communities. The growth in this type of residential building land use in the post-1994 era is accelerated by socio-economic factors such as income and class, which has seen a widening gap between the rich and the poor. People's need for safer environments as crime rates increase has also been an accelerator for gated estates and security villages; however, class is still the main driver (Landman, 2000). The growth of security estates however is argued to have spatial implications such as their contribution to old patterns of undesired densities and fragmented development (Landman, 2004).

Contrary to the growth in residential density of the rest of the classes in the municipality, complexes showed as a negative growth during the study period. Two possible scenarios can explain this decline in densities. Firstly, it could have been a result of converting residential to commercial building or any other non-residential type. Secondly, it could be errors in the classification of the buildings by GTI where these complexes were classified as non-residential in 2018 but are in fact residential. The results of the study further indicated that there were areas with very low residential densities, particularly in the eastern and northern parts of the municipal area. One of the reasons for these low densities is that most of the land in these areas

is either part of the land where low densities are advocated for or in areas where growth is restricted. Growth restriction areas include protected biodiversity areas, landfill sites and open spaces, specified by the city. The areas where low densities are advocated for according to the CDS are for either legal reasons or the spatial locations of these areas (City of Tshwane, 2018).

The results also indicated that the municipal area had a substantial amount of EAs whose densities remained constant between 2010 and 2018. This consistency could be an indication that the urban footprint in these areas has not changed due to stability, or an indication that there is no point in further developing these areas due to environmental factors, price of land, land use regulation or the areas are just unfeasible for further development.

5.3 STATISTICAL ANALYSIS

From the results of the correlation between population and residential density which sought to determine the type of relationship that's exists between the two variables, the output for the 2010 residential and 2011 population correlation produced a correlation coefficient of 0.69. This indicated that there was a strong positive correlation between the two variable. The second correlation test between 2018 population and 2018 residential densities produced an output of r = 0.49, which indicated that there was an average positive correlation between the two variables. Both results gave an indication that for the most part, population density increases were occurring on the same location as residential density increases.

The main aim of the study was to assess the impact of the city's 2005 Compaction and Densification Strategy on the observed residential densities between 2010 and 2018. The results from the descriptive statistics (Table 4) indicated that the average residential density areas that had their centroid within the CDS densification zones were mostly lower than the specified CDS densities. The regression analysis that was undertaken firstly with CDS as the independent and 2010 residential densities as the dependent variable produce an output of R Square = 0.006. This result gave an indication that only 0.6% of the densities occurring in the municipality were influenced by the CDS strategy. Another regression between the CDS densities and the 2018 residential densities gave an output of $R^2 = 0.005$ which indicated that only 0.5% of the residential densities were predicted by the CDS strategy. The adjusted R square for both 2010 and 2018 residential densities with the CDS strategy was 0.005 which meant that in both cases only 0.5% of the dependent variable was predicted by the independent

variable. Both these regression models were poor fits, thus it can be concluded that the CDS strategy is a poor predictor of residential densities.

Although the results of the regression showed that there was a poor fit between the dependent and independent variables, it is arguable that there is some influence between the two. The results of this study indicated that development in the city occurred in already existing urban residential footprint and only 2% of the city's EAs had new development in 2018 and none in 2010. This is in line with the results from a study conducted by Ludick & Le Roux (2018), where they simulated urban growth for the City of Tshwane over the next 30 years under the Compaction and Densification Strategy. The results from their study indicated that the implementation of the CDS policy does have the potential to lead to the development of a more compact city. The results further indicated that most of the development would occur within the 25 km radius form the CBD, around major routes and the metro's urban cores. More evidence to support the results obtained in this study is from a study by Chobokoane & Horn (2015), where they conducted a study to measure the then current urban form against the Mangaung Metropolitan Municipality's Spatial Planning Proposal for Compaction. The results from their study indicated that although the Metro had a compaction strategy in place, it was only slightly denser in 2011 than it was in 2001. Furthermore, there needed to be a more focused densification in the city in order to maximise on strategy.

One of the possible explanations to the CDS having minimal influence on the density changes could be that the type of development that is occurring is not the type that maximises on density. For instance, densification through low-cost housing will have minimal effect compared to densification through multi-storey buildings. The type of development occurring in areas such as Orchards in Akasia, Pretoria north where there is a focus on free stand single-family housing is what should be avoided by the city, as this type of developments encourages sprawl. It is imperative that densities are not just increased without any consideration of the bulk infrastructure that will be needed to accommodate the population in these high-density residential areas. The reality is that there needs to be a consideration of whether the current bulk infrastructure will have the capacity to provide for further densification. Not just bulk infrastructure but also the facilities around those densified areas should have the capacity to cater for the entire population. However, Biermann (2000) argues that the capital cost of bulk infrastructure does not simply decrease as densities increase, but there is an interrelationship between infrastructure thresholds, capacities, location and density over time and space. Hence

it is important to have an engineering services infrastructure cost in determining densities that the city wants in specific areas.

5.4 CHAPTER SUMMARY

This chapter discusses the finding of the study giving possible explanations of the results obtained. It further discusses the impacts of unprecedented density increases on bulk infrastructure.

6. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides the summary of the findings of this study relating to the main study objectives as well as the research questions provided in the first chapter, the limitations and recommendations, and the conclusions drawn from the study.

6.1 MAIN FINDINGS

The main aim of this study was to assess changes in residential and population densities in the City of Tshwane and assess the impact of the city's 2005 Compaction and Densification Strategy on the observed residential and population density changes. From the results obtained, it was found that in terms of both residential and population densities the city had an increase in densities. Most of this densification was found to be occurring in the city's townships such as Mamelodi in the east, Mabopane, Ga-Rankuwa and Soshanguve in the north, Saulsville and Atteridgeville in the west, and Olievenhoutbos in the southern parts of the city. The results further indicated that most of the growth occurred in the informal building class, coupled with the backyard class. Hence, most of the high-density areas were in the townships. There was also a substantial growth in the estate and security village classes and these are thought to be driven by socio-economic factors such as income and class, as well as people feeling the need for better security as crime rates increase. The results also showed a decline in residential densities in some parts of the city and these are thought to be the result of the redevelopment of residential buildings into commercial buildings. The results also indicated that there were areas that experienced constant densities for both 2010 and 2018 and this was found to be occurring around the suburban areas where no further development has occurred either due to the land in the area being expensive, land use regulation restricting further growth or the area just being unfeasible for further development.

Statistical analysis in the form of regression was conducted in order to assess the impact the city's strategy has on residential densities for both 2010 and 2018. The results from this analysis indicated that there was a weak positive influence of the dependent variable by the independent variable. This means that only a small fraction of the observed residential densities are as a result of the implementation of the city's strategy. By comparing these findings with that of Chobokoane and Horn (2015) it was concluded that the implementation of compaction strategies in the South African context although limited, does influence densities in the city. Ludick & Le Roux (2018) indicate in their study that the implementation of the CDS strategy in Tshwane does have the potential of influencing densities in the city. Although there is a

potential for influence, the results of the current study give an indication that this is still minimal influence at this stage. The descriptive statistics on the average residential densities in areas that fall within the CDS zones gave an indication that for the most part, current densities are still lower than the desired densities by the CDS.

The second statistical test undertaken was a Spearman correlation. This correlation test was used to determine the type of relationship that exists between residential and population densities. From the correlation between 2011 population and 2010 residential output, the regression coefficient was 0.69, which indicated a strong positive correlation between the two variables. The second correlation was between the 2018 population and 2018 residential densities, which produced a correlation coefficient of $r = 0.49$. This correlation indicated that there was an average positive relationship between the two variables, which indicated that residential densities increased where population densities increase. The results from the Anova test indicated that the output p-value was $p = 0.00$ which was lower than the chosen level of statistical significance of 0.05 (95% confidence). Therefore the null hypothesis that stated that there is no relationship between the Compaction and Densification Strategy was rejected, thus the alternative hypothesis was accepted. There is 95% confidence that there is a relationship between 2005 CDS and the observed density changes.

6.2 STUDY LIMITATIONS AND RECOMMENDATIONS

There were some limitations to the study. These limitations have an effect on the overall quality of the results obtained for the study. The first limitation was with regards to the inconsistent population data sources. The smallest level one could obtain the 2011 population data from census was at the Small Area Layer (SAL) level. The CSIR did a disaggregation of the population to create a dwelling frame that has points with associated number of people in that dwelling. This allowed the data to be aggregated to the EA level. On the other hand, the 2018 population data was estimated by GTI at EA level based on 2014 mid-year estimates. The challenge was then with combining these two datasets is that they probably had varying levels of accuracy. The second limitation was with regards to the calculation of residential densities. This study only focused on the gross residential density in each EA, which includes land assigned for other land uses. Working with net residential densities could have improved the quality of results because one would first eliminate all the non-residential areas.

Due to the limitations of the study, some recommendations have been made to improve the quality of results for future studies of this nature. Firstly, the study should be done at an

administrative level where all the datasets in the project fit perfectly in without any manipulation that will compromised the quality of the data. The second recommendation is that a researcher uses datasets from the same source. For instance in the population density case, one should either stick with using population from census or population estimates from GTI. The third recommendation is to obtain a shapefile that outlines the residential areas in the city. This shapefile would allow for the accurate calculation of net residential densities with high levels of accuracy. The current layer that the municipality has is not accurate and has not been updated in years.

6.3 CONCLUSION

From the results obtained in this study, it is evident that densities in the city have increased. However, most of this densification is occurring in townships. The results show that the average densities in the city's compaction and densification zones for both 2010 and 2018 are lower than the desired densities specified in the CDS. Although there is minimal influence, the CDS does have the potential to influence the changes in residential densities. It is thus important that policy makers and planners ensure that the right type of development is prioritised. The focus should be more on high-rise buildings than free-stand houses because these results in sprawl. Also increasing densities in the already densified townships does not just put pressure on the bulk infrastructure, facilities and has the potential to affect the quality of life of the residents. Hence, better housing type needs to be prioritised.

REFERENCES

Acioly Jr CC 2000. Can urban management deliver the sustainable city? Guided densification in Brazil versus informal compactness in Egypt. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 127-140. London: Spon Press.

Ajaero CK & Onokala PC 2013. The effects of rural-urban migration on rural communities of south-eastern Nigeria. *International Journal of Population Research*, 2013.

Anabtawi S, De Vries WT, Masum F, Espinoza J & Graefen, C 2016. *Scaling up compact city development strategies – a solution to cope with urban sprawl in developing countries.* Paper presented at the 2016 World Bank Conference on Land and Poverty. The World Bank - Washington DC, March 14-18, 2016.

Anabtawi S 2018. The Compact City: Utopian Vision or Practical Solution to Medium-sized Cities in Developing Countries. Doctoral dissertation. München: Technische Universität München, Institut für Geodäsie, GIS und Land Management.

Artmann M, Inostroz, L & Fan P 2019. Urban sprawl, compact urban development and green cities. How much do we know, how much do we agree? *Ecological indicators* 96: 3-9.

Badenhorst MS 2002. Cities in the suburbs: an exploratory look at Pretoria East as an evolving edge city. *Stads-en Streeksbeplanning= Town and Regional Planning* 45: 60-69.

Banai R & DePriest T 2014. Urban Sprawl: Definitions, Data, Methods of Measurement, and Environmental Consequences. *Journal of Sustainability Education* 7.

Bank L 2007. The rhythms of the yards: urbanism, backyards and housing policy in South Africa. *Journal of Contemporary African Studies* 25(2): 205-228.

Barger K 2016. Densification as a tool for sustainable housing development: a case study of Umhlanga high-income area in Durban. Doctoral dissertation. Durban: University of KwaZulu-Natal, School of Built Environment and Development Studies.

Biermann, S. 2000. Bulk engineering services: Costs and densities. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 295-310. London: Spon Press.

Buhaug H & Urdal H 2013. An urbanization bomb? Population growth and social disorder in cities. *Global environmental change* 23(1): 1-10.

Burchell RW, Listokin D & Galley CC 2000. Smart growth: More than a ghost of urban policy past, less than a bold new horizon. *Housing policy debate* 11(4): 821-879.

Burchell RW & Mukherji S 2003. Conventional development versus managed growth: the costs of sprawl. *American Journal of Public Health* 93(9): 1534-1540.

Burgess R 2000. The compact city debate: A global perspective. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 9-24. London: Spon Press.

Burton E 2000. The compact city: just or just compact? A preliminary analysis. *Urban studies 37*(11): 1969-2006.

Campbell JB 1983. *Mapping the Land: Aerial Imagery for land use information.* Washington DC: Association of American Geographers.

Cheng V 2010. *Understanding density and high density*. In Ng E (ed) *Designing High-Density Cities*, 37-51. London: Earthscan.

Chobokoane N & Horn A 2015. Urban Compaction and densification in Bloemfontein, South Africa: measuring the current urban form against Mangaung metropolitan municipality's spatial planning proposals for compaction. *In Urban Forum* 26(1): 77-93.

City of Cape Town 1999. *The Draft Municipal Spatial Development Framework,* Planning and Development Directorate of the City of Cape Town, Cape Town.

City of Cape Town 2009. *Cape Town Densification Strategy: Technical Report*. Cape Town: City of Cape Town

City of Tshwane 2005. *Densification and Compaction Strategy*. City of Tshwane Metropolitan Municipality: The Department of Housing, City Planning and Environmental Management.

City of Tshwane 2018. *Regionalized Municipal Spatial Development Framework*. City of Tshwane Metropolitan Municipality: The Department of Housing, City Planning and Environmental Management

Cobbinah PB & Amoako C 2012. Urban sprawl and the loss of peri-urban land in Kumasi, Ghana. *International Journal of Social and Human Sciences* 6: 388-397.

Dave S 2010. High urban densities in developing countries: A sustainable solution? *Built environment* 36(1): 9-27.

De Brauw A, Mueller V & Lee HL 2014. The role of rural–urban migration in the structural transformation of Sub-Saharan Africa. *World Development* 63: 33-42.

Devereux S 2000. *Famine in the twentieth century*. Working Paper No. 105. Institute of Development Studies (IDS).

Dewar D 2000. The relevance of the compact city approach: the management of urban growth in South African cities. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 209-218. London: Spon Press.

Dieleman F & Wegener M 2004. Compact city and urban sprawl. *Built environment* 30(4): 308-323.

European Commission 2014. *6th Report on Economic, Social and Territorial Cohesion*. Brussels.

Faludi A 2000. The performance of spatial planning. *Planning practice and Research* 15(4): 299-318.

Flannery D, Duarte R, Norman B, O'Donnell T, Sinclair H &. Steffen W 2015. Light Rail Transit and Residential Density in Mid-Size Cities. Canberra Urban and Regional Futures (CURF), University of Canberra, Australia.

Glover DR & Simon JL 1975. The effect of population density on infrastructure: the case of road building. *Economic Development and Cultural Change* 23(3): 453-468.

Geyer Jr SH, Geyer SH, du Plessis D & van Eeden A 2012. Defferential urbanisation trends in South Africa – regional and local equivalents. *Environment and Planning* 44: 2940-2956.

Hattingh PS & Horn A 1991. In *Homes Apart* (ed) Lemon A. David Phillip Publishers, Cape Town, 146–161

Habibi S & Asadi N 2011. Causes, results and methods of controlling urban sprawl. *Procedia Engineering* 2: 133-141.

Holcombe RG & Williams DW 2008. The impact of population density on municipal government expenditures. *Public Finance Review* 36(3): 359-373.

Hosseini SH & Hajilou M 2018. Drivers of urban sprawl in urban areas of Iran. *Papers in Regional Science* 98(2): 1137-1158.

Howley P 2009. Attitudes towards compact city living: Towards a greater understanding of residential behaviour. *Land use policy* 26(3): 792-798.

Jabareen YR 2006. Sustainable urban forms: Their typologies, models, and concepts. *Journal of planning education and research* 26(1): 38-52.

Karakayaci Z 2016. The Concept of Urban Sprawl and Its Causes. *Journal of International Social Research* 9(45).

Kruger R 2017. The extent of urban densification in Stellenbosch. Doctoral dissertation. Stellenbosch: Stellenbosch University, Department of Geography and Environmental Studies.

Landman K 2000. Gated communities and urban sustainability: Taking a closer look at the future. Presented at 2nd Southern African conference on sustainable development in the built environment strategies for a sustainable built environment, Pretoria South Africa.

Landman K 2004. Gated communities in South Africa: Comparison of four case studies in Gauteng. Pretoria: CSIR Council for Scientific Information Research

Lategan LG & Cilliers JE 2016. Towards more compact South African settlements through informal housing: The case of backyard densification in Bridgton and Bongolethu, Oudtshoorn. *Town and Regional Planning* 68: 12-26.

Le Roux A, Arnold K, Makhanya S & Mans G 2019. Green Book. South Africa's urban future: Growth projections for 2050. Pretoria: CSIR. Available at: https://pta-gis-2-web1.csir.co.za/portal/apps/GBCascade/index.html?appid=5180459a765c4e63bfb3fa527c7302b3.

Leeson GW 2018. The Growth, Ageing and Urbanisation of our World. *Journal of Population Ageing* 11(2): 107-115.

Litman T 2016. *Determining Optimal Urban Expansion, Population and Vehicle Density, and Housing Types for Rapidly Growing Cities*. Proceedings of the World Conference on Transport Research, Shanghai, China, 10-15.

Ludick C & Le Roux A. 2018. A Geospatial modelling approach to simulating the impact of future planning policies on the City of Tshwane. Proceedings of the AfricaGEO 2018 Conference, Emperors' Palace, 17-19 September 2018.

Macedo J 2013. Planning a sustainable city: The making of Curitiba, Brazil. *Journal of Planning History* 12(4): 334-353.

Mahtab-uz-Zamam QM, Lau SS & Mei SH 2000. The compact city of Hong Kong: a sustainable model for Asia? In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 255-268. London: Spon Press.

Marshall JD 2007. Urban land area and population growth: A new scaling relationship for metropolitan expansion. *Urban Studies* 44(10): 1889-1904.

Marutlulle NK 2017. Causes of informal settlements in Ekurhuleni Metropolitan Municipality: An exploration. *Africa's Public Service Delivery and Performance Review* 5(1): 1-11.

Mouton J 2011. *How to succeed in your master's and doctoral studies: A South African Guide and Resource book.* Pretoria:Van Schaik Publishers.

Musakwa W & Van Niekerk A 2014. Monitoring Urban Sprawl and Sustainable Urban Development Using the Moran Index: A Case Study of Stellenbosch, South Africa. *International Journal of Applied Geospatial Research* 5(3): 1-20.1995

Nallathiga R & Campus MC 2007. Compact city and smart growth as policy guiding models for achieving sustainable city development: The case of Mumbai metropolis. *ICFAI Journal Urban Policy* 2(1): 42-59.

Pacione M 2009. *Urban geography: A global perspectives*. London: Routledge

Pawan L 2016. Urbanization and Its Causes and Effects: A Review. *International Journal of Research and Scientific Innovation* 3(9): 110-112.

Odindi J, Mhangara P & Kakembo V 2012. Remote sensing land-cover change in Port Elizabeth during South Africa's democratic transition. *South African Journal of Science* 108(5-6): 60-66.

Pernegger L & Godehart S 2007. Townships in the South African geographic landscape–physical and social legacies and challenges. *South Africa, Training for Township Renewal Initiative* [online] Pretoria, South Africa: National Treasury. Available from http://www.treasury.gov.za/divisions/bo/ndp/TTRI/TTRI%20Oct%202007/Day%201%20-%2029%20Oct%202007/1a%20Keynote%20Address%20Li%20Pernegger%20Paper.pdf [Accessed 29 October 2019].

Richardson HW, Bae CHC & Baxamusa M 2000. Compact cities in developing countries: assessment and implications. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 25-36. London: Spon Press.

Roberts BH 2007. *Changes in urban density: its implications on the sustainable development of Australian cities*. In Proceedings of the State of Australian Cities National Conference, 720-739.

Robson TF 2005. An Assessment of Land Cover Changes Using GIS and Remote Sensing: A Case Study of the UMhlathuze Municipality, KwaZulu-Natal, South Africa. Doctoral dissertation. Pietermaritzburg: University of KwaZulu-Natal, Centre for Environment, Agriculture and Development.

SACN 2016. *State of South African Cities Report 2016*. Johannesburg: SACN ISBN No. 978-0-620-71463-1.

Schoonraad MD 2000. Cultural and institutional obstacles to compact cities in South Africa. In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 219-230. London: Spon Press.

Segura S & Pedregal B 2017. Monitoring and Evaluation Framework for Spatial Plans: A Spanish Case Study. *Sustainability* 9(10): 1706.

Siedentop S & Fina S 2010. Urban sprawl beyond growth: the effect of demographic change on infrastructure costs. *Flux* 1: 90-100.

Sivam A, Karuppannan S & Davis MC 2012. Stakeholders' perception of residential density: a case study of Adelaide, Australia. *Journal of Housing and the Built Environment* 27(4): 473-494.

South Africa (Republic of) 1995. *Development facilitation Act*. Cape Town: Government Printers.

Todes A, Weakley D & Harrison P 2018. Densifying Johannesburg: context, policy and diversity. *Journal of Housing and the Built Environment* 33(2): 281-299.

Statistics South Africa 2011. *The people of South Africa Population* Census, 2011. Statistics South Africa, Pretoria.

Thierstein A & Reiss-Schmidt S 2008. Urban Development Management in Munich, Germany Integrated strategy, impacts, learning from external evaluation. In *44th ISOCARP Congress*.

Todes A 2014. New African suburbanisation? Exploring the growth of the northern corridor of eThekwini/KwaDakuza. *African Studies* 73(2): 245-270.

Todes A, Weakley D & Harrison P 2018. Densifying Johannesburg: context, policy and diversity. *Journal of Housing and the Built Environment* 33(2): 281-299.

United Nations 2011. *Sustainable Development in the 21st Century: Implementation of Agenda 21 and the Rio Principles*. Detailed Report on the Implementation of Agenda 21. Department of Economic and Social Affairs: New York.

United Nations 2014. *A new strategy of sustainable neighbourhood planning: Five principles. Nairobi, Kenya:* United Nations Human Settlements Programme.

United Nation 2018. 68 percent of world population will live in urban areas by 2050, says UN [Online]. New York. Available from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html. [Accessed 05 July 2019]

Van Der Burg AJ & Dieleman FM 2004. Dutch urbanisation policies: from 'compact city'to 'urban network'. *Tijdschrift voor economische en sociale geografie* 95(1): 108-116.

Wang Y & Shaw D 2018. The complexity of high-density neighbourhood development in China: Intensification, deregulation and social sustainability challenges. *Sustainable Cities and Society* 43: 578-586.

Westerink J, Haase D, Bauer A, Ravetz J, Jarrige F & Aalbers CB 2013. Dealing with sustainability trade-offs of the compact city in peri-urban planning across European city regions. *European Planning Studies* 21(4): 473-497.

Yusuf MP & Allopi DR 2010. The impact of urban sprawl on the inhabitants of the Ethekwini municipality and the provision of infrastructure. Presented at the *South African Transport Conference 2010.*

Zhang XQ 2000. High-rise and high-density compact urban form: The development of Hong Kong. . In Jenks M & Burgess R (eds) *Compact cities: Sustainable urban forms for developing countries*, 245-254. London: Spon Press.

Zweig PJ 2015. Everyday hazards and vulnerabilities amongst backyard dwellers: A case study of Vredendal North, Matzikama Municipality, South Africa. *Jàmbá: Journal of Disaster Risk Studies* 7(1): 1-8.