

**University of Cape Town**  
**Faculty of Engineering and Built Environments**  
**School of Architecture, Planning and Geomatics**  
**Geomatics Division**



**The integration of Geographical Information Systems with  
Multicriteria Decision Making techniques to improve  
poverty eradication planning**

Towards the completion of a degree for Master of Science in Geomatics  
By: Roger Hubert Daniels  
Supervisor: Associate Professor Julian Smit

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I, ***Roger Hubert Daniels*** know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

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## ABSTRACT

Poverty eradication as a policy issue has received significant attention since the promulgation of the South African National Development Plan (NDP). The NDP envisages that by 2030 poverty should be eradicated. To do this government must accurately target their interventions ensuring that the intended population benefits from the actual poverty eradication intervention. With the evolution of systems and processes in the Science and Technology industry over the past two decades, the integration of Geographical Information Systems (GIS) and MCDM techniques has achieved encouraging results within different planning domains (Lidouh, 2012: 2). This research paper presents a vector – based GIS – MCDM methodology that integrates both Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) and COMplex PROportional Assessment (COPRAS) within a GIS environment. This integration is facilitated through the use of loose coupling within the ArcGIS 10.2 environment.

A case study in the City of Cape Town is used to demonstrate the use of the methodology and how it can be applied to conduct an evaluation study to rank each of the communities based on multiple poverty/capability level domains. The results of the GIS – MCDM analysis show that between 2001 and 2011 the capability deprivation in the City of Cape Town is increasing. When spatially analysing each of the domain model outputs using both the Global and Local Moran's I spatial autocorrelation methods, the results show a significant cluster of high levels of multiple deprivation existing in the southern parts of the City of Cape Town: Khayelitsha, Philippi, Gugulethu, Nyanga ect. The overlapping domain results indicate that these communities experiencing multiple deprivations are characterised by a particularly severe form of segregation or isolation which Massey and Denton (1989:373) refers to as "hypersegregation". While the less deprived or more affluent communities such as Durbanville, Rondebosch, Constantia and Newlands were clustered into regions with minimal exposure to severely deprived citizens subsuming large portions of land further away from the centre and typically clustered near to other affluent communities. According to Massey and Fischer (2000:671), under such high levels of segregation, the added poverty created between 2001 and 2011 is typically absorbed by smaller and more densely populated communities that are spatially clustered together, thereby further eroding the communities' capability levels.

To understand how government is tackling poverty, fiscal allocations for the City of Cape Town and the location of different housing programmes are analysed in relation to the different spatial MCDM model outputs. The spatial analysis shows that firstly a significant proportion of fiscal spend already going towards communities with high levels of capability deprivation which has prompted the immigration of the poor from poorly serviced provinces to serviced regions within the City of Cape Town. Secondly, the analysis demonstrates how various housing programmes implemented by government further entrenches residential segregation patterns in the City of Cape Town resulting in the further proliferation of capability deprivation/poverty in poorer communities.

# **CHAPTER ONE: INTEGRATION OF GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND MULTI-CRITERIA DECISION MAKING TECHNIQUES FOR POVERTY ERADICATION PLANNING**

## **1.1 INTRODUCTION**

The use of a Geographical Information System (GIS) has been sourced back to as far as the Canadian Land Inventory compiled in the 1960s, which used automated processes to collect data in the form of a map (Goodchild, 2000:5). Throughout the 1970s and 1980s, GIS became known for their spatial data processing abilities that allow for the storage; display; manipulation, and analysis of multiple spatial datasets (Jankowski, 1995:251). However, like most processing software, its processing abilities are limited. For example, the majority of its analytical functionalities are appropriate when decision problems are well defined, with clearly defined questions and quantifiable outcomes (Armstrong, 1994:669). Therefore, many spatial analysts are able to use its buffering and overlay operations when deriving solutions for structure decision making problems. Cowen (1988:1554), a well-known GIS researcher, concluded that, "...GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment". However, other GIS experts such as Densham and Goodchild (1989) disputed this definition citing that the abilities of GIS fell well short. These shortcomings are largely due to its limiting analytical and modelling capabilities for solving unstructured decision problems that incorporate multiple conflicting evaluation criteria.

Since the 1990s, the analytical and modelling capabilities of GIS have been enhanced significantly through the coupling of GIS with multi-criteria decision making techniques (Chakhar & Mousseau, 2008:1159). These techniques provide decision makers with the necessary analytical tool sets needed to analyse unstructured decision making problems that are related to certain exact locations in space. This allows planners and decision makers to select the ideal decision alternative from several other feasible alternatives, based on multiple and often conflicting criteria. The issue of multi-criteria selection in a decision making environment is the principal challenge faced by many planners and decision makers. According to Jankowski (1995:252), the nature of the problem is twofold, namely (1) the manner in which alternatives are selected based on common objectives that satisfy multiple decision making parties, and (2) in which manner can the set of choice alternatives be ranked and reduced to identify the most suitable alternative. These types of challenges could be attributed to a host of spatial decision making scenarios. For example, to identify the location of sustainable human settlement development sites, several conflicting criteria must be considered, including water availability; unemployment; transport routes, and access to essential services such as schools and health facilities. There are no ideal solutions for this human settlement decision problem, although decision makers and planners might have preferences for site(s) selection, including, but not limited to sites having adequate access to public transport routes and critical services such as schools and health

facilities ideally being situated within a five kilometer radius. It should also be noted that the above-mentioned multi-criteria decision making techniques allow for a decision to be made based on a specific type of procedural logic, which has the ability to incorporate the already noted types of decision maker preferences.

Thus, a methodical approach to decision making analysis is essential to improving the quality of complex decision making and to justify the appropriate actions required to meet the problem objectives. In this regard a framework that integrates GIS functionalities with Multicriteria Decision Making aggregating techniques seems appropriate. In this study, the appropriate decision alternative will be generated by coupling Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and COmplex PROportional ASsessment (COPRAS) techniques with GIS. It should be stressed that these MCDM techniques were selected for the purposes of this study due to the fact that the procedural logic for both TOPSIS and COPRAS are coherent and comprehensible. Despite the fact that scholarly contributions on the use and application of TOPSIS and COPRAS are substantial, paucity exist with respect to the potential of integrating these two MCDM techniques with GIS. Thus, this study focuses on the development of a framework for integrating TOPSIS and COPRAS with GIS. More specifically, this study will ascertain how this framework could be applied to analyse capability deprivation within a poverty eradication context within the City of Cape Town metropolis.

## **1.2 PROBLEM STATEMENT**

Through the promulgation of the National Development Plan (NDP), the South African Government has set the goal of eradicating poverty in all regions of South Africa, including the City of Cape Town by 2030. To achieve this goal the South African Government requires various credible data sources in order to develop; implement, and manage the different developmental strategies needed to eradicate poverty. Many of these data sources relating to poverty possess a spatial context and for that reason location is a critical explanatory element of poverty. In this context, the role of GIS in assessing the spatial patterns of poverty has thus become fundamentally important, particularly as a way for generating the appropriate strategic management information needed to inform the locality of various poverty programmes and interventions.

Measuring and assessing the spatial patterns of poverty between various communities has become a central developmental theme since the adoption of the Reconstruction and Development Plan (RDP) by the then Government of National Unity (GNU) in 1994; the Millennium Development Goals (MDGs) Declaration by United Nations (UN) members in September 2000, and the NDP by the South African Government in 2012. All of these policy documents acknowledge poverty as being multi-dimensional in nature, and therefore requiring several predefined criteria to conceptualise the extent of poverty eradication interventions needed at a community level. With the emphasis being placed on denoting the multiple poverty domains, poverty measurements are developed for application using numerous mathematical techniques; multiple conflicting data sources, and different model

assumptions (Akinyemi, 2010:86). These complexities often pose hindrances to planners and decision makers who has to select the criteria domains, techniques and assumptions, with the final output often generating biased and skewed strategic management information. These skewed outputs are of concern to government given that the information will be used to inform the allocation of consistently shrinking public budgets and limited resources.

Keeping all of the above in mind, it becomes apparent that what is required is a structured spatial decision making model that can overcome these concerns and guide the evaluation of the feasibility of poverty eradication initiatives in regions and/ or communities. The spatial decision making model must provide planners and decision makers with a rigid framework for the transformation and combination of geographical data and decision maker preferences to generate credible strategic information for decision making. The integration of GIS with MCDM techniques can provide the necessary rigid spatial model structure to assist decision makers in producing credible strategic information for poverty eradication planning as GIS is frequently recognised as “a decision support system involving the integration of spatially referenced data in a problem solving environment” (Cowen, 1988:1554). In comparison, MCDM techniques provide a robust set of procedures for structuring complex decision problems, and planning, assessing and ranking multiple decision alternatives (Malczewski, 2006: 703).

### **1.3 THE NEED FOR POVERTY ERADICATION PLANNING**

Poverty is primarily considered as the most critical economic and social problem in most developmental policy environments today. The ideal is that no South African should be excluded from sharing in the economic growth opportunities generated since the advent of democracy in 1994. Accordingly, the South African Government envisages a country where each and every citizen is free of poverty, able to take hold of their full potential, and where access to various social and economic opportunities are determined by citizen capabilities rather than by their race, social status or birth (NPC, 2012:24). To realise this, the country’s economy should be transformed in such a way that economic growth is pro-poor, benefitting all citizens. The need for meticulous poverty eradication planning thus becomes critical for government and is duly recognised by the World Bank’s Consultative Groups and all UN Development Planning (UNDP) Round Table discussions concerning Official Development Assistance (ODA) (OECD, 2005:35). The prerequisite for meticulous poverty planning includes ensuring that planners and decision makers are able to identify who and how many are poor, and where these poor are located. For this to happen, planners and decision makers must be provided with credible strategic management information that is based on a comprehensive analysis of multiple criteria such as illiteracy; informal dwellings; access to piped water; employment status, and so forth. While many analytical techniques exist for combining multiple criteria into a single index used for decision making, credible strategic management information is only produced when planners and decision makers intervene so as to add value through knowledge sharing and by providing insight

into the different variations in the results. In the context of this study, the process of decision makers value add is achieved through consulting with multiple experts on the different domains to be used to assess poverty. To address such a multi-faceted problem, a methodical approach for decision making is required to accommodate the multi-dimensional nature of poverty.

#### **1.4 POVERTY ERADICATION PLANNING - A SPATIAL MULTI-CRITERIA DECISION MAKING PROBLEM**

In terms of poverty eradication, both China and India has made significant progress with more than 500 million citizens being raised above the poverty threshold (Thorat & Fan, 2007:704). According to these researchers this accomplishment can be accredited to various factors such as economic and social policy reform, and increased public investments by government in the human development and science as well as **information sectors**. These policy reforms and increased public investments by government has been instrumental in stimulating the necessary economic growth needed to further eradicate poverty and ensuring that adequate resources are being targeted to the officially specified poorer regions (Gustafsson & Zhong, 2000:983). To achieve this, consensus between planners and decision makers on how poverty is conceptualised was crucial. This included (1) a standard measure for the level of well-being; (2) a poverty threshold that differentiates the poor from the non-poor, and (3) a poverty measure or index that amalgamates different conflicting criteria with decision maker preferences on the well-being of the poor (Besley & Kanbur, 1990:3). All of the above noted processes involve a spatial perspective and includes multiple criteria decision making, which is used to identify where the poor are located and helps in identifying the appropriate resources needed to eradicate poverty in a specific region. Thus, the need for an informed decision assessment on the part of the planner and decision maker in order to reach consensus on the definition of poverty becomes essential.

Many factors need to be taken into consideration when identifying a poorer region for intervention. Complex regional features such as access to piped water; proper sanitation services, and electricity make region selection complicated. Apart from these basic services considerations, other conflicting factors such illiteracy; unemployment, and informal dwellings are also important in the decision making process. The complexity further increases when multiple domain experts on poverty are involved in the decision making process, as this often leads to conflict in the criteria selection and weighting processes (Rahman *et al.*, 2012:62). GIS and its spatial analytical tools alone will not efficiently enable the operationalisation of various parameters relating to poverty eradication as set out by the various domain experts. These spatial analytical tools are unable to deal with ambiguity and possible divergences, which in all likelihood results in poor and biased decision making resulting in the non-poor benefiting from unintended government interventions (Bailey *et al.*, 2003:9). When GIS is coupled with various MCDM techniques it can provide planners and decision makers with adequate structured procedures for dealing with planning within a poverty eradication context. For instance,



numerous impoverished communities; multiple conflicting criteria; policies, and political spheres can seamlessly be taken into consideration by the Spatial Multicriteria Decision Making process.

### **1.5 PURPOSE OF THIS STUDY**

The purpose of this study is to explore the potential of integrating GIS with MCDM techniques for effective poverty eradication programme planning, coupled with, as noted before, developing a Framework to analyse capability deprivation within a poverty eradication context in the City of Cape Town metropolis. Thus, this study seeks to develop an appropriate methodology that links impact assessments for poverty eradication with government's policy responses, and this will be done by integrating MCDM techniques with GIS.

In addition to the above, this study also seeks to:

- Assess the changing topography of poverty in the City of Cape Town between 2001 and 2011;
- Develop a transparent and adaptable poverty eradication planning tool, whose results can be easily interpreted and explained by planners and decision makers;
- Define appropriate indicators related to Amartya Sen's Capability Approach (CA) Framework as developed in 1979, coupled with developing a Poverty Index, and;
- Demonstrate spatially whether both Provincial and Local Government spending is in line with where the poor are located.

### **1.6 RESEARCH QUESTIONS**

Some of the most important research questions to be discussed in this study include the following, namely:

- How are appropriate alternatives ranked and selected? Alternatives in the context of this study refer to the different communities across the City of Cape Town.
- Do the proposed spatial multi-criteria decision making model outputs conform to the five normative principles as set out in the NDP (2012:277)?
- How are biased decision making avoided?
- Does the capability approach add anything to the ability of planners to attempt to eradicate poverty?
- Can GIS spatial analytical tools be incorporated with MCDM techniques to improve decision making?
- Can the CA be operationalised adequately to assess poverty?
- Does the use of MCDM provide planners with any apparent advantage?

### **1.7 METHOD OF RESEARCH**

This study is based on an analysis of literature (both primary and secondary sources), and is supplemented by using a case study focusing on the City of Cape Town metropolis. The data and information required to assess poverty eradication in the case study area will be informed by Amartya

Sen's CA Framework and sourced from Statistics South Africa's (Stats SA) Census 2001 and 2011. In order to address any bias concerns in terms of criteria weight selection, this study utilises a mathematical technique called Principle Component Analysis (PCA) as the method for calculating decision criteria weightings. All PCA will be calculated using a statistical software called STATA 12.

Furthermore, although GIS has a broad range of spatial analysis capabilities, the focus is limited to the development of a methodology that integrates MCDM techniques with GIS to ultimately assess the extent of poverty eradication intervention, through the lens of the CA, required in the City of Cape Town. This study will provide a rigorous structure for the integration of MCDM and GIS within a governmental context. It should be stressed at this stage that the application of integrating MCDM and GIS in this study might not be able to provide the necessary guidance needed for a highly complex decision making problem like poverty, since this often requires a complex combination of detail regarding both financial and governance processes.

## 1.8 FUNDAMENTAL CONCEPTS

Within the ambits of this particular study, a number of concepts fundamental to the discourse need to be conceptualised.

**1.8.1 Geographical Information Systems:** Is a computer-based system able to store, edit, manipulate, display and analyse structured data with a spatial context.

**1.8.2 Multicriteria decision making techniques:** Are a set of analytical techniques used to configure unstructured decision problems comprising of multiple conflicting evaluation criteria.

**1.8.3 Spatial multicriteria decision making:** Is a decision making process in which: firstly, the decision making problem occurs within a spatial context, is unstructured in nature and comprises of multiple conflicting criteria; secondly the unstructured problem is applied to one of the many multicriteria decision making techniques which are used to structure the decision problem and outputs logical and interpretable decision solutions; and thirdly these solutions are coupled with GIS to spatially render the decision solution for analysis.

**1.8.4 Loose coupling:** In this approach, the integration of GIS capabilities with MCDM techniques is achieved by sharing data files developed in Microsoft Excel workbooks.

**1.8.5 Functionings:** Is a collective term used to define the sets of resources and features that citizen consider as being important to their living.

**1.8.6 Capabilities:** Refer to the various freedoms that citizens have to attain the standard of living that he/she has reason to value and can thus be expressed as having the aptitude to achieve desired functionings.

**1.8.7 Poverty:** Is typical likened to the deprivation of a certain pre-defined phenomena. In the context of this study, poverty is defined as the deprivation of basic capabilities needed to achieve desired

functions. A community or citizen is considered to be impoverished if it does not meet the minimum capability threshold as set out in the case study.

**1.8.8 Capability deprivation:** Poverty and capability deprivation is used interchangeable in this study.

**1.8.9 Poverty eradication:** In this study, poverty eradication refers to all communities or citizens meeting the minimum capability threshold as set out in chapter four of this study.

**1.8.10 Capability set:** Is defined as the aggregated set of evaluation criteria used to assess poverty or its related domain i.e housing, education, labour force and basic services.

**1.8.11 Evaluation criteria:** Is a pre-defined criteria sourced from Census 2001 and 2011 relating to its specific capability set.

**1.8.12 Capability space:** Refers to space or community in which poverty is being assessed.

**1.8.13 Weighting:** Assigns criteria importance in the spatial decision making model and developed using a mathematical technique called Principal Component Analysis.

## **1.9 STRUCTURE OF THE STUDY**

The study consists of six chapters, plus an Appendix. This first chapter describes the aim, the context and the justification as well as the general structure of the study. Chapter 2 provides the Literature Review, which details various research works related to the operationalisation of the CA; GIS; MCDM; spatial MCDM, and poverty.

An overview of the methodology and assessment framework utilised to integrate the MCDM techniques and GIS to help facilitate spatial planning and decision making within a poverty eradication context is provided in chapter 3. Chapter 4 presents the assessment results generated by applying the spatial-MCDM methodology to the case study area. This is followed by a discussion of the results generated from the proposed planning methodology in chapter 5. Chapter 6 concludes with a summary of the main findings discussed throughout the study as well as guidelines and recommendations.

Finally, the Appendix includes various Excel workbooks showing the MCDM calculations and the related evaluated criteria used in these calculations sourced from Census 2001 and 2011. The Appendix also includes the STATA results of the PCA used to derive the criteria weights, and the images of the different maps produced.

### **1.10 BENEFITS AND LIMITATIONS OF STUDY**

Many spatial decision problems such as developing alternative poverty eradication resource allocation plans in different decision spaces are complex and require the use of spatial multi-criteria decision making models to develop the appropriate resource allocation solution. Within this context, by developing a spatial multicriteria decision making model to help inform poverty eradication planning in the City of Cape Town, this study offers numerous benefits to planners and decision makers such as

- Providing a comprehensive assessment of poverty in the City of Cape Town metropolis between 2001 and 2011;
- Assisting in developing better decision solutions on appropriate resource allocation plans for poverty eradication interventions; providing and monitoring the extent of poverty between 2001 and 2011;
- Maintaining and improving the well-being of all citizens living in the City of Cape Town; aiding in the identification of communities that would require alternative forms of socio-economic interventions such as informal dwelling upgrades and improving access to basic services, and;
- Comparing and ranking the different communities in the City of Cape Town metropolis according to their poverty levels.

The above-mentioned benefits notwithstanding, it is imperative to stress that it is not the intention of the study to be conclusive on all the aspects of poverty eradication and associated models such as the spatial multi-criteria decision making model. This model, for instance, also has its own limitations, including spatial data sources that are primarily sourced from Stats SA's Census datasets that exclude other qualitative and quantitative criteria relating to poverty and capabilities such as safety, health care and political freedom; criterion weighting, which is developed using a mathematical technique called Principal Component Analysis and is not derived using a consultative process as it is assumed that this may result in skewed spatial results; and geographical boundary changes between inter census periods thus the region topography for investigation in this study changes between 2001 and 2011.

### **1.11 CONCLUSION**

This chapter addressed the main objectives, purpose of, and research questions guiding this study. The next chapter will review different literature related to conceptualising, operationalising and measuring poverty; operationalising the CA, and using GIS and MCDM techniques to assess poverty. This Literature Review is crucial as it will ultimately be utilised to assist in informing the development of the appropriate GIS-MCDM integration methodology used to spatially evaluate the extent of poverty in the City of Cape Town between 2001 and 2011.

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 INTRODUCTION**

In order to assess capability deprivation/poverty it is essential to detail the central themes and methodological approaches to be applied in this study. Thus, this chapter is focused on providing the basic understanding of the objectives of evaluating capability deprivation by detailing multiple authors' studies relating to the use of GIS and MCDM to assess capability deprivation/poverty.

### **2.2 POLICY CONTEXT**

As noted in the previous chapter, since the advent of democracy in South Africa in 1994, the eradication of high levels of poverty and inequality had become the nucleus of policy development and was promulgated through the enactment of the RDP. The RDP was conceptualised as a comprehensive socio-economic policy framework that aimed at pooling all the country's resources in a concerted effort to undo the legacies of the now defunct Apartheid regime (Corder, 1997:184). In efforts to realise this, the government underpinned the framework with six basic principles that, when used simultaneously, created the social; economic, and governance perspectives that sustained the RDP. These six principles were highlighted as follows in the RDP White Paper (1994:8-9), namely as an integrated and sustainable programme, which is a people driven process that promotes peace and security for all, allowing for nation-building by linking reconstruction and development, resulting in the democratisation of South Africa.

To achieve the above-mentioned six basic principles, five key programmes were highlighted for implementation. According to the (The Office of the President, 1994:9), these key programmes included the following:

- 1) Meeting the basic needs of the population, including work opportunities; decent housing; access to water, and sanitation as well as transport;
- 2) Developing human resources through the provision of extensive education and skills development training;
- 3) Building the economy by following a conservative approach, coupled with implementing appropriate tax reform policies and review exchange controls;
- 4) Democratising the state and society by ensuring adequate racial and gender representation, and;
- 5) Implementing the RDP successfully with the view of empowering the poor to gradually be in control of their own development.

Unfortunately, the hype created around the implementation and long-term successes of the RDP was short lived as the RDP Office within the Presidency was closed in March 1996, and much of the strategic functions had been reassigned to various other portfolios within the Presidency (Blumenfeld, 1996:3). Much of the RDP failures resulted from a lack of any general accord relating to specific social and economic policy issues. The RDP framework also provided no operational guidelines or

fiscal budget breakdown on how it would achieve its outcomes of reducing poverty and inequality nor did it recommend any policy priorities and was thus largely perceived by many as more of a 'wish list' rather than a strategic mechanism for promoting economic growth in South Africa (Blumenfeld, 1996:2). Emanating from the failed attempts of the RDP to effectively reduce poverty and inequality was two key pieces of economic reform policies, namely the Growth, Employment and Redistribution (GEAR) policy, which attempted to redress the high levels of poverty and inequality through the upsurges in economic growth accomplished by the rapid expansion in the private sector (Streak, 2004: 272), and the Accelerated and Shared Growth Initiative for South Africa (ASGISA) policy, which endeavoured to halve poverty and unemployment between 2004 and 2014. The latter, i.e. ASGISA, envisages achieving its aim by addressing the following six binding constraints, namely government's incapacity; instability of the South African currency; investment in infrastructure and services; inadequately skilled graduates, technicians and artisans; competitive industrial and services sectors and weak sector strategies, and inequality and marginalisation (The Presidency, 2007:2).

In June 2011, the then newly established National Planning Commission (NPC) released its first Diagnostic Report on South Africa's achievements and shortcomings since 1994. The Report noted that while South Africa has achieved significant progress since 1994 through the implementation of the RDP; GEAR, and ASGISA, that too many South Africans still live in poverty and too little work opportunities has been created. Thus, stemming from this Report, the NPC released a new multi-dimensional framework called the National Development Plan (NDP). The aim of the NDP is to eradicate poverty and reduce inequality by 2030 by raising the minimum living standards of citizens through the creation of more employment opportunities, promoting productive growth thereby improving income levels, increasing access to social wage and quality public services (NPC, 2011: 25). To achieve this, six interconnected priorities were identified. These are to:

- Achieve prosperity and equity by unifying all South Africans around a common programme;
- Support development, democracy and accountability by encouraging active citizenry;
- Stimulate robust economic growth by enabling higher foreign direct investment;
- Promote increased labour absorption;
- Develop critical capabilities of the citizen and state, and;
- Urge stronger societal leadership (NPC, 2011:26).

Within the context of this study, it should be stressed that the NDP draws considerably on the concepts of 'capabilities' and 'functionings', and how these concepts could play a crucial role in citizens leading valued lives. For instance, viewed as a key enabler for eradicating poverty and reducing inequality, human capabilities and the development thereof plays an important role in allowing for citizens to improve their own lives.

### 2.3 CAPABILITY APPROACH

Capabilities and functionings together form the nexus of Amartya Sen's broad normative framework called the Capability Approach (CA) as developed in 1979. The latter could be utilised by planners and decision makers to evaluate and assess several features of citizen's well-being, such as poverty and inequality (Robeyns, 2007:94). The CA framework can also be used as an alternate methodology for developing and evaluating the outcomes of various socio-economic policies or also as a conventional cost-benefit analysis tool used for assessing programme benefits (Robeyns, 2006:352). The key value of this framework is its philosophical underpinning that focuses more on citizen's 'doings' and 'beings'—referred to as functionings—the things he or she has reason to value rather than the insistent focus on citizens' income and expenditure levels. These 'doings' and 'beings' can include functionings such as being well educated, exercising self-respect, participating in elections, and so forth. While functionings reflect the actual citizen achievements, capabilities refer to the different functioning bundles a citizen has the freedom to select from in order for him/ her to lead valued lives (Sen, 1979:218).

With respect to well-being and poverty, Sen (1999:87) argues that poverty must be seen as a deprivation of basic capabilities, as this approach focuses more on the deprivation of the fundamentally important conditions rather than only on the instrumentally (i.e. income) significant conditions. Thus, citizens and their prosperity, rather than a monetary increase, should be the 'end' of economic development. This simply implies that under the CA, the augmentation of living conditions are the primary objective of economic welfare and that the expansion is considered to be an essential part of development (Sen, 1988:16). Sen's CA to poverty reduction has now been broadly accepted in economic and development theory as a normative framework for evaluating poverty. For example, developmental agencies such as the UN's Educational, Scientific and Cultural Organisation (UNESCO); the World Bank, and now the NPC has successfully adopted this approach in their policy development work. Yet many authors (e.g. Gore (1997) and Deneulin & Stewart (2002)) critiqued Sen's work for being too individualistically focused and its failure for not taking into consideration the importance of collective capabilities. For example, Gore (1997:237), for his part, critiques the CA as being too individualistic because of its poverty or well-being measurements being primarily based on individual capability and not acknowledging the importance of collective resources.

While not explicitly conceding to the importance of collective capabilities, Sen (1993:48) states that the CA has been deliberately underdeveloped, as it does not identify immediate evaluation criteria for the operationalisation of the CA. He proceeds to argue against the endorsement of a generalised list of basic capabilities, because, according to Sen, by endorsing a finite list, the CA as an evolving framework for assessing human well-being would be regressed. Likewise, Sen stated that the application of the CA should always be integrated with varying socio-economic policies and frameworks; thus, always resulting in different capabilities and functionings being selected. This

criticism has led to various authors proposing lists of basic capabilities to operationalise Sen's CA. The following section provides a review of various capability lists proposed to operationalise poverty using the CA.

## 2.4 OPERATIONALISING THE CAPABILITY APPROACH

Nussbaum (2003:40) endorses a list of central human capabilities with a specific focus on the "dignity of human beings, and of a life that is worthy of that dignity". With this understanding, Nussbaum proposed a list of ten central human capabilities that operate on the basis of fundamental entitlement and partially accounts for social justice. Nussbaum goes on to note that any community that impedes any one of these capabilities are classed as not being a 'full just society'. Thus, any community that disregards any of the listed capabilities and promotes the other has deprived its citizens of social justice (Nussbaum, 2001:1023). Nussbaum's (2003:41) endorsed list of ten central human capabilities includes:

1. Life: This capability is predominantly defined by life expectancy. A citizen should be able to live an average length life by not dying unexpectedly or prematurely.
2. Bodily Health: The bodily health capability encompasses criteria such as good health, not being malnourished and being adequately sheltered.
3. Bodily Integrity: This capability includes being free from social exclusion and being free from all forms of assault.
4. Sense, Imagination and Thought: The sense capability embraces the freedoms to use one's sense to reason and imagine. The imagination and thought capabilities are used interactively with experience to create work of one's own choice.
5. Emotions: The emotions capability includes the ability to love and care, to grieve, and experience anger.
6. Practical Reason: This central capability involves the notion of good and thinking critically about one's life trajectory.
7. Affiliation: Refers to being able to show affection and participate in different forms of social, economic and political engagements. It also means not being discriminated against based on race, gender, religious affiliations, and so forth.
8. Other species: This capability entails being able to live in apprehension for and in relation to other non-human species such as animals and plants.
9. Play: Citizens should be able to play freely and participate in recreational endeavours.
10. Control over your own environments: Persons must have the freedom to participate in political environments. This capability also includes being able to look for employment and exercising worker rights.

Klasen (2000:36) operationalised the CA through the use of a deprivation index to measure the depth of poverty in South Africa using the so-called SALDRU household survey as developed by the South



African Labour and Demographic Research Unit. This survey sampled 9000 households and included various capability themes relating specifically to household composition; income; expenditures; employment; health status; education; transport; housing; agriculture, and perceptions and aspirations of the population (Klasen, 2000:36). The deprivation index was derived using 14 components that had associated indicators that related directly to the above-mentioned survey themes. Each of the interrelated indicators was scored on a scale of one to five. The index score of five represents the ideal condition, an index score of three allows for a simple yet safe and healthy living, while an index score of one indicates severe deprivation (Klasen, 2000:39). Klasen (2000:40) used the following components and their related indicators to derive the deprivation index:

1. Education: Average years of schooling of all adult (16 +) household members.
2. Income: Expenditure quintiles.
3. Wealth: Number of household durables (list includes vehicles, phone, radio, television).
4. Housing: Dwelling type.
5. Water: Water source.
6. Sanitation: Sanitation type.
7. Energy: Main source of energy for cooking.
8. Employment: Share of adult members of households employed.
9. Transport: Type of transport used to get to work.
10. Financial: Ratio of monthly debt service to total debt stock.
11. Nutrition: Share of children stunted in household.
12. Health Care: Use of health facilities during last illness.
13. Safety: Perception of safety inside and outside of house, compared to five years ago.
14. Perceived Well-being: Level of satisfaction of household.

Van Ootegema and Spillemaeckers (2010:384), set out to examine the usefulness of utilising qualitative data to explore the depth and complexities of the CA framework. They transformed the CA theory into a framework to allow for focus group discussions on well-being and poverty. The initial framework for discussion was populated using a list of dimensions that characterises and effects poverty and that would be relatively simple for all of the focus group members to comprehend. The list of dimensions used for deriving the poverty measure was compiled based on an extensive literature review on different prevailing poverty indices. The different indices consulted were the Human Development Index (HDI), the Index of Economic Well-being, and the Measure of Economic Welfare. Based on these, eight dimensions were identified and used for discussion in the focus groups. The eight dimensions chosen were:

1. Health;
2. Social Environment;
3. Wealth;

4. Work;
5. Physical environment;
6. Leisure;
7. Education, and;
8. Political life (Ootegema & Spillemaeckers, 2010:386).

According to Canoy *et al.* (2010:391), the European Commission is required to provide Impact Assessments (IAs) for each key policy proposal so as to enhance the quality of all European regulatory frameworks. At this point in time, the operational bases for these IA's are not sufficiently detailed as it is uncertain on how its objectives are interconnected and play an overall role in meeting its goal of improving the well-being of all European citizens.

The CA was also selected by the European Commission as the preferred normative framework to be used for developing sound operational foundations for all IAs. To operationalise the CA, the European Commission defined a list comprising nine fundamental and universally 'applied basic capabilities' used to assess trade-offs, investigate unintended policy consequences and impacts. Canoy *et al* (2010:392) list the fundamental and universally 'applied basic capabilities' as:

1. Health, longevity;
2. Safety;
3. Education;
4. Standard of living;
5. Productive and valued activities;
6. Quality of social interactions;
7. Environment;
8. Culture and entertainment, and;
9. Basic rights.

Martinetti (2000:207) attempts to advance the possibilities of developing an empirical application for assessing Sen's concept of poverty and well-being by using the so-called fuzzy sets theory. With this objective of analysing the CA methodology, a quantitative exercise based on micro- data from Italy was conducted. To implement this analysis a list of functionings and related indicators used for assessing poverty were identified. Martinetti (2000:220) highlighted these functionings and indicators as:

- 1) Housing: This capability set encompasses a crowding index, defined as the number of rooms available for each family and a basic housing utility measure that includes telephone and water availability.
- 2) Health conditions: The health conditions capability explains the absence and presence of 15 different chronic illnesses.

- 3) Education and knowledge: This capability is measured using the following indicators, namely highest educational attainment; number of books read in the last twelve months, and frequency of reading the newspaper.
- 4) Social interaction: Refers to the relationships with other citizens and being able to participate in social life. Participation is assessed using 15 variables that are divided into three groups, namely passive participation; active participation, and political interests.
- 5) Psychological conditions: This capability articulates the citizen's perception of their own condition. To operationalise this capability, nine variables were used and classed into five groupings, namely economic conditions; personal and social relations; health conditions; working conditions, and leisure time.

While the previous section discusses the criteria used to operationalise Sen's normative framework, the following section will review different combination rules used to operationalise unstructured decision problems. According to Sen (1981), both poverty and well-being can be defined as being approximate and thus unstructured in nature. This is largely because of these two concepts being based on multiple and often conflicting criteria. From an operational point of view, MCDM techniques can play a critical role since their main strengths lie in their ability to solve complex questions typified by different inconsistent assessments, thereby allowing for a joint assessment of poverty and well-being (Munda, 2003:1).

## **2.5 MULTI-CRITERIA DECISION MAKING (MCDM) TECHNIQUES**

All poverty and well-being related problems are complex and multi-criteria in nature because of multiple objectives highlighted by planners and decision makers. MCDM techniques assist policy planners and decision makers to understand these problem objectives, values and preferences. These techniques ultimately guide them in the process of ranking and comparing different alternatives to assist in the selection of the most preferred solution to the decision problem, which, for the purposes of this study, is the most capability deprived community in the City of Cape Town.

### **2.5.1 PREVIOUS STUDIES IN APPLYING MCDM TECHNIQUES TO POVERTY AND WELL-BEING**

In Vancouver, Bell *et al.* (2007:1) applied an Ordered Weighted Average (OWA) multi-criteria technique to amalgamate 21 reselected Census indicators and their related weighting schemas into a single socio-economic status deprivation index. In this study, the OWA index was developed from a sequence of intersection operations. Furthermore, an OWA weighting logic was applied to analyse the extent to which the original weights assigned by the medical health officers provided a more credible indication of community social economic status than when the data driven weighting schemas were assigned (Bell *et al.*, 2007:2). The first set of weighting schemas assigned to each of the indicators were referred to as global weights and represented the initial importance ranking of each indicator while a local weighting schema was consigned on a case by case basis. Each of the cases in this study

represented individual geographical units. The local weights were assigned according to the indicator's position relative to the other indicators' position in the database (Bell *et al.*, 2007:6).

Based on these OWA model structures various weighting scenarios could be developed. These scenarios ranged from the classical risk adverse Boolean intersection model ( $\cap$ ) to the risk seeking Boolean union model ( $\cup$ ). The advantages of using this OWA approach was that the indicators that were most representative of each community's Socio-Economic Status (SES) ranking relative to the other surrounding communities were allowed to influence its ranking. This allowed the socio-economic status model to show less influence from the medical health officer's global weights, but provided planners and decision makers with a conjectural base to evaluate the rank importance of each indicator selected (Bell *et al.*, 2007:6). The full intersection or AND ( $\cap$ ) model allocates an order weight of 1 to the indicator theme within each geographical unit that had the lowest index score and 0 to the remaining six indicator themes. The full intersection model not only identifies the severely deprived community, but also assesses the strength of the social economic status indicator relationships with a higher degree of control of the weights given by the medical health officer (Bell *et al.*, 2007:7). The full union or OR model assigns an order weight of 1 to the indicator theme with the highest index score and 0 to the remaining six themes. A full trade-off (average) of the order and local weights were obtained when all indicator themes were assigned order weights of equal proportion.

Qizilbash and Clark (2005:109) used a so-called fuzzy logic multi-criteria model to operationalise Sen's (1979) CA to assess poverty and well-being in South Africa. The main reasons for using this model was not to address the issue of poverty intensity but more to address the vagueness or imprecision of poverty. The vagueness of poverty and well-being relates to the notion that no clear delineation exists between the poor and non-poor, and is not specific to a particular variable. Qizilbash and Clark (2005:103) draw on the work concerning fuzzy poverty measurement of Cerioli and Zani (1990) that denote the group of poor people as A.  $\mu_A$  is described as the degree of membership of A and is assigned to the interval [0,1]. Thus, if a citizen is classed as being poor then  $A=1$  and if citizens are classed as being non-poor then  $A=0$  (Qizilbash & Clark, 2005:106). However, if a citizen is classed as being part of the poor to a certain extent then  $0 < \mu_A < 1$ . In order to rank levels of deprivation using the several dimensions, Qizilbash and Clark (2005:107) utilise an ordinal method of scoring. This method is used because if one citizen has higher levels of poverty, then that citizen is allocated a lower number. Qizilbash and Clark (2005:107) operationalise the fuzzy measure by using  $\varphi$  for rank order score, thus  $\varphi'$  is the value below which a citizen is classed as being poor in dimension  $a$ .  $\varphi''$  is defined as being the best score for poverty in dimension  $a$ .  $\varphi_{ba}$  gives the score of citizen  $b$  in the  $a^{th}$  dimension. Citizens  $b$ 's degree of membership of the group of the deprived in dimension  $a$  is written as  $z_{ba}$ . It is set to 1 if  $\varphi_{ba} \leq \varphi'_a$  and to 0 if  $\varphi_{ba} \geq \varphi''_a$ . If  $\varphi'_a < \varphi_{ba} < \varphi''_a$ ,

then  $z_{ba} = (\varphi_a'' - \varphi_{ba})/(\varphi_a'' - \varphi_a')$ . The degree to which the citizen is classed in the poor group,  $\mu_A$  is the weighted average of  $z_{ba}$  (Qizilbash & Clark, 2005:108).

Furthermore, Qizilbash and Clark (2005:110) apply the research done by Cheli and Lelli (1995) that focuses on cut-off limits to define citizens as being definitely poor or non-poor. This cut-off approach ranks citizens according to their attainments in terms of variable  $x$  for dimension  $g$ .  $q$  provides the ranking order for the level of attainment in terms of  $x$ , and is assigned a value of one for the highest ranking level, two for the second highest, three for the third highest, and so on (Qizilbash and Clark, 2005:108). In terms of the work done by Qizilbash and Clark (2005:108), they denote the degree of membership of the group of deprived citizens for someone ranked,  $x$  in terms of  $r_a$  as  $h(r_a^x)$ . Qizilbash and Clark (2005) set  $h(r_a^x) = 0$  for  $x = 1$ . The distribution for  $r_a$  sorted from increasing ordering according to  $x$  as  $F(r_a)$ , then for  $x > 1$ , the degree of membership is  $h(r_a^x) = h(r_a^{x-1}) + \{F(r_a^x) - F(r_a^{x-1})\}/(1 - F(r_a^{(1)}))$  where  $h(r_a^x)$  falls on the interval  $[0,1]$  and is a measure for dimension  $a$  only (Qizilbash & Clark, 2005: 108).  $h(r_a^x)$  can be utilised in various ways of aggregating across the dimensions and shows that citizens that are doing best in terms of the distribution of a certain indicator are classed as not being poor and the citizen who is doing worst is classed as poor. Qizilbash and Clark (2005:110) continue the discussion by delineating how the upper and lower cut-off limits for the fuzzy poverty measure were developed and note the limitations and misconceptions of the fuzzy logic approach.

Qizilbash and Clark (2005:110) noted in their evaluation study on poverty that they have not attempted to amalgamate several indicators to derive an overall deprivation measure to assess the intensity of poverty. This is a common misconception by many, as the fuzzy poverty measures are used to address the issue of imprecision and not the intensity of poverty (Qizilbash & Clark, 2005:109). Sen maintains in his work regarding the CA that poverty is unconditional in a capability space even within certain material spaces. This study allures to the concept of 'relative position' when considering MCDM techniques for assessing poverty. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is the preferred technique to be used as it operates on the concept of the best alternative having the shortest position from the positive ideal solution and the farthest position from the negative ideal solution.

Carbonaro (2011:4079) uses the TOPSIS MCDM method to evaluate citizen well-being using 11 indicators for 19 different regions within Italy. The method provides planners and decision makers with a priority list of regions, indicating which region requires urgent government attention and immediate action in one or more dimensions. In the evaluation study, the 19 regions were assigned as the alternatives and the 10 indicators sourced from the Italian National Institute of Statistics were used as the evaluation criteria. The objective of the study was to rank the 19 alternatives in terms of their well-being. The central view of the TOPSIS method is that in most multiple criteria decision

scenarios, the ideal solution does not exist, thus within a certain region you will never find all indicators of a certain dimension to be at its best level (Carbonaro, 2011:4080). In using the TOPSIS method to evaluate citizen well-being, Carbonaro (2011:4084) notes three main advantages of the approach, namely the:

- 1) Best criterion performance provides the ideal solution. Thus, the ideal solution represents the yardstick to be achieved by regions with lesser performance;
- 2) Difference between the region with the ideal solution and other alternatives illustrates the effort necessary to achieve improved performance, and;
- 3) Weighting schema used for TOPSIS allows for weighting schema and indicator modification, and for this reason the method is adaptable to accommodate for multiple dimensions and trade-offs.

By focusing on the Zhejiang Province in China, Xiajing and Junjie (2011:135) used the TOPSIS method to amalgamate 10 evaluation criteria to assess regional economic disparity in 11 cities located in the Zhejiang Province between 2007 and 2009. The outputs of the TOPSIS method showed the economic progress made in the Zhejiang Province between 2007 and 2009. The results of the TOPSIS analysis were used by planners and decision makers to identify regions where regional developmental emphasis are required so that government could introduce multiple built environment programmes and interventions that promote massive infrastructure investment in especially the transportation system (Xiajing and Junjie, 2011:139). In this study it becomes apparent that space occurs in an arena of regional disparity, not only as an inert support but also as an operational influence in its own conversions. In this instance, it thus becomes imperative to spatially analyse the regional disparity and predict its spatial growth according to the combination of multiple conflicting criteria (Openshaw & Openshaw, 1997). According to Previl *et al.* (2003:3), space and time can thus be considered as being continuous and regional disparities can be spatially analysed. If these events are made discrete, the 11 cities can be categorised and according to Previl *et al.* (2003:3) be made a suitable application field for GIS.

## **2.6 GEOGRAPHICAL INFORMATION SYSTEMS (GIS)**

As mentioned in the previous chapter, Geographical Information Systems (GIS) are defined as being computer based systems that enable the storage; retrieval; manipulation; display, and analyses of spatial data (Church, 2002:541). The main feature of GIS is the utilisation of location referencing classification, which allows users to spatially analyse data in relation with other specific location data (Church, 2002: 541). Given that poverty/ capability deprivation has a spatial context and is evaluated within a capability space, it has the ability to concentrate within various smaller communities and in doing so, creating smaller pockets of poverty. Planners and decision makers require a tool such as GIS to identify concentrated regions with high levels of poverty and inequality in order for appropriate poverty programmes and interventions to be correctly targeted at communities most in need of government interventions. By narrowly targeting community intervention, government can prevent

the wrongful application of poverty programmes and minimise any fiscal 'leakages'. Notwithstanding, using narrowing spatial targeting methodology does not provide proviso to investigate the spatial correlations in the spatial patterns of poverty. This spatial correlation phenomena is called spatial autocorrelation and is present when a criterion score X at location A is dependent upon the score of variable X at location B. The presence of spatial autocorrelation can be best explained using Tobler's (1930) first law of geography, which states that "Everything is related to everything else, but near things are more related than distant things". Put in another way, autocorrelation is spatially present when events are geographically clustered. For example, a high capability deprivation score of one community is likely dependent on the capability level and socio-economic conditions of the adjacent community. Different spatial autocorrelation methods such as Moran's I (Orford, 2004; Amarasinghe *et al.*, 2005) has been used to examine this spatial dependency and identify spatial patterns of poverty that provides planners and decision makers with a better perspective and extent of poverty eradication planning.

Orford (2004:711) uses ESRI's ArcView GIS (version 3.2) and a local Moran's I spatial statistical method called LISA, which was incorporated into the GIS software using Avenue scripts. The GIS software was used to identify regions with concentrated poverty and affluence of inner London between 1896 and 1991. This study of inner city poverty and affluence was conducted to gain a perception of the spatial distribution of the rich and poor in the inner city and the processes that preserves the spatial arrangements. According to Orford (2004:702), while copious amounts of research exists on measuring and identifying deprived communities, very little research has been done on understanding what the social and economic outcomes of concentrated affluence will have on the socio-economic fabric of cities. The study used a 10% sample from the 1991 Census to derive the Ward Poverty Index (WPI), which was used to measure social class status. The WPI ranges between zero and one. A community with a WPI value of less than 0.5 represents wards where a large number of citizens were classed as being more affluent. Communities with a WPI score greater than 0.5 represents wards where a large number of citizens were classed as being more poor (Orford, 2004:708). These WPI results were used as inputs into the spatial statistical methods called LISA to identify concentrated regions of poor and affluent. The spatial clustering patterns between 1896 and 1991 identified the changing topography of poverty and affluence in inner London and also suggested that affluent regions remained more stable to change as compared with poorer regions (Orford, 2004:715).

In the research conducted by Peters and Skop (2007:149), the researchers assess the transforming patterns of poverty and segregation amongst various socio-economic groups in Metropolitan Lima, Peru. Their work is divided into two main objectives; i.e. (i) to uncover the core themes of segregation within Latin America using detailed national Census data for 1993 as sourced from the Peruvian Census of Population and Housing combined with metropolitan survey data, and (ii) to investigate the

advantages of a diversified model to assess segregation in the Latin American context. In order to meet these two objectives, they developed a SES index using three indicator themes, namely Education; Employment, and Tenancy. The SES was used as the input into the spatial autocorrelation measure (i.e. LISA) to investigate the pattern of segregation for social economic status. The LISA results were consistent with urban development theory and showed segregation and clustering in the bordering communities, where regions of affluent communities were isolated from the poorer communities. The spatial autocorrelation results also showed fragmentation at a local level where various social groups lived near each other (Peters & Skop, 2007:165).

Amarasinghe *et al.* (2005:1) assessed the spatial topography of poverty in Sri Lanka using a nutrition-based poverty line. The analysis was completed by using a divisional secretariat poverty map, developed by merging the principal component analysis and small area estimation techniques, as data input into the both the Global Moran's I and Local Moran's I measures. The results of the divisional secretariat poverty mapping showed that significant spatial clusters of poorer households existed in four rural districts of Sri Lanka where agricultural subsistence was the main source of revenue for most of the households in these rural districts (Amarasinghe *et al.*, 2005:8). The spatial clustering of poorer districts on the periphery of the urban centres also suggested that poorer households had limited access to various economic opportunities. The spatial autocorrelation measures that were used to measure the significance of the spatial clusters and to illustrate the spatial variation of poverty across Sri Lanka displayed a positive relationship between the spatial clustering of poor and non-poor households and irrigated areas. These results showed that access to irrigation services in these rural districts can play a significant role in reducing poverty (Amarasinghe *et al.*, 2005:20).

The above review on the application of GIS shows the advantages of the 'front end' and 'back end' functionings of GIS that allowed various researchers to better interpret, understand and communicate their research findings. Despite these advantages, GIS alone does not provide planners and decision makers with unlimited abilities to manage and understand the degree and complexities that exists with respect to un/semi-structured decision making problems. In 1988, a well-known GIS researcher concluded that, "...GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen, 1988:1554). This definition was later disputed by others citing that the abilities of GIS fell well short of providing decision makers with the necessary decision making tools needed to make informed decisions (Densham & Goodchild, 1989)). Since the 1990s, the decision making capabilities of GIS has been enhanced by coupling GIS with multi-criteria decision making techniques (Chakhar & Mousseau, 2010:1159)

## **2.7 SPATIAL MULTI-CRITERIA DECISION MAKING**

Multi-criteria decision making analysis allows planners and decision makers to develop comprehensive decision making solutions for complex decision problems involving multiple conflicting decision criteria. A number of MCDM techniques exist for analysing such complex



decision problems. The evaluation criteria used in these non-spatial MCDM techniques assume spatial homogeneity; however these conflicting evaluation criteria typically differ in space (Kordi & Brandt, 2012:43). Therefore, it is necessary to couple MCDM techniques with GIS to incorporate the spatial element in the decision making analysis process (Malczewski, 1999). In spatial multi-criteria decision making analysis, spatial data and value judgements are integrated to develop a more informed evidence-based solution.

Passuello *et al.* (2012:2) developed a spatial multi-criteria decision support tool to identify the suitability of various agricultural lands in the North Eastern part (i.e. Catalonia) of Spain to receive sewage sludge as an organic amendment. This spatial decision support tool was created by coupling Logic Scoring of Preference MCDM method with GIS and populating the tool using 12 evaluation criteria. The criteria selection process was informed by various literature reviews, legislation and specialist opinions (Passuello *et al.*, 2012:3). The Logic Scoring of Preference MCDM method was used to amalgamate the 12 evaluation criteria and was selected because of the method's ability to deal with criteria 'simultaneity' (Passuello *et al.*, 2012:5). To execute the spatial model, the software Idrisi Andes v.15 was used because of its extensive range of appropriate operators developed to be used in raster format (Passuello *et al.*, 2012:6). The results of the spatial analysis found that most areas were mainly located in the Central Depression and in the Ebro River catchment areas in Catalonia. (Passuello *et al.*, 2012:7).

In a study conducted by Sánchez-Lozano *et al.* (2013:545), the researchers combined GIS and MCDM methods to evaluate the ideal location for the placement of photovoltaic solar power plants in the Cartagena area in Spain. The suitable locations were identified and evaluated using the MCDM method called Analytical Hierarchy Process (AHP) to determine the importance of each evaluation criteria, and coupled with this, TOPSIS was used to amalgamate the weighted criteria into a suitability index. The suitability index was used to rank all relevant evaluation criteria to identify the ideal solution i.e. the most suitable area for the development of solar photovoltaic plants (Sánchez-Lozano *et al.*, 2013:548). The results of the MCDM method were coupled with GIS software called gvSIG. The gvSIG was the preferred software because it is free; it has the ability to work with both vector and raster files, and it allows the user to access server maps (Sánchez-Lozano *et al.*, 2013:546). The GIS-MCDM outputs classified the suitable alternatives into four intervals (i.e. poor; good; very good, and excellent).

## **CHAPTER THREE: METHODOLOGY FOR INTEGRATING MCDM TECHNIQUES AND GIS TO FACILITATE POVERTY ERADICATION PLANNING**

### **3.1 INTRODUCTION**

The evolution of systems and processes in the Science and Technology Industry over the past two decades has led to the coupling of GIS and MCDM techniques achieving encouraging results within different planning domains. The main reason behind these successes is the ability of GIS and MCDM techniques to integrate multiple decision maker perspectives simultaneously and produce a single coherent spatial multi-variate result that can be used to inform decision making. Poverty eradication planning is a complex multi-criteria decision making problem, which involves reaching consensus amongst multiple informed decision makers within various political spheres. The major challenge for these decision makers is the structuring of a complex decision making problem like poverty in such a way that they are able to develop a multi-faceted pattern in a space that incorporates multiple ideas and perspectives that could be utilised to inform the decision problem.

This chapter explores the integration of MCDM techniques and GIS to help facilitate spatial planning and decision making within a poverty eradication context. Multi-criteria analysis will be used to simultaneously integrate both qualitative (i.e. decision makers perspectives) and quantitative (i.e. Census criteria) data, which will be used to identify the most deprived alternative. As noted in the previous chapter, two different GIS - MCDM methodologies will be used, namely spatial TOPSIS and spatial COPRAS for the multi-criteria poverty eradication evaluation.

### **3.2 DEFINING POVERTY**

Between 1994 and 2014, the progress made in terms of poverty eradication has been slow (NPC, 2012:1). Too many South Africans are still unemployed and living too close or under the poverty line (NPC, 2012:24). At the time of writing, the official unemployment rate for the Western Cape was 20.9% (Stats SA, 2014:xvi), while in 2011 approximately 47.8% of the labour force population earned less than R800 per month. One of the key components to the slow progress made over the last two decades has been the government's inability to reach consensus on how poverty should be conceptualised and defined. However, the South African Government share this inability with a number of other governments and researchers since poverty is defined in different ways by different people and institutions, making it a highly contested concept. May (2001:23), in reviewing 24 studies of poverty in developing countries, speaks of an 'elusive consensus' when it comes to definitions, measurement and analysis of poverty. This inability has disadvantaged the poor significantly in terms of creating sufficient socio-economic opportunities as the South African Government has been unable to consistently measure, locate and manage where the poor live. Work by Hagenars and de Vos (1988:212) states that these issues largely stem from pragmatic arguments based on data availability; political decisions, and historical patterns.

These measurement, location and management issues were noted by the former South African Minister of Finance, Mr Trevor Manuel at Stats SA's launch of its report on measuring poverty in South Africa in 2003. He stated that, "If we cannot measure it, we cannot manage it" (Manual, 2000:3). This study goes further arguing that if one cannot define poverty, you cannot start to measure poverty, let alone manage poverty. The point is, one needs to determine a practical definition for poverty in order to address and ultimately eradicate it. One step towards cementing a coherent definition of poverty has been the shift away from the conventional one, i.e. the one-dimensional (income) approach of evaluating poverty, to a multi-dimensional approach as this methodology proved to provide more intuitive insight for planners and decision makers in targeting impoverished communities (Ballon & Krishnakumar, 2008:3).

In 1994, the South African Government through the promulgation of the RDP theorised poverty within a multi-dimensional framework known as the Basic Needs Approach. This particular approach refers to a minimum threshold of certain basic services necessary to meet the needs of the citizen (Yip, 2012:4). Thus, a citizen was classed as being poor if he/ she had inadequate access to a set of predefined basic consumptions such as land and housing; safe water and sanitation; affordable and sustainable energy sources; access to good quality education and training for children and adults; and improved health care services (The Office of the President, 1994:9). Nonetheless, what the basic needs approach fails to contemplate is that a hierarchy of basic needs exists for each citizen. Therefore, each citizen has his/ her own desires and priorities and the failure of the RDP to acknowledge this issue had resulted in the South African Government's failed attempts to redress the high levels of poverty in this country.

To address this issue and effectively eradicate poverty by 2030, the NDP conceptualises poverty through the lens of Amartya Sen's CA Framework, which shifts the policy focus primarily from fiscal growth/ material deprivation to more interpersonal matters such as freedom, human dignity, and personal well-being (Clark, 2005:1340). According to Robeyns (2007:93), the CA is a broad socio-economic framework used to evaluate and assess citizens' well-being and social pre-arrangements, and conceives various socio-economic policy reforms through the promotion of citizen functionings and capabilities. Sen (2005:5) describes functionings as "...an achievement of a person" and includes matters such as a good education and a good job, whereas capabilities refer to the freedoms that citizens have to achieve the lifestyle that he/she desires and has reason to value; for example, freedom to migrate and freedom to be well educated and healthy (Frediani, 2010:175). From the perspective of the NDP, poverty is now viewed more than just as a shortage of monthly income or the deprivation of certain basic needs, but as the lack of certain citizen capabilities needed to achieve their valued functionings (NPC, 2012:38). Sen (1999:87) states that income deprivation is an influencing variable on poverty but from a capabilities perspective rather than just from a monetary based perspective. His reasons for this are the following:

- Poverty can be rationally recognised using the capabilities approach that focuses on deprivation measures that are contextually and fundamentally important to decision makers, unlike fiscal measures that are only instrumentally important to researchers and planners;
- Capability deprivation is affected by multiple factors other than income deprivation, and;
- The spatial relations between capability deprivation and income deprivation are varied between countries; provinces; districts; communities, and even between households. Accordingly, a subjective impact of income on capabilities exists (Sen, 1999:87).

Based on the above-mentioned points, poverty can be defined as the *deprivation of basic capabilities needed by citizens to achieve valued functionings*. This study will adopt this capabilities approach definition of poverty as a framework for assessing poverty eradication in the City of Cape Town between 2001 and 2011. Despite this preferred definition of poverty, the fundamental problem is still the implementation of the CA and the identification of appropriate basic capabilities needed by all South Africans to lead lives free of poverty. In this regard Sen, the conceptual architect of the CA, over the last three decades has failed to provide researchers and planners with any clear operational guidelines or frameworks to apply in assessing poverty. He maintains that the operationalisation of poverty must be based on an assortment of capabilities selected based on value judgements that are to be made using a collaborative approach (Alkire, 2007:6).

### 3.3 OPERATIONALISATION OF POVERTY

As defined in the previous section, poverty is conceptualised using a broad based definition that is not primarily based on fiscal resources but on the citizens' inability to realise a certain threshold of basic capabilities required to function optimally. This definition however does not describe specific criteria or capabilities that researchers and planners can consider when developing poverty models. Consequently, the major challenge in assessing poverty as indicated by Robeyns (2006:352) lies in the translation of the capability theory into actual practise. This is largely due to Sen's inability to define a single coherent list of usable basic capabilities or propose a methodology that could be utilised when selecting basic capabilities.

The question many researchers ask is whether there should be a so-called capabilities list. Nussbaum (2003:40) supports the idea of endorsing a single list of capabilities and believes that a capabilities list can play a significant part in "fundamental constitutional guarantees". She proposes an open-ended list of central human capabilities themed around Women and Human Development. Accordingly, her proposed list of capabilities is:

- Life: living a full life and not dying prematurely;
- Bodily health: having a healthy lifestyle, being well-nourished and being reproductively healthy;
- Bodily integrity: being free from social exclusion and violent threats;

- Sense, imagination and thought: being free to use one's senses, to conceive ideas and to deliberate;
- Emotions: supporting relations which is important to human development
- Practical reason: engaging in critical thinking when planning one's life;
- Affiliation: to participate in various forms of human interaction and being part of a non-discriminating society;
- Other species: living in interest with nature;
- Play: enjoying leisure activities; and
- Control over one's environment: being part of a democratic society and having the right to seek equal employment.

Sen (1993:32) has argued against the endorsement of a generalised list of basic capabilities and functionings because, by endorsing a finite list, the capabilities approach as an evolving framework for assessing human well-being would regress. Sen also states that the application of the capabilities approach should always be integrated with varying socio-economic policies and frameworks, thus always resulting in different capabilities and functionings being selected. For these purposes, Sen has intentionally not properly defined the CA and not endorsed a fixed list of capabilities and functionings.

At this point, the use of the capabilities approach framework to evaluate poverty has become extremely complex. The absence of an endorsed functionalities list places the responsibility of capabilities selection directly in the hands of the researcher or policy planner. Therefore, any proposed list of capabilities would be scrutinised and be made vulnerable to biasness (Robeyns, 2003:39). The work done by Alkire synthesises five main approaches used by researchers and planners to elicit lists of usable capabilities and functionings, thereby attempting to neutralise the biasness factor. These five approaches are (Alkire, 2007:7):

- selecting capabilities and functionalities based on data availability or data agreements;
- choosing capabilities and functionalities based on assumptions of a person's values;
- using a public accord when eliciting capabilities and functionalities;
- selecting capabilities through a continuous consultative process, and;
- extracting capabilities and functionalities from an analysis of people's values based on qualitative and quantitative data.

Within the context of the NDP, starting with a pre-defined list of capabilities is essential to avoiding researcher or planner biasness or political manipulation. This list will help researchers and planners in assessing adjustments and assist them in evaluating unintended policy outcomes (Canoy *et al.*, 2009:392). The list also provides a reference frame for deliberations on various policy plans amongst the various organs of state who are involved in the implementation of the NDP. In the absence of any

operational guidelines or frameworks for the selection of capabilities and functionings, the NPC, through an extensive deliberation and community participatory process, has identified a compendium of citizen capabilities to be subsumed into various policies and frameworks with the goal of eradicating poverty by 2030. The list of capabilities identified for evaluation is (NPC, 2012:38):

- Nutrition;
- Housing;
- Water, Sanitation and Electricity;
- Transport;
- Education and skills;
- Safety and Security;
- Health Care;
- Employment;
- Recreation and leisure; and
- Clean Environment.

This list of basic capabilities identified in the NDP is adopted in this study as capability sets to be used in developing a poverty model used to evaluate capability deprivation in the City of Cape Town. The following section provides an operational framework called a spatial MCDM method. This model-based set of techniques is used to analysis spatial decision problems by processing various capability sets and the related conflicting evaluation criteria to assist planners and decision makers' in their planning processes.

### **3.4 CONTEXT OF SPATIAL MCDM**

Snyder and Glueck (1980:73) define planning as “activities which are concerned specifically with determining in advance what actions and /or human and physical resources and required to reach a goal. It includes “identifying alternatives, analysing each one, and selecting the best ones”. When interpreting this definition within a GIS-MCDM problem context, planning includes those activities that assist in identifying the ideal solution by ranking different alternatives based on the planners and decision makers' inclinations in unification with various area specific criteria. Based on these spatial rankings, appropriate human and physical resources can be allocated. These allocations based on GIS-MCDM planning are therefore complex because not only does it incorporate multiple conflicting criteria, but it also builds into the spatial decision model as well as the planners and decision makers' preferences.

The problem of poverty eradication planning is assessed in an attempt to develop a robust GIS-MCDM methodology which can be used to inform the efficient and effective distribution of the appropriate government resources required to effectively eradicate poverty. This methodology requires that accurate data and information be available in suitable formats to ensure that the most

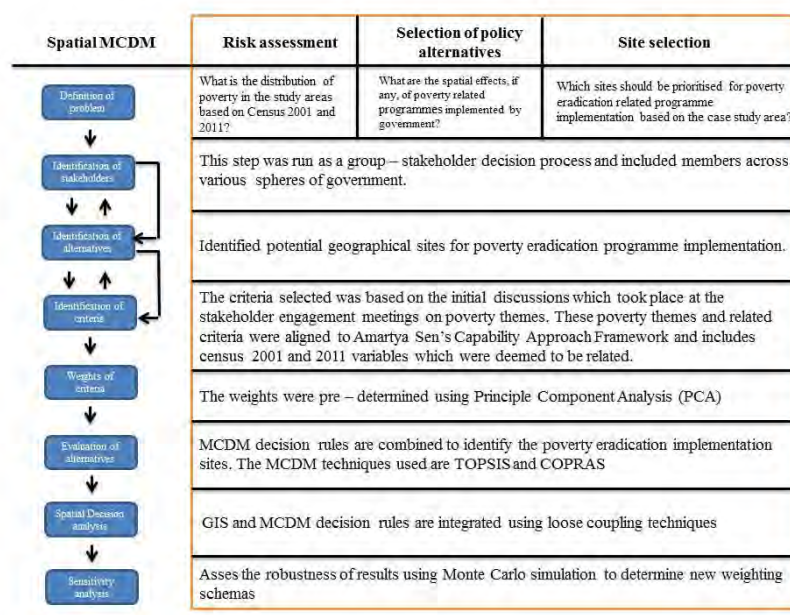
appropriate decisions can be made, thereby ensuring that the necessary government interventions are provided to those people who are most deprived. According to Keeney (1982:807), this decision making process generally encompass four general activities, including structuring the decision problem; assessing the possible impact of each alternative; determining the preferences of decision makers, and evaluating and comparing each alternative.

In this study, the above-mentioned activities will be incorporated into an eight phase theoretical multi-criteria decision making model, which will be used to develop an integrated multi-criteria decision making methodology used in assessing poverty eradication. These phases are:

1. Defining the decision making problem;
2. Identification of stakeholders;
3. Identification of alternatives;
4. Identification of decision criteria;
5. Calculating the criteria weights;
6. Evaluation of the alternatives;
7. Spatial decision analysis, and;
8. Conducting sensitivity analysis.

The figure below represents the GIS-MCDM framework that this study will utilise to provide methodical sustenance to a complex multiple criteria decision making problem. As noted already, the GIS-MCDM process commences when the decision maker formulates the decision making problem, thereby defining the main objectives of the multi-criteria decision making problem, and culminates in a sensitivity test to assess the robustness of the ranking results.

Figure 1: GIS-MCDM framework for poverty eradication planning



Source: Adopted from work done by Keeney (1982:807) and Hongoh *et al.* (2011:19)

### 3.4.1 DEFINING THE PROBLEM

The NDP aims at eradicating the proportion of households living with a monthly income of less than R443 (in 2011 prices) per person by 2030, through the enhancements of quintessential capabilities such as education and skills, and access to work opportunities (NPC, 2012:363). Since Stats SA only publishes monthly income data as grouped categories, the R0–R800 and R0–R9 600 Census proxy variables were used for monthly and annual income, respectively, to assess progress. While these Census proxy variables differ from the R443 per month figure provided by in the NDP, it is still significantly low given that the minimum prescribed income for domestic workers, at the time of writing, is R1 877.70 per month. These outcome indicators fundamentally translate into income being considered as the primary manifestation of citizens ‘living valued lives’. From a policy planning and decision maker’s perspective, this means that the conceptualisation of community based policy and programme interventions developed to redress capability issues will be driven solely from a conventional monetary perspective.

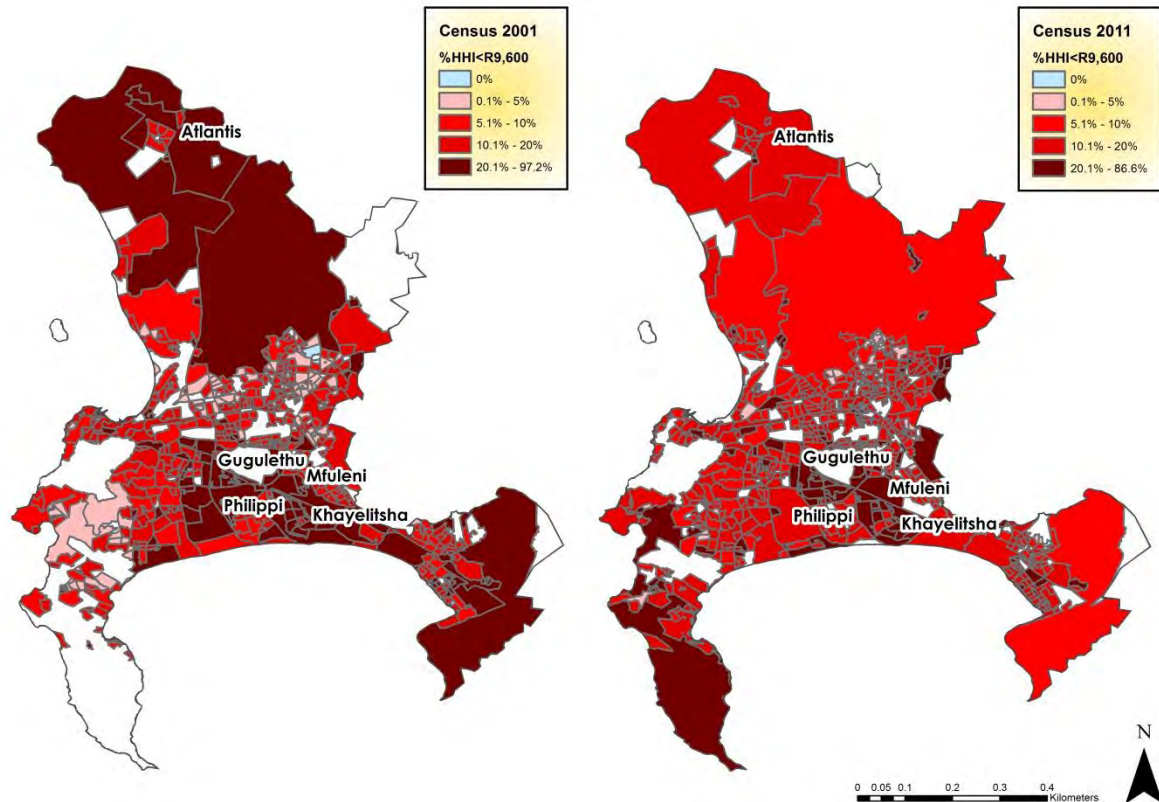
In the City of Cape Town, between 2001 and 2011 the proportion of households earning an annual income of less than R9 600 (annual Census proxy for R443 per month) had decreased from 24.5% to 20.4%. Due to the wide range of capability determinants, risk of deprivation is homogeneously distributed in the City of Cape Town, and the understanding of where risk occurs and how the level of risk may vary from one community to another is a common area of study in the field of capability deprivation. Thus the percentage change does not necessarily translate into more people living ‘valued lives’ as 74% of all service delivery protests in the Western Cape in 2011 occurred in the City of Cape Town (Karamoko and Jain, 2011:26), and also the City of Cape Town consisting of one suburb (i.e. Nyanga) which is consistently classed as the murder capital of South Africa. These communities do not live ‘valued lives’, when considering more than income alone, thus viewing poverty from a single dimension perspective would be problematic for decision makers.

The use of a traditional one-dimensional approach such as income for measuring poverty has shown to have resulted in significant losses of critical information. This approach removes the nuances and complexities that exist between the poor and non-poor; thus many countries begun to steer clear from using this traditional one-dimensional approach for assessing poverty (Belhadj & Limam, 2011:995). The loss of information results in the skewed distribution of government policy alternatives, allowing for most of the intended policy programme benefits going disproportionately to the unintended population. The consequences of this type of inadequate programme targeting are that government departments are not able to achieve the desired policy outcomes, such as eradicating income poverty. Map 1 below shows that while progress has been made in terms of eradicating income poverty in the City of Cape Town, the progress has been slow. This is largely as a result of poorly located social and economic projects such as EPWP, Informal Housing Upgrading and other transport related projects. Thus from a decision maker perspective it is important to do a proper site selection planning so as to



control the allocation of limited resources available to government thereby ensuring that the intended population benefit from government’s poverty specific interventions.

Map 1: City of Cape Town comparison between 2001 and 2011 of households earning less than R9 600 per annum



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### 3.4.2 IDENTIFICATION OF STAKEHOLDERS

In the CA, poverty or deprivation is conceived by Sen (1993) as a person’s inability to achieve a set of capabilities to lead a valued life. Poverty or deprivation can be conceptualised using a variety of theoretical and practical underpinnings. In order to evaluate and assess the degree and the structure of poverty and deprivation along capability lines, it is essential to empirically analyse the key building blocks of a citizen’s capability set. Consequently, a range of determinants (i.e. capability sets) are selected and adopted for the purposes of this study in order to assess the spatial changes in capability deprivation in the City of Cape Town.

According to Robeyns (2007:106), Sen firmly believes that any capability set used to assess poverty or deprivation must be compiled through some form of debate amongst various content experts. In 2012, the Western Cape Government (WCG) facilitated a Socio–Economic Index development workgroup session to develop a methodology for constructing a multi–dimensional poverty index to be utilised to inform policy planning and decision making. To achieve this, a comprehensive quantitative and qualitative knowledge base was developed in the context of poverty eradication

planning. In an attempt to populate the so-called knowledge base, a number of experts with relevant expertise and experience in various socio-economic domains were invited from all three spheres of government (i.e. national, provincial and local) to participate and offer their insights. In the end, four predefined capability sets based on Census categories were proposed and approved. These sets included the Labour Force; Education; Housing, and Basic Services, and are used and applied in this study to derive the capability deprivation indices.

### **3.4.3 IDENTIFICATION OF ALTERNATIVES**

The purpose of this study is to concurrently evaluate each of the identified alternatives by developing and using a GIS-MCDM methodology. Within the context of this study, alternatives refer to the different communities within the City of Cape Town that are evaluated. This evaluation will be done by using a predefined set of potentially conflicting evaluation criteria sourced from Stats SA's 2001 and 2011 Census Data. These criteria will then be combined using a MCDM technique to create an overall poverty index.

The poverty index will be used to rank each of the case study alternatives as shown in the figure below. These rankings will help decision makers in identifying which communities in the City of Cape Town are deprived of the basic capabilities needed to live valued lives. Based on this index, each of the identified alternatives (i.e. Census sub-places) will be ranked accordingly, identifying which alternatives require certain local, provincial and national government interventions.

As will become evident throughout this study, there are at least 580 and 705 evaluated alternatives for 2001 and 2011, respectively. As noted before, these evaluated alternatives are derived from Stats SA's 2001 and 2011 Census Data that identified sub-place boundaries for possible poverty eradication intervention.

The 580 and 705 evaluated alternatives for 2001 and 2011, respectively, were determined using the following criteria; the alternatives:

- Are derived from Statistics South Africa's Census database;
- Have an enumeration area classification type of formal, informal and traditional residential only, and;
- Must have a total dwelling count of more than 100 dwelling units. This dwelling count criterion is chosen to ensure that the outputs generated from the different spatial MCDM models provide meaningful and statistically significant results that could be utilised by decision makers to ultimately improve their decision making.

Map 2: Study area



Source: ESRI, i-cubed, GeoEye

### 3.4.4 DETERMINING DECISION CRITERIA

The identification of communities that are most deprived and requiring certain social and economic interventions are complex and an ever evolving political debate and an issue that needs to be informed by multiple domains (i.e. capabilities) and its related criteria (i.e. functionings). The complexity of this process is enhanced by the transitioning of the CA from a theoretical framework to a practical application due to the absence of any endorsed list of basic capabilities and functionings. Robeyns (2007:106) notes that it is imperative that there is an extensive debate by researchers and policy planners. This debate should ideally focus on the development of specific domain related criteria that could be used to assess deprivation with an emphasis on functionings as a resource and quality of life, or poverty in this case, as the definitive outcome (Wagle, 2009:514).

Bearing in mind the recommendations by Sen, this study will, firstly follow a participatory process when selecting relevant criteria domains, and secondly integrate the CA with other socio-economic frameworks. As mentioned before, in its efforts to develop a multi-dimensional poverty index, the WCG reduced the nine capabilities identified in the NDP to four principal capabilities. These capabilities (i.e. basic services; labour force; housing, and education) will also be used in this study to assess poverty in the City of Cape Town, and were selected using a collection of functionings, which are based on data availability as sourced from the latest 2011 Census data (Dingani, 2013:5).

#### 3.4.4.1 MEASURING CAPABILITIES AND FUNCTIONINGS

The purpose of each domain is to include a limited list of criteria within the confinements of data availability, i.e. 2011 Census data, which systematically captures the extent of deprivation for each of the identified domains (Nobel *et al.*, 2010:287). Data availability plays an important role in shaping the way the CA is conceptualised in this, or any similar study, for that matter (Alkire, 2007:7). Although there are other critical capabilities and functionings, such as crime and access to employment opportunities that are also crucial in understanding the evolution of poverty in the City of Cape Town, they are excluded from this study due to administrative data constraints, including the availability, quality, and level of disaggregation of data. Therefore, of the ten capabilities proposed in the NDP only four could be applied, namely Housing; Electricity; Water and Sanitation; Education and skills, and Employment. It should be kept in mind that when interpreting the results of this study, one should be cognisant that the CA is an open framework, and thus the approach used to evaluate poverty will differ.

#### I. *Basic Services*

In terms of the basic services capability, deprivation is primarily caused by the lack of absolute minimum rights as defined in the South African Constitution (Republic of South Africa, 1996:1255). The purpose of this capability within the scope of this study is to rank each of communities within the City of Cape Town experiencing some form of basic services deprivation. Multiple functionings are

used, depending on available Census data, to determine the ranking index of each community. Different capability studies (e.g. Martinetti (2000); Qizilbash & Clark (2005), and Èchevin (2013)) have been used and multiple criteria relating to basic household utilities such as a percentage of people with access to piped water and sanitation as well as electricity, have been selected to measure capabilities deprivation for the purposes of this study.

## **II. Education**

Keeping the work of Canoy *et al.* (2010:393) in mind, the percentage of persons aged 15 years and older (who are classified to be functionally illiterate) and the percentage of persons aged between 15 years and older with a highest education level of at least Grade 12 and more, were selected as criteria to evaluate knowledge deprivation in the City of Cape Town.<sup>1</sup> According to Qizilbash and Clark (2005:110), knowledge defined by using educational attainment (i.e. years of schooling) as a functioning can be considered as a useful resource.

## **III. Labour Force**

In the labour force domain, the marginalisation of any part of the economically active population from the labour market impedes on the citizen's ability and right to lead the life he/ she has reason to value. Informed by the research conducted by Klasen (2000:40); Nobel *et al.* (2010:288), and Yuan and Wu (2014:144), the deprivation measure for the labour force domain was compiled using the percentage of economically active persons aged between 15 and 64 years earning less than R800 per month; the percentage of economically active persons aged between 15 and 64 years who are officially unemployed, and the percentage of economically active females aged between 15 and 64 years who are employed. Nussbaum (2000:1) alludes to the unbalanced social, economic and political environments in which females have inadequate levels of human capabilities as compared to males. For this reason, the above criterion will primarily focus on female employment.

## **IV. Housing**

The domain for housing is assessed by measuring the proportion of households experiencing certain levels of deprivation. This domain is significantly influential to poverty eradication given that good quality housing is central to key components of well-being and safety (Klasen, 2000:40). The criteria for this domain include the percentage of dwellings constructed from informal building materials; the percentage of households headed by people younger than 18 years old, and the percentage of households with an annual household income of less than R9 600.

Table 1 below provides the theoretical framework for the CA as integrated with the NDP and the related criteria selected to measure poverty deprivation in the City of Cape Town within the scope of this study.

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<sup>1</sup> The definition of functionally illiterate is adapted from the work of Aitchison and Harley (2006: 90). The authors define illiteracy as all persons aged 15 years and more with less than Grade seven as the highest level of education.

Table 1: Theoretical structure for objectives and criteria

<b>Criteria domains</b>	<b>NDP objectives</b>	<b>Derived evaluation criteria</b>
Basic services	Providing basic services that enable people to develop capabilities to take advantage of opportunities	No electricity for lighting
		Access to piped water in dwelling or yard
		No refuse removal by local authorities
		Sanitation access (no bucket system)
Education	Improve the quality of education in underperforming schools and further education and training colleges	Functionally illiterate (15 years and older)
		Grade 12 and more (15 years and older)
Labour Force	Introduce active labour market policies and incentives to grow employment, particularly for young people and in sectors employing relatively low-skilled people	Official unemployment rate (15–64years)
		Individual income less than R800 per month (15–64 years)
		Employment rate for females (15–64years)
Housing	Promote mixed housing strategies and more compact urban development	Informal dwelling type
		Annual Household Income less than R9 600
		Child (i.e. younger than 18 years) Headed Households

### 3.4.4.2 DERIVING THE EVALUATION CRITERIA

#### A. METHODOLOGY FOR DERIVING THE EVALUATION CRITERIA

This section will provide the methodology used for deriving each of the evaluation criteria that serves as a proxy for the frequently used features of poverty, i.e. housing; labour force; education, and basic services. Census 2011 at a sub-place level was used as the main data source to populate these evaluation criteria.

##### I. *Basic services*

##### 1. **Electricity for lighting**

The evaluation criterion, electricity for lighting, is assessed using the percentage of persons who do not have electricity as a source for lighting. The ratio was assessed by equating person numbers to energy source for lighting. This evaluation criterion was calculated by dividing the total number of persons that do not have electricity as a main energy source for lighting within each alternative with the total number of persons residing in the identified alternative.

$$X_{light_i} = \frac{X_{gas_i} + X_{paraffin_i} + X_{candle_i} + X_{solar_i} + X_{none_i}}{X_{Total_i}} \quad [1]$$

Where

$$0 \leq X_{light_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

##### 2. **Access to piped water**

The evaluation criterion used to assess the piped water criterion is the percentage of persons that have access to piped water in their dwellings. This percentage was determined by equating person numbers to access to piped water. The access to piped water variable was calculated by combining both the total numbers of persons with access to piped water inside a dwelling and total number of persons with access to piped water inside a yard. This (newly conceptualised) variable was then divided with the total number of persons living in the identified alternative.

$$X_{piped\ water_i} = \frac{X_{piped\ in\ dwelling_i} + X_{piped\ in\ yard_i}}{X_{Total_i}} \quad [2]$$

Where

$$0 \leq X_{piped\ water_i} \leq 1 ; 0 = \text{worst and } 1 = \text{ideal}$$

##### 3. **Refuse removal**

For refuse removal, the evaluation criterion used is the percentage of persons that do not have their refuse removed by local authorities. The refuse variable was determined by concatenating refuse removed by local authorities at least once a week and refuse removed by local authorities less often. To determine the evaluation criterion, this community specific variable was then divided with the total number of persons living in the identified alternative.

$$X_{refuse_i} = \frac{X_{at\ least\ once\ week_i} + X_{less\ often_i}}{X_{Total_i}} \quad [3]$$

Where

$$0 \leq X_{refuse_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

#### 4. Sanitation facilities

The evaluation criterion used for sanitation facilities is the percentage of persons not using the bucket system (including no toilets). This variable was determined by adding flush, chemical, pit and other types of sanitation facilities for this specific alternative. This variable was then divided with the total population for the identified alternative.

$$X_{toilet_i} = \frac{X_{flush_i} + X_{chemical_i} + X_{pit_i} + X_{other_i}}{X_{Total_i}} \quad [4]$$

Where

$$0 \leq X_{toilet_i} \leq 1 ; 0 = \text{worst and } 1 = \text{ideal}$$

## II. Education

### 1. Functionally illiterate

The evaluation criterion functionally illiterate is assessed using the percentage of persons aged between 15 years and older with an educational level less than Grade 7 (includes no schooling). It was assessed by equating persons aged between 15 years and older with highest educational levels. This evaluation criterion was calculated by dividing the total number of persons aged 15 years and older with a highest educational level of less than Grade 7 with the total number of persons 15 years and older.

$$X_{illiterate_i} = \frac{X_{no\ schooling_i} + X_{grade\ 1_i} + X_{\dots\dots\dots_i} + X_{grade\ 6_i}}{X_{Total_i}} \quad [5]$$

Where

$$0 \leq X_{illiterate_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

### 2. Grade 12 and higher

The Grade 12 and higher criterion is evaluated using the percentage of persons 15 years and older that has a highest qualification of at least Grade 12 and higher. This criterion equates persons aged 15 years and higher with highest level of education. The variable was developed by adding all persons with a highest education level of at least Grade 12 and higher. The denominator was the total number of employed persons aged between 15 years and older.



$$X_{MOREGR12_i} = \frac{X_{GR12_i} + X_{University_i} + X_{TECH}}{X_{Total_i}} \quad [6]$$

Where

$$0 \leq X_{employMOREGR12_i} \leq 1 ; 0 = \text{worst and } 1 = \text{ideal}$$

### III. Housing

#### 1. Informal households

In this case, informal households were assessed by equating the percentage of households with dwelling type. For the purposes of this study, informal households are defined as dwellings constructed out of informal and traditional building materials and are normally located in informal settlements or backyards. This criterion was calculated by grouping all relevant Census dwelling categories (i.e. traditional dwelling/ hut/ structure made of traditional material/ informal dwelling (i.e. shack in backyard) and informal dwelling (i.e. shack; not in backyard but in an informal /squatter settlements or on a farm) into a category called informal households and dividing it by the total number of dwellings.

$$X_{informal_i} = \frac{X_{Informal_i} + X_{traditional_i}}{X_{Total_i}} \quad [7]$$

Where

$$0 \leq X_{informal_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

#### 2. Annual household income of less than R9 600

The following evaluation criterion, i.e. percentage of households with an annual household income of less than R9 600 was assessed by equating households with annual income. The criterion was calculated by grouping all household annual income categories of less than R9 600 and dividing it with the total number of households.

$$X_{HIncome_i} = \frac{X_{HHIncomelessR9600_i}}{X_{Total_i}} \quad [8]$$

Where

$$0 \leq X_{formal\ households} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

### 3. Child Headed Households

The following evaluation criterion, i.e. the percentage of households headed by a child aged younger than 18 years was assessed by equating head of households with age. The criterion was calculated by dividing the total number of heads of households aged younger than 18 years with the total number of heads of households.

$$X_{HHAge_i} = \frac{X_{HHageless18_i}}{X_{Total_i}} \quad [9]$$

Where

$$0 \leq X_{HHAge} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

### IV. Labour force

#### 1. Employment status

For employment status the evaluation criterion is the percentage of persons aged between 15 and 64 years who are unemployed. This criterion was estimated by equating the economically active, using a narrow definition; population with employment status. It is developed using the narrow unemployment definition as defined by Stats SA that excludes discouraged work seekers. The variable was calculated by dividing the total number of persons aged between 15 and 64 years who fall within the unemployed category by the narrowly defined economically active population.

$$X_{unemploy_i} = \frac{X_{unemploy_i}}{X_{unemploy+employ_i}} \quad [10]$$

Where

$$0 \leq X_{unemploy_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

#### 2. Monthly income of less than R800 per month

The monthly income evaluation criterion is the percentage of the economically active, using a narrow definition; population aged between 15 and 64 years who earns less than R800 per month. This criterion was developed by equating the economically active population aged between 15 and 64 years with monthly income. The variable was calculated by dividing the total number of economically active persons earning less than R800 per month by the total number of economically active persons.

$$X_{Income_i} = \frac{X_{incomelessR800_i}}{X_{economically\ active_i}} \quad [11]$$

Where

$$0 \leq X_{income_i} \leq 1 ; 0 = \text{ideal and } 1 = \text{worst}$$

### 3. Female employment

For female employment, the criterion is the percentage of females aged between 15 and 64 years who are employed. This criterion was estimated by equating the economically active (narrow definition) female population with employment status. It was calculated by dividing the female population aged between 15 and 64 years who fall within the employed category by the narrowly defined female economically active population.

$$X_{Femploy_i} = \frac{X_{Femploy_i}}{X_{economically\ active_i}} \quad [12]$$

Where

$$0 \leq X_{Femploy_i} \leq 1 ; 0 = \text{worst and } 1 = \text{ideal}$$

#### 3.4.4.3 DESCRIPTIVE STATISTICS

As mentioned above, the results generated for each of the criteria domains are based on Census 2001 and 2011 datasets being disaggregated to a sub-place geographical level, which in turn, is utilised to assess poverty eradication measures in the City of Cape Town. Table 2 below shows the descriptive statistics (i.e. minimum; maximum; mean, and standard deviation) for each of the evaluation criteria selected to populate each of the four dimensions of poverty. These statistics provides an insight into important features of the data used in this study to develop a composite poverty index.

Regarding the education domain, a general improvement between 2001 and 2011 is noted in both the functional illiteracy levels and tertiary educational achievement levels as shown by the mean values. These figures could be credited to government's attempts to meet the UN's MDGs and the realignment of its policy priorities to meet the educational demands of the citizens living in the City of Cape Town. Furthermore, the decreasing standard deviation reflects to a certain extent the narrowing of educational disparities achieved by government in the City of Cape Town between 2001 and 2011.

Concerning the labour force domain, advancements in the labour market between 2001 and 2011 for the City of Cape Town is prominent and evident in Table 2 below. It shows that while labour force inequalities (including income) are still prevalent across the City of Cape Town, government has

nonetheless made progress in terms of addressing the high levels of inequality. This is proven in the standard deviation and mean reduction between 2001 and 2011 for all three labour force related criteria, i.e. unemployment; income, and female employment. What is concerning though, is that certain communities across the City of Cape Town are still deeply entrenched in income poverty and inequality as indicated in the MAX column for the income criterion.

With respect to the basic services domain, smaller improvements between 2001 and 2011 is noted for access to piped water, electricity for lighting and adequate refuse removal services while marginal increases were shown for persons using the bucket system (including no toilets). The limited improvements, shown by the mean, could be as a result of continuous in-migration of persons from neighboring provinces and African countries to reside in Cape Town. The small increase in the standard deviation specifically for people's access to piped water in dwelling or yard underlines government's struggling efforts to keep pace with basic services provision because of the increased in-migration trends.

Similar to the basic services domain, the housing domain shows very little improvement for all domain related criteria. When analysing the mean and standard deviation for the informal dwelling type criterion between 2001 and 2011, it is evident that the creation of housing opportunities remain a significant challenge for both the local and provincial governments. The two main contributing factors to the slow progress made in terms of housing delivery are firstly, the already mentioned increased in-migration of persons from other provinces and the inadequately defined roles and responsibilities between local and provincial government in terms of who is actually responsible for housing delivery.

Table 2: Descriptive statistics for study area 2001 and 2011

<b>CRITERIA</b>	<b>YEAR</b>	<b>OBS</b>	<b>MEAN</b>	<b>STD. DEV</b>	<b>MIN</b>	<b>MAX</b>
SANITATION	2001	580	0.9469	0.1609	0.0167	1.0000
	2011	705	0.9580	0.1408	0.0044	1.0000
REFUSE REMOVAL	2001	580	0.0372	0.1325	0.0000	1.0000
	2011	705	0.0242	0.0895	0.0000	0.9784
ELECTRICITY	2001	580	0.0557	0.1687	0.0000	1.0000
	2011	705	0.0308	0.1182	0.0000	1.0000
PIPED WATER	2001	580	0.9054	0.2017	0.0000	1.0000
	2011	705	0.9374	0.1992	0.0040	1.0000
FUNCTIONALLY ILLITERATE	2001	580	0.0965	0.1152	0.0000	0.9538
	2011	705	0.0586	0.0598	0.0000	0.4180
GRADE 12 AND HIGHER	2001	580	0.5090	0.2584	0.0126	0.9458
	2011	705	0.2681	0.2072	0.0000	0.7369
UNEMPLOYED	2001	580	0.1582	0.1632	0.0000	0.7143
	2011	705	0.1364	0.1260	0.0000	0.6398
INCOME	2001	580	0.2439	0.2095	0.0000	0.9248

	2011	705	0.2105	0.1444	0.0315	0.7791
FEMALE EMPLOYMENT RATE	2001	580	0.3900	0.0985	0.0000	0.8333
	2011	705	0.4111	0.0784	0.1065	0.6000
INFORMAL DWELINGS	2001	580	0.1009	0.2229	0.0000	1.0000
	2011	705	0.0953	0.2242	0.0000	1.0000
ANNUAL INCOME LESS THAN R9 600	2001	580	0.1540	0.1555	0.0000	0.9294
	2011	705	0.1423	0.1040	0.0063	0.8663
CHILD HEADED HOUSEHOLDS	2001	580	0.0014	0.0036	0.0000	0.0446
	2011	705	0.0016	0.0024	0.0000	0.0180

Note: unit of measurement for mean, min and max is proportion

#### 3.4.4.4 WEIGHTING ESTIMATION OF CRITERIA

The proliferation of poverty as a policy issue is a key confounding factor in enhancing the capabilities of citizens living in the Western Cape. In addition, the lack of efficient and effective allocation of appropriate government resources has slowly become one of the most acute policy problems facing all three spheres of government in South Africa. The City of Cape Town already has one of the highest population growth rates of all metropolitan cities in South Africa, which ensues in an upsurge of poverty in the City of Cape Town, which, in turn, hinders government's ability to achieve the policy goals set out in the NDP. Therefore, there is a need to develop a mechanism that supports the principles of poverty eradication and informs the core task for policy decision making, which is the integration of all relevant dimensions i.e. Basic services; Education; Housing, and Labour force into an overall preference rank value. These results are then used as a means to develop future policies, strategies and implementation plans.

The integration of GIS and MCDM techniques provides the means for the integration of all relevant dimensions and the ranking of alternatives. In this study, section 3.4.5 focuses on different MCDM models that can be used to integrate all relevant criteria dimensions and rank the various decision alternatives. The purpose of this section is to focus on the weighting estimation technique, used unambiguously to aggregate criteria specific values that are used to create the ranking value. The weighting of criteria and dimensions are the most important steps in the decision making processes because all of the multi-faceted matters related to the idea of poverty eradication are not just basic services, education, housing and labour force related, it is the combination of all 12 criteria and four dimensions as selected by this study.

According to Kao (2010:1779), deriving a weight showing criterion importance can be produced in two ways, namely direct and indirect explication. The direct explication of criteria weights involves obtaining weights before the data collection process takes place, through the use of data collection tools such as survey questionnaires that are used to survey policy planners and decision makers. These weights obtained are called priori weights. The indirect explication of criteria weights refers to when

weights are derived from the data. These weights are obtained after the data collection process has transpired and are therefore called posteriori weights (Kao, 2009:1779).

## I. POSTERIORI WEIGHTS USED IN ESTIMATING DEPRIVATION

Attempting to ascertain which of the dimensions (i.e. household services; education; housing, and economy) would carry more weight in a poverty eradication decision making model often proves to be difficult as it is bound to elicit mixed and biased results. For instance, some experts would argue that the provision of appropriate housing structures is a fundamental dimension to poverty eradication and should therefore be heavily weighted in a decision making matrix while other experts might debate that decent education should be the primary dimension and should therefore take priority. Thus, choosing a so-called primary dimension for a poverty eradication decision making model is a subjective exercise.

This type of biased behaviour concerning decision making is well documented in a vast array of literature related to behavioural decision making. One such type of decision bias is called anchoring and adjustment. It often occurs when a decision maker anchors his/ her opinion about a specific criterion weight and then later often fails to adequately change and/ or reconsider the anchor which often affects the overall preference values of the alternatives in the spatial MCDM model (Buchanan & Corner, 1997:907). According to Chen et al. (2010: 1583) criteria weights are often the main contributor to uncertainty and may affect the way government apportions its resources and could result in smaller percentages of the poor being reached with a given fiscal budget. Based on all of this, in an attempt to negate any biased results, this study utilises posteriori weights to assign importance to each of the evaluation criteria.

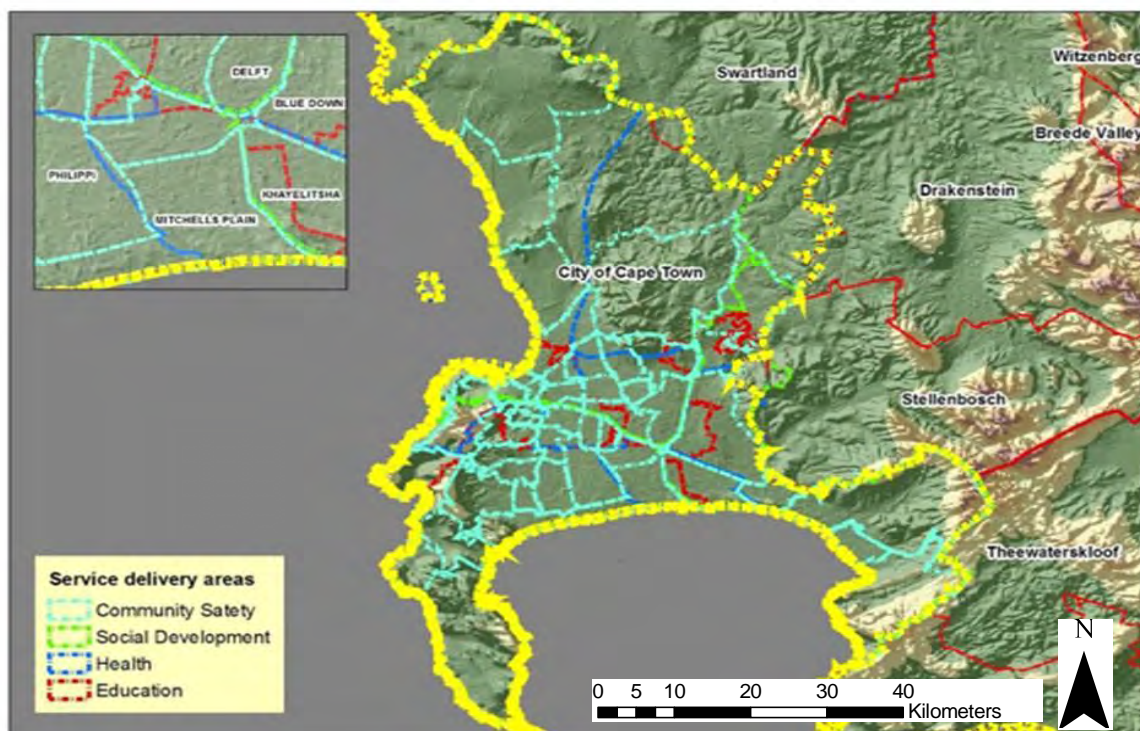
## II. SOURCING DATA TO DETERMINE POSTERIORI CRITERIA WEIGHTS

As stated above, the derivation of posteriori weights are dependent on data availability. The value of these posteriori weights, in terms of being able to appropriately assign importance to each of the evaluation criteria, is dependent on the data sources being of high quality. The reason for this is that only high quality data sources will enable each MCDM model to generate results that are unbiased and precise, thus avoiding the risk of extracting incorrect assumptions. For the purposes of this study, the use of the latest 2011 Census data was favored as opposed to conducting a small scale survey or using administrative data to determine criteria importance. The reasons for this include that:

- Census 2011 data provides a detailed geo-official data snapshot as at October 2011 for the City of Cape Town, and therefore, associations between inter-Census datasets and data dimensions are possible and less complicated;
- Depending on sample size, a sample survey may not be entirely representative of the full population;

- Data collected from the sample surveys have a high degree of sampling errors. This type of error occurs when a sample is used to approximate an entire population factor (Das, 2012:113). For example, if the monthly income of 100 people in a suburb of 1 000 individuals were to be measured, the average monthly income of the 100 people will not be representative of all 1 000 people in the suburb. Accordingly, the difference between the sample value and the population value is deemed to be a sampling error;
- Since sample surveys are meant to be reflective of an entire population, it often results in less comprehensive information. For instance, the labour force results from a sample survey will not be able to accurately reflect the total monthly income of individuals aged between 15 and 64 years residing in a specific suburb, and;
- The map below depicts the WCG’s service delivery areas with respect to its Departments of Health; Education; Social Development; and Community Safety for the City of Cape Town region. These service delivery areas are unique and can be demarcated independently of other government departments as defined in their existing legislative frameworks, i.e. Chapter 7 of the South African Police Services Act, Act 68 of 1995; Chapter 2 of the South African Schools Act, Act 84 of 1996, and Chapter 5 of the National Health Act, Act 61 of 2003. The implication of these legislative frameworks is that no administrative data can be spatially compared at community–based levels.

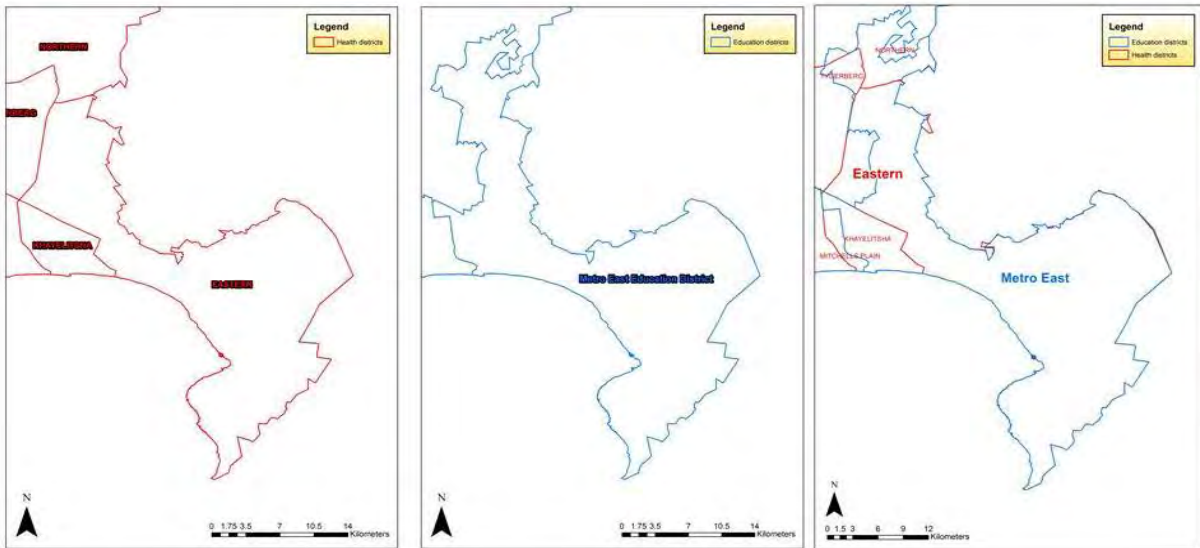
Map 3: Departmental service delivery areas in the City of Cape Town



Source: Department of Education, Health, Social Development and Community Safety

Table 3 and Map 4 below highlight the incomparable data for the Departments of Health and Education. It shows that while service regions are named similarly, the geographical space, as shown in Map 4, of each department is completely different. This implies that administrative data at a community-based level cannot be directly compared. To build credible MCDM models, spatial synergy must exist between service delivery areas' boundaries, thus administrative data sources cannot be considered as reliable data sources for developing MCDM models.

Map 4: Department of Health and Education geographical boundaries



Source: Spatial data was sourced from Department of Health and Education

Table 3: Department of Health and Education administrative data

Secondary school enrolment			
	2007	2008	2009
METRO SOUTH	54,201	54,673	52,440
METRO NORTH	61,967	62,199	61,058
<b>METRO EAST</b>	<b>55,702</b>	<b>55,342</b>	<b>55,365</b>
METRO CENTRAL	55,472	55,340	55,260
<b>Total</b>	<b>227,342</b>	<b>227,554</b>	<b>224,123</b>

Teenage pregnancy			
Sub-district	2007 - 2008	2008 - 2009	2009 - 2010
<b>Cape Town Eastern Health sub-District</b>	<b>409</b>	<b>398</b>	<b>439</b>
Cape Town Northern Health sub-District	154	134	149
Cape Town Southern Health sub-District	692	194	201
Cape Town Western Health sub-District	920	1,532	1,393
Khayelitsha Health sub-District	366	361	364
Klipfontein Health sub-District	432	462	379
Mitchells Plain Health sub-District	273	238	286
Tygerberg Health sub-District	1,443	1,201	1,277
<b>Total</b>	<b>4,689</b>	<b>4,520</b>	<b>4,406</b>

Source: Department of Health and Education, coupled with own calculations

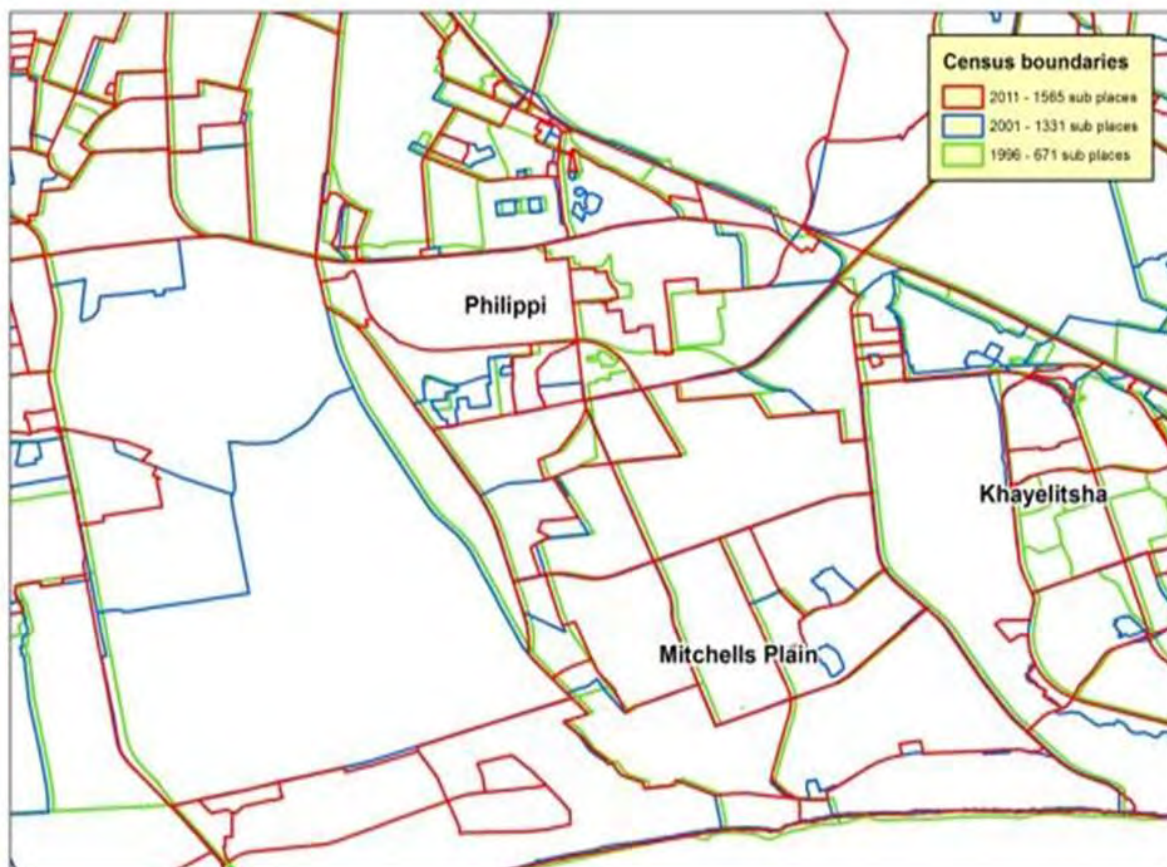


### III. CHALLENGES WITH CENSUS DATA

While Census data presents certain advantages for developing credible MCDM models at community-based levels, the main disadvantage thereof is its inability to, at a community-based level at least, compare inter-Census datasets and variable dimensions. This type of spatial logic problem presents policy and decision makers with significant challenges in accumulating the necessary support data needed for developing, monitoring and evaluating community-based policies. The map below presents the spatial logic for the various Census years from 1996 to 2011. It shows that:

- Since 1996, the total number of communities in the Western Cape had grown from 671 to 1565 in 2011, i.e. a percentage change (i.e. an increase) of 133%;
- (Rapid) Urbanisation is a crucial policy issue to keep in mind, and;
- Current government resource allocation is, especially at an Integrated Development Plan (IDP) level, based on single year observations with no interpretation and consideration for time series data

Map 5: Census place – names for 1996, 2001 and 2011

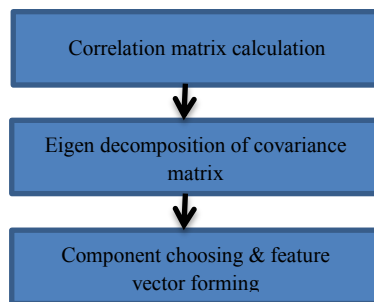


Source: Spatial data sourced from Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

#### IV. THE APPLICATION OF PRINCIPAL COMPONENT ANALYSIS (PCA) TO DETERMINE CRITERIA WEIGHTS

An efficient and effective approach used in selection and estimation decision problems to determine criteria weighting is Principal Component Analysis (PCA). It is a useful multi-variate statistical method used to transform a set of multiple correlated variables into a set of uncorrelated variables without losing the underlying variability of the original dataset. The figure below depicts the steps generally followed in PCA:

Figure 2: Principal Component Analysis steps



Source: Adopted from Javanmardi *et al.*, 2011:170

The typical application of PCA reduces the dimensionality of a dataset through the descending ranking of newly calculated PCAs, which shows the degree of criteria importance. The first principle component determines the linear combination of the criteria that explains most of the variations in the original data matrix. For PCA to be beneficial to the MCDM process there must be a certain degree of significant correlation in the evaluation matrix (Hodgkin *et al.*, 2005:177).

This study will analyse 12 criteria by means of the PCA to determine a average weighting schema for each spatial MCDM model. These criteria will be examined in a vector  $x_i = \{x_1, x_2, \dots, x_j\}$  and there are 580 and 705 alternatives for each of the criteria for 2001 and 2011 respectively. The decision making matrix D is presented below:

$$D = \{x_1, x_2, \dots, x_{12}\} = \begin{pmatrix} X_{1,1} & X_{1,2} & \dots & \dots & X_{1,12} \\ X_{2,1} & X_{2,2} & \dots & \dots & X_{2,12} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ X_{n,1} & X_{n,2} & \dots & \dots & X_{n,12} \end{pmatrix} \quad [13]$$

The PCA methodology determines a new set of criteria  $\omega_i$  where  $\omega_i = \{\omega_1, \omega_2, \dots, \omega_i\}$  which are a linear function of D.

$$\begin{bmatrix} \omega_{1,1} \\ \omega_{2,1} \\ \cdot \\ \cdot \\ \omega_{n,j} \end{bmatrix} = \begin{bmatrix} \varphi_{11} & \varphi_{12} & \dots & \varphi_{1i} \\ \varphi_{21} & \varphi_{22} & \dots & \varphi_{2i} \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ \varphi_{n1} & \varphi_{n2} & \dots & \varphi_{ni} \end{bmatrix} \times \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_n \end{bmatrix} \quad [14]$$

Where

$$\omega_i(PCA) = \varphi_{i1}x_1 + \varphi_{i2}x_2 + \dots + \dots + \varphi_{in}x_n \quad [15]$$

$|\varphi_{ij}|$  is the absolute weight value that indicates the amount of influence of vector  $x_i$  to the  $\omega_i$ .

The normalisation of the  $\varphi_{ij}$  is

$$\varphi_{i1} + \varphi_{i2} + \dots + \varphi_{in} = 1 \quad [16]$$

The average weighting schema is determined by applying an average across the 2001 and 2011 weighting schemas.

### 3.4.5 EVALUATION OF ALTERNATIVES

The objective of this evaluation is to strengthen decision making processes by providing a robust methodology for the integration of GIS and MCDM techniques. This methodology will assist decision makers and planners with identifying and assessing the spatial distribution of poverty and inequality through the aggregation of multiple conflicting poverty eradication related criteria such as employment status; illiteracy; and so forth. In totality, poverty eradication is defined by a predefined set of 12 evaluation criteria that are categorised into four criteria domains, namely basic services; education; labour force, and housing. These evaluation criteria are aggregated into an overall evaluation index using MCDM techniques that is used to reverse rank each of the alternatives.

#### 3.4.5.1 THE PHASES FOR MULTI-CRITERIA DECISION ANALYSIS

Each decision making problem is unique in nature but consists of overlapping or generic themes that can be applied to all decision problems to assist planners and decision makers to gain a better understanding of the decision problem. The following section outlines a generic framework for multi-criteria decision problems that could be adapted by decision makers or analysts to address any decision problem. There are seven phases of this generic framework (Keeney, 1982:807), including:

- Determining the decision context;
- Defining options or alternatives;
- Define problem objectives and evaluation criteria;
- Develop a performance matrix;
- Identify the preference based on the performance matrix;
- Select an aggregation method, and;
- Analyse results and conduct sensitivity analysis.

### I. Phase 1: Determining the decision context

In order to conduct multi-criteria decision analysis it is important to understand the decision problem and objectives by identifying central areas of concern, identifying knowledgeable experts and stakeholders, and understanding the decision problem aims. Without this understanding, it is impossible to understand what alternatives need to be selected to solve the decision problem (Department of Communities and Local Government, 2009:10).

### II. Phase 2: Defining options or alternatives

Once the decision context is understood, the next phase is to define potential options or alternatives to be taken into consideration. This is done by either listing the options or alternatives if there are few alternatives to be considered or detailing the attributes associated with each option or alternative if the numbers or options are large (Vincke, 1992).

### III. Phase 3: Defining problem objectives and evaluation criteria

The evaluation criteria are derived from the problem objectives. These criteria are viewed as a so-called real-valued function used to evaluate and compare two options (i.e. a and b) quantitatively (Bouyssou, 1990:4). According to Bouyssou (1990:4), a criterion is defined as:

$$a P_g b \Leftrightarrow g(a) > g(b) \text{ and}$$

$$a I_g b \Leftrightarrow g(a) = g(b),$$

where  $P_g$  is defined as ‘strictly preferred to’ and  $I_g$  as ‘indifferent to’ taking into account consequences on criteria  $g$ .

### IV. Phase 4: Developing a performance matrix

A multi-criteria decision problem can be defined in the following way: Let  $\mathbf{A}$  be a finite set of  $n$  options (alternatives);  $\mathbf{m}$  is the number of unique evaluation criteria  $g_i \ i = 1,2,3,\dots,n$ ; and  $\mathbf{G}$  is the set of unique  $\mathbf{m}$  (evaluation criteria). According to Munda (2003:1),  $\mathbf{g}$  can be defined as the function on set  $\mathbf{A}$  of possible options (alternatives) such that  $\mathbf{g(a)}$  and  $\mathbf{g(b)}$  can be compared making it possible to analyse the results of option  $\mathbf{a}$  and  $\mathbf{b}$ . Now that  $\mathbf{A}$  and  $\mathbf{G}$  has been defined, a performance matrix  $\mathbf{P}$  ( $\mathbf{n} \times \mathbf{m}$ ) with performance elements  $p_{ij} \ (i = 1,2,3, \dots, n; j = 1,2,3, \dots, n)$  which represents the performance of the  $j$ -th option by means of the  $i$ -th criterion (Munda, 2003:1).

Table 4: General structure of a performance matrix

		Alternatives					
Criteria	Units	$a_1$	$a_2$	$a_3$	.	.	$a_n$
$g_1$		$g_1(a_1)$	$g_1(a_2)$	$g_1(a_3)$	.	.	$g_1(a_n)$
$g_2$		$g_2(a_1)$	$g_2(a_2)$	$g_2(a_3)$	.	.	$g_2(a_n)$
$g_3$		$g_3(a_1)$	$g_3(a_2)$	$g_3(a_3)$	.	.	$g_3(a_n)$
.		.	.	.	.	.	.
.		.	.	.	.	.	.
.		.	.	.	.	.	.

$g_n$	$g_n(a_1) \quad g_n(a_2) \quad g_n(a_3) \quad \dots \quad g_n(a_n)$
-------	---

Source: Munda, 2003: 2

### V. Phase 5: Developing preferences values based on the pairwise comparison matrix

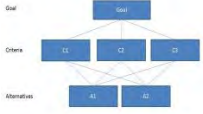
The following phase estimates preference values based on the pairwise comparison matrix in order for different criteria to be ranked and selected. This phase cannot be done in isolation, and requires the inputs from content experts as well community members. These inputs from stakeholders lead to the subjective weighting that are assigned to criteria. In this study, stakeholder engagements are used to elicit the multiple capability domains which are used to develop the capability deprivation measure. The subjective criteria weights are derived using the first principle component in PCA.

### VI. Phase 6: Selection of an aggregation method

Over the last few decades the number of MCDA methods increased exponentially. These methods provide structured frameworks for combining weighted information with performance matrices to attain the best problem alternative. According to Guitouni and Martel (1998:502), neither of these methods have present planners with the ideal alternative to a decision problem as all of these methods focus primarily on the enhancements of the algorithmic steps rather than focusing on the essential aspects of the decision making process. In general, most planners do not have sufficient insight or knowledge to justify MCDM method selection. Typically, the method selection is motivated by prior knowledge of the specific method (Guitouni & Martel, 1998:502). The table below shows that every MCDA method has its own sets of assumptions and hypotheses on which it has based all its theoretical and axiom development. Based on these assumptions, this study applies an aggregation method based on two selection criteria, namely availability of applicable case study material and method simplicity.

Table 5: Various MCDM techniques

Method	Formula	Description of method
Weighted Sum	$v_i = \sum_{j=1}^m s_{ij} \cdot w_j$ <p>where <math>v_i</math> = the value (or utility) of the <math>i</math>th alternative relative to the other alternatives, <math>s_{ij}</math> = the standardized value of <math>x_{ij}</math> (the performance measure for the <math>i</math>th alternative against the <math>j</math>th criterion), <math>w_j</math> = the weight of the <math>j</math>th criterion</p>	The global performance of an alternative is computed by multiplying the performance measures with its weights and then summed for each option to get the performance score (Al-Hadu <i>et al.</i> , 2011).
TOPSIS	<p>Closeness index (CI) =</p> $\frac{(R)^-}{(R)^+ + (R)^-}$ <p>Distance difference</p> $= \sqrt{\sum_{i=1}^n (x_{i+1} - x_i)}$	The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method selects the best alternative by calculating the distance from the ideal solution. Therefore, the shorter the distance the more ideal the solution (Munier, 2011).

Method	Formula	Description of method
AHP		<p>AHP converts individual assessments of relative importance into a set of weights. The AHP method uses a pairwise comparison matrix to decompose a decision problem, make comparative judgments on comparative elements and measure of the relative importance. The values are recombined into an overall rating of each alternative (Guitouni &amp; Martel, 1997)</p>

## VII. Phase 7: Analysing results and conducting sensitivity analysis

The main advantage in using MCDA methods is its ability to mathematically integrate the knowledge of community stakeholders and decision makers into a decision making process to derive the most suitable problem alternative. Therefore, to ensure legitimacy of the results, it is important that the decision analyst does not interpret the results of the study in isolation of the decision maker and stakeholders. This is fundamental to the implementation of large scale government interventions. Also, it is important to conduct a sensitivity analysis on the decision making outputs. Such sensitivity analysis allows the decision maker to understand the ambiguity that exists between different decision maker preferences by adjusting the weights of the criteria. This allows the decision maker to examine which criterion is more crucial than others in terms of their influence on the overall outcome.

### 3.4.6 SPATIAL MULTI-CRITERIA DECISION MAKING

The combination of the conflicting criteria is done by using two compromising MCDM techniques called Techniques for Order Preference by Similarity to Ideal Solution (TOPSIS) and COMplex PROportional ASsessment (COPRAS). Two MCDM techniques are used to evaluate the poverty index results and assess the spatial differences in results. For the purposes of this study, these two techniques were integrated with ArcGIS using loose coupling resulting from the following spatial evaluation mechanisms:

- Spatial TOPSIS, and;
- Spatial COPRAS.

#### 3.4.6.1 SPATIAL TOPSIS

The TOPSIS technique was developed by Hwang and Yoon in 1981. This decision making technique ranks alternatives that simultaneously have the shortest distance from the positive ideal solution and furthest distance from the negative ideal solution (Behzadian *et al.*, 2012: 13052). When the TOPSIS technique is applied to solve a multi-criteria decision making problem within a spatial environment this method is referred to as Spatial TOPSIS. The procedure for the TOPSIS method is applied to criteria in the table below to derive a composite poverty measure. The process used for depriving the composite measure can be described in the five steps as listed below.

Table 6: Initial evaluation criteria matrix

Criteria	Min/Max	Data source	Measurement unit
No electricity for lighting (LIGHT)	-	Census 2011, 2001	Percentage
Piped water in dwelling (WATER)	+	Census 2011, 2001	Percentage
No refuse removed by local authority (REFUSE)	-	Census 2011, 2001	Percentage
No Bucket system (TOILET)	+	Census 2011, 2001	Percentage
Functionally illiterate (ILLITERATE)	-	Census 2011, 2001	Percentage
Grade 12 and more (EMPLGR12)	+	Census 2011, 2001	Percentage
Informal dwelling type (INFORMAL)	-	Census 2011, 2001	Percentage
Child Headed Households (CHH)	-	Census 2011, 2001	Percentage
Annual Income less than R9600 (ANNUAL)	-	Census 2011, 2001	Percentage
Unemployment (UNEMPLOY)	-	Census 2011, 2001	Percentage
Monthly income less than R800 (INCOME)	-	Census 2011, 2001	Percentage
Employed females (FEMPLOY)	+	Census 2011, 2001	Percentage

**Step 1: Construct normalised decision matrix**

$$x_{ij} = X_{ij} / \sqrt{\sum X_{ij}^2} \quad [17]$$

for  $i = 1, \dots, m$ ;  $j = 1, \dots, n$

where  $X_{ij}$  is the raw evaluation criteria score

$x_{ij}$  is the normalised evaluation criteria score

**Step 2: Construct the weighted normalised decision matrix**

$$\omega_{ij} = |\varphi_j| x_{ij} \quad [18]$$

where

$|\varphi_j|$  is the absolute weight for the  $j^{th}$  criterion derived from the PCA

**Step 3: Ascertain the positive ideal solution ( $P^+$ ) and negative ideal solution ( $N^-$ )**

Within the context of this study, the negative ideal solution forms the focal point for this analysis. The negative ideal solution is usually known given that this solution is determined by the poorest score for each of the evaluation criteria with regards to maximisation and minimisation (Munier, 2011:90). For example, the poverty index calls for minimisation therefore an alternative with a high poverty index is categories as high or severe poverty. This technique was chosen because of its ability to fully utilise criteria attributes that provides a basic ranking of all alternatives (Behzadian *et al.*, 2012: 13052).

*Positive ideal solution*

$$P^+ = \{(\max_i \omega_{ij} \text{ if } j \in J), (\min_i \omega_{ij} \text{ if } j \in J') \text{ where } i = 1, \dots, m\} = \{\omega_{1, \dots, n}^+, \omega_n^{+*}\} \quad [19]$$

*Negative ideal solution*

$$N^+ = \{(min_i \omega_{ij} \text{ if } j \in J), (max_i \omega_{ij} \text{ if } j \in J') \text{ where } i = 1, \dots, m\} = \{\omega_1^-, \dots, \omega_n^-\} \quad [20]$$

where

$$\omega_i^+ = \{\max(\omega_{ij}) \text{ if } j \in J; \min(\omega_{ij}) \text{ if } j \in J'\} \quad [21]$$

$$\omega_i^- = \{\min(\omega_{ij}) \text{ if } j \in J; \max(\omega_{ij}) \text{ if } j \in J'\} \quad [22]$$

#### **Step 4: Determine separation measures for each of the alternatives**

The separation measures  $S_i^+$  and  $S_i^-$  from the negative and positive ideal solution are calculated using the Euclidean distance measure.

*Positive ideal alternative separations*

$$S_i^+ = [\sum(\omega_i^+ - \omega_{ij})^2]^{\frac{1}{2}} \text{ for } i = 1, \dots, m \quad [23]$$

*Negative ideal alternative separations*

$$S_i^- = [\sum(\omega_j^- - \omega_{ij})^2]^{\frac{1}{2}} \text{ for } j = 1, \dots, n \quad [24]$$

#### **Step 5: Estimate the relative closeness to the positive ideal solution $C_i^+$**

$$C_i^+ = \frac{S_j^-}{(S_i^+ + S_j^-)} \quad 0 < C_i^+ < 1 \quad [25]$$

$$\text{Poverty index} = 1 - C_i^+$$

This closeness index will be used to rank each of the study's alternatives. The alternative poverty index was derived by subtracting one from the  $C_i^+$ . The index value closest to one indicates areas that require certain immediate poverty eradication related interventions whereas alternatives with an index value closer to zero requires little to no intervention. Given the dynamic abilities of ArcGIS to provide and support spatial Algebra, the results of the TOPSIS technique can be effortlessly rendered in both a vector-based and raster-based context (Demesouka *et al.*, 2013:5).

#### **3.4.6.2 SPATIAL COPRAS**

The COPRAS technique was first conceptualized by Zavadskas *et al.* in 2008. This easy to use method estimates the priority of each alternative by means of a stepwise ranking and evaluation method that utilises the multiple predefined quantitative and qualitative decision criteria (Das *et al.*, 2011:236). The method selects the best alternative by accounting for both the negative (i.e. minimisation) and positive (i.e. maximisation) features of each decision alternative (Mulliner *et al.*, 2012:274). Like TOPSIS, the COPRAS method can easily be applied in a spatial context and is referred to as Spatial COPRAS.



The COPRAS method consists of the following steps:

**Step 1: Construct a normalised decision matrix**

$$x_{ij} = \frac{X_{ij}}{\sum_{i=1}^n X_{ij}} \quad [26]$$

for  $j = 1, 2, \dots, n$

where  $X_{ij}$  is the raw evaluation criteria score

$x_{ij}$  is the normalised evaluation criteria score

**Step 2: Construct the weighted normalised decision matrix**

$$\omega_{ij} = \varphi_j x_{ij} \quad [27]$$

where

$\varphi_j$  is the weight for the  $j^{th}$  criterion

**Step 3: Sum weighted normalised criteria**

The sum of the weighted normalised positive ( $S_i^+$ ) and negative ( $S_i^-$ ) decision criteria for each alternative is calculated. The higher the  $S_i^+$  value, the better. Likewise, the lower the  $S_i^-$  value, the better. The  $S_i^+$  and  $S_i^-$  are calculated using the following equations:

$$S_i^+ = \sum_{j=1}^k \omega_{ij} \text{ for positive alternatives} \quad [28]$$

$$S_i^- = \sum_{j=k+1}^n \omega_{ij} \text{ for negative alternatives} \quad [29]$$

**Step 4: Determine the significance of each decision alternative**

The importance of each decision alternative is determined on the basis of the positive and negative qualities of each alternative. The importance ( $Q_i$ ) of each alternative is determined using the following equations:

$$Q_i = S_i^+ + \frac{\sum_{i=1}^m S_i^-}{S_i^- \sum_{i=1}^m \frac{1}{S_i^-}} \quad [30]$$

**Step 5: Calculate the performance index of each alternative**

In the final step the performance index is calculated to determine the complete ranking of all decision alternatives. This ranking is done by comparing each of the decision alternatives with the most proficient alternative. The performance index is calculated using the following equation:

$$P_i = 1 - \frac{Q_i}{Q_{max}} \times 100 \quad [31]$$

The value of each performance index related to the specific alternative will range between 0% and 100%. Thus, within the scope of this study, the community with the highest performance index value will identify areas that require significant poverty eradication related intervention.

### 3.4.6.3 TESTING FOR THE PRESENCE OF MULTI-COLLINEARITY

The presence of multi-collinearity amongst independent criteria can significantly skew any statistical analysis and results as generated, and it is largely considered as information repetition. This is largely due to multi-collinearity influencing the ability to determine the effects of the independent criteria (i.e. informal dwellings, piped water, and so forth) on the dependent criterion (i.e. poverty). When a single independent ( $X_1$ ) criterion is highly correlated with other independent criteria ( $X_2$  and  $X_3$ ), these criteria ( $X_2$  and  $X_3$ ) will also significantly affect the outcome of the dependent criterion ( $Y_i$ ) and thus generate biased estimates. This bias effect is primarily caused due to the least square estimates of these variables having large variances.

To test for large variances, this study utilises variance inflation factors (VIF) that are generated through the development of multi-dimensional regression models. These VIF are used to negate the presence of multi-collinearity for the labour force, education, housing, basic services and poverty spatial MCDM models. It should be stressed that all multiple regression models and VIF analysis are done using statistical software called STATA 12.

#### A. Variance Inflation Factor

As mentioned before, the presence of highly correlated criteria significantly skews the MCDM model outputs. These effects are reflected in the large variance estimates of the criteria. The variance estimates can systematically be evaluated by using a diagnostic tool called the Variance Inflation Factor (VIF) (Spanos & McGuirk, 2002:367). Suppose that a generalised multiple regression model with  $m$  independent observation can be written as (Stine, 1995:53-54):

$$y_j = B_0 + B_1x_{j1} + B_px_{j2} + \dots + B_px_{jp} + \epsilon_j \quad [32]$$

where  $j = 1, \dots, m$  and  $\text{var}(\epsilon_j) = \sigma^2$

In vector form, this regression model can be expressed as  $Y_j = X_i\beta + \epsilon_j$  where  $X_i$  is the  $m \times (k + 1)$  matrix with columns  $X_0, X_1, \dots, X_p$ . The VIF results from expressing the variance of the least square estimates  $\hat{\beta}_i$  where  $i = 1, \dots, j$

$$\begin{aligned} \text{var}(\hat{\beta}_i) &= \sigma^2 (X'X)^{-1}_{ii} \\ &= \frac{\sigma^2}{SS_i} VIF_i \end{aligned}$$

where  $SS_i = \sum_j (x_{ji} - \bar{x}_j)^2$  and

$$VIF_i = \frac{1}{1 - R_i^2} \quad [33]$$

In the case of the five MCDM models developed for this study, any criteria with high VIFs indicate a strong presence of multi-collinearity amongst the independent criteria and thus removed from the final MCDM process. According to Stine (1995:54), there is no accepted upper limit for VIF but has

proposed the use of an upper limit of  $VIF > 10$ ; and for this reason, this upper limit is also applied for the purposes of this study.

#### **3.4.6.4 SPATIAL ASSOCIATION**

An assessment of spatial associations in multiple spatial datasets is critical to any research concerning poverty eradication and inequality reduction. The analysis of spatial associations in the field of poverty eradication refers to the process of determining whether various communities living with high levels of poverty are located in close proximity to each other. Understanding these spatial associations are important to policy planners and decision makers in order to fundamentally grasping the spatial relationships between the eradication of poverty and improved educational levels; better access to basic services; pro-active labour markets, and the provision of adequate housing opportunities. This improved understanding of poverty will better assist planners and decision makers in ensuring that the intended programme beneficiaries indeed benefit from community designed interventions. The introduction and implementation of Stats SA's Quality Assessment Framework, underlines the geographical reference of most administrative and official data, which allows policy and decision makers to quantitatively measure the spatial associations between different communities, and in doing so, it empowers planners and decision makers to make more evidence-based decisions. Over the last two decades a number of spatial statistics have been developed and introduced to measure spatial association. These include the LISA statistic; G statistic, and Moran's I statistic (Moran's I, 1950; Getis and Ord, 1992; Anselin, 1995).

##### **I. Global Moran's I**

To analyse the spatial characteristics of location data, a global spatial autocorrelation measure can be derived using the Global Moran's I statistic. This autocorrelation measure is used to describe the spatial correlations of criteria at various locations. According to Guo *et al.* (2013:385), the word 'global' is used to place emphasis on one important characteristic of Global Moran's I, which is that all spatial locations identified in this study are used to determine the spatial autocorrelation measure. This implies that the averages are taken across all coefficients and used to only show the spatial pattern and not the exact locations of the spatial association.

Furthermore, the Global Moran's I is considered to be a standardised statistic that ranges between -1 and +1, thus denoting three types of spatial autocorrelation classifications, namely dispersed; random, and clustered. Typically, a Moran's I statistic close to +1 indicates the spatial clustering of locations, while a Moran's I statistic close to -1 denotes the spatial dispersion of communities. In this study, the Global Moran's Index and a Z score, which indicates statistical significance, is calculated using the spatial statistics tool in ArcGIS 10.2. Using the Z score, the null hypothesis of no spatial clustering can be tested for. If the Z score is greater than the desired  $\rho$  value, the null hypothesis of 'no spatial clustering' can be rejected and there is less than 1% likelihood that this clustered pattern could be the result of random chance.

## **II. Local Moran's I**

The Local Moran's I statistic is used to determine the spatial autocorrelation of a criterion at each location by taking into consideration the neighbouring criterion values (Malczewski, 2010:84). It can also be defined as a statistical tool used to differentiate local variability in spatial patterns (Boots, 2003:140). Similar to the Global Moran's I statistic, the Local I statistic determines the extent to which a certain criterion located in a specific location varies from its neighbouring criterion scores (Anselin, 1995:95). The value of the Local Moran's I statistic for each community provides the planner and decision maker with insight into the degree of spatial clustering of related scores around a certain identified community (Malczewski, 2010:87). Over the last two decades, two spatial data statistics have received significant attention in the field of local variability measures, namely the Getis and Ord family of  $G_i(d)$  distance based statistic and Anselin's Local Indicators of Spatial Association (LISA). Both of these local spatial statistics are used to detect the spatial clustering of communities with infrequently high (i.e. hotspots) or low (i.e. cold spots) scores (Mencken and Barnett, 1999; Ord & Getis, 2001; Diniz-Filho *et al.*, 2003; Frasier *et al.*, 2013)

### **a. $G_i(d)$ distance based statistic**

In response to the lack of spatial statistics used to determine local patterns of spatial association, Getis and Ord (1992) conceptualised, developed and introduced the  $G_i(d)$  and  $G_i^*(d)$  statistics. These statistics enable the decision maker to quantitatively measure the spatial autocorrelation of criteria scores located within a user defined distance. The  $G_i(d)$  and  $G_i^*(d)$  are both distance based statistics used to measure the proportion of the sum of values in neighbouring locations that are defined within the given range  $d$  (Páez and Scott, 2004: 56). The two spatial statistics vary in that the  $G_i^*(d)$  statistic includes the criterion score observed at  $i$  while the  $G_i(d)$  does not. When interpreting these statistics, a cluster of communities that have statistically significant  $Z [G_i^*(d)]$  and  $Z [G_i(d)]$  can be considered as either hotspots or cold spots (Fischer & Getis, 1997). Therefore, negative  $G_i(d)$  and  $G_i^*(d)$  statistics indicate the clustering of low criterion scores while positive  $G_i(d)$  and  $G_i^*(d)$  statistics indicate the clustering of high criterion scores.

### **b. Local Indicator of Spatial Association (LISA)**

The second spatial association statistic used in the field of local spatial variability (or spatial association) measurements is the LISA statistic developed by Anselin (1994). This statistic provides the user with a different approach to analysing spatial association by decomposing the global statistic used to measure spatial association. According to Lloyed (2012), the LISA statistic is best described by Anselin (1994) using the following two characteristics, namely:

- I. A LISA for each spatial event (i.e. community) must indicate the degree of significant spatial clustering around the spatial event.

II. The product of all LISAs together for all spatial events must be proportional to the Global Moran's I.

Much like  $G_i$  and  $G_i^*$  statistics, a LISA can also be used to detect hotspots and carry inferences on spatial association through determining a normalised statistic (Anselin, 1995:95). Páez and Scott (2004:56) observe that, based on the outputs of a LISA, there are four types of local spatial association, namely:

- High–High (H–H) association: When a criterion score ( $x_i$ ) is greater than the average score ( $\bar{x}$ ) and the score of ( $x_j$ ) at the neighbouring area is also above the average score, the LISA statistic is positive;
- Low–Low (L–L) association: When both criteria ( $x_i$  and  $x_j$ ) are below the mean, the LISA statistic is positive;
- High–Low (H–L) association: When the criterion score ( $x_i$ ) is higher than the average score and the score of ( $x_j$ ) at the neighbouring area is below the average score, the LISA statistic is negative, and;
- Low–High (L–H) association: When the criterion score ( $x_i$ ) is lower than the average score and the score of ( $x_j$ ) at the neighbouring area is higher than the average score, the LISA statistic is negative.

### III. *Kernel Density Estimation (KDE)*

The Kernel Density Estimation (KDE) is defined as a non–parametric technique used to derive the probability density of a certain random criterion (Yu *et al.*, 2014:81). It is commonly used as an estimation method for assessing first order characteristics of a spatial point data file (Xie & Yan, 2013:64). It assesses poverty by overlaying a uniform surface over a central point (i.e. community) of a specific criterion (i.e. poverty) and creates a spherical shape known as a kernel over each point with a predefined bandwidth. This process is then repeated for each point, thus allowing for a kernel to be placed over each point (i.e. community). These point specific kernels are then summed together to provide the user with a density estimate in the form of grid cells (raster), showing the spatial distribution of poverty over a study area (Fotheringham *et al.*, 2000). The density of each kernel is determined by dividing the research study area into a predefined number of cells. A spherical neighbourhood is drawn around each feature point (community) with high levels of poverty. An algebraic equation is then applied with the output ranging from 1 (i.e. position of the feature point) to 0 (i.e. neighbourhood boundary) (Anderson, 2009:360). The two main advantages of the KDE method are that the risk distribution can be defined by the region around a cluster where the probability of an incident, like poverty, occurring is high, and by applying this density technique, a subjective spatial measuring unit which is homogeneous in nature can be applied for the entire region, thus allowing comparability (Anderson, 2009:360).

The KDE method is utilised within the scope of this study as a secondary analysis tool to validate the results of the G ‘family’ statistics. The KDE analysis will be done using ArcGIS 10.2 and its related Spatial Analyst extension. To initiate the KDE analysis, the poverty feature dataset derived from the MCDM process is converted into a point file. The poverty index attribute related to each point (community) is used as the population field into the kernel density estimate analysis.

### 3.5 SENSITIVITY ANALYSIS

For government to effectively eradicate poverty in the City of Cape Town by 2030, effective evidence-based decision making must incorporate the development of credible and relevant community-based policies and interventions. The development of credible and relevant poverty eradication policies and interventions are dependent on the robust models developed using the MCDM process. Typically in the evidence-based decision making environment, researchers and policy planners are continuously validating results generated from the forecasting and decision making models before decision makers are able to utilise the results to draw final policy conclusions. The initial policy choice, for example, may indicate that the provision of universal access to piped water inside of the dwelling structure or yard may eradicate poverty in the City of Cape Town by 2030. Nevertheless, in a caucus of multiple content experts and decision makers, the credibility of the result generated from the initial poverty model may be questioned. The content experts may, for instance, question the many sources of uncertainty relating to the model input sources. Model uncertainties could arise due to a lack of, or outdated information, coupled with the poor conceptualisation of the model (Burrough & McDonnell, 1998:19).

Sensitivity analysis can play a critical role in improving the MCDM model assurance and its forecasting abilities. It provides the researchers and planners with an understanding of how the model criteria reacts to multiple model input changes. These input changes can be applied by making minor changes to the initial model weighting schema generated through the PCA. The simulation of model inputs are considered by some researchers, including Butler *et al.* (1996:1) and Feizizadeh *et al.* (2013:86) as the most applicable technique to be used when analysing uncertainties and sensitivities in the MCDM model. In this study, the Monte Carlo simulation capabilities have been selected as the preferred technique to be used in generating the various weighting schemas. It has been selected as the preferred technique because of its ability to take into consideration the stochastic characteristics of the predefined set of evaluation criteria (Tenerelli & Carver, 2012:728). The simulation using the Monte Carlo approach in this study is described by the following steps, namely:

- Compute the initial MCDM model rank index;
- Generate a random weighting schema using the Monte Carlo approach. All Monte Carlo simulations will be done using STATA 12 and using the average PCA weighting schema as the reference weights;

- Apply the random weighting schema to the GIS-MCDM model;
- Repeat the simulation twice, and;
- Spatially analyse the results generated from the two models and compare with the initial results generated.

### **3.6 CONCLUSION**

In this chapter, the methodology to be used to integrate GIS with MCDM techniques for poverty eradication planning was discussed. The following chapter will utilise this GIS–MCDM methodology to identify and rank communities in the City of Cape Town which are severely deprived of basic capabilities/ entrenched in severe levels of poverty. The results generated will also show the changing topography of poverty across the City of Cape Town between 2001 and 2011. This spatial analysis can be used by decision makers to better inform their decision making processes regarding the targeting of appropriate poverty eradication programmes.

## CHAPTER FOUR: CASE STUDY: CITY OF CAPE TOWN

### 4.1 INTRODUCTION

The case study will analyse the extent of poverty eradication required in the City of Cape Town through the capability lens as proposed by the NDP. This capability lens has a strategic temperament as it includes the improvement of access to basic services; quality education; housing, and active labour markets. This strategic temperament of the capability lens makes the proposed GIS–MCDM methodology particularly appropriate because of its abilities to logically rearrange complex data and information issues and formulate a single uniform result, which decision makers can use to inform future community–based policy programmes and interventions. Thus, this chapter will demonstrate the full application of the proposed GIS-MCDM methodology by using both Spatial TOPSIS and Spatial COPRAS.

### 4.2 SPATIAL TOPSIS

Spatial TOPSIS is the amalgamation of both systems and analytical processes. It integrates the functionalities of GIS with the rigid mathematical processes of TOPSIS to identify suitable communities for poverty eradication programmes through the consumption of content expert preferences and census polygon data (Demesouka; Vavatsikos, *et al*, 2013:2).

As discussed in section 3.4.5.1, the TOPSIS method comprises five steps. These steps can be categorised into two processes. These steps and processes are:

- Construct normalised decision matrix, and;
  - Construct the weighted normalised decision matrix
  - Ascertain the positive ideal solution (*i. e. P*<sup>+</sup>) and negative ideal solution (*i. e. N*<sup>-</sup>);
  - Determine separation measures for each of the alternatives, and;
  - Estimate the relative closeness to the positive ideal solution  $C_i^+$
- } Identification the decision criteria
- } Identification of ideal solution

This methodology will be applied to each of the four criteria domains, namely education; basic services; labour force, and housing. The application to these themes will result in a theme index, i.e. ranking each of alternatives. Once applied to all the domains, a composite poverty index will be developed to conceptually identify where necessary government interventions are required to effectively eradicate poverty.

#### 4.2.1 BASIC SERVICES

The eradication of poverty has become a primary developmental objective for the South African Government. To redress this developmental objective, the NDP notes ‘public infrastructure investment’ as a critical action point for implementation. Gafar (2005:96) points out in his research on access to basic services that through public infrastructure investment, income can be redistributed back into the poorer communities. Therefore, improving basic infrastructure services in poor



communities is identified in this study as a critical criteria theme for eradicating poverty in the City of Cape Town Metropolis.

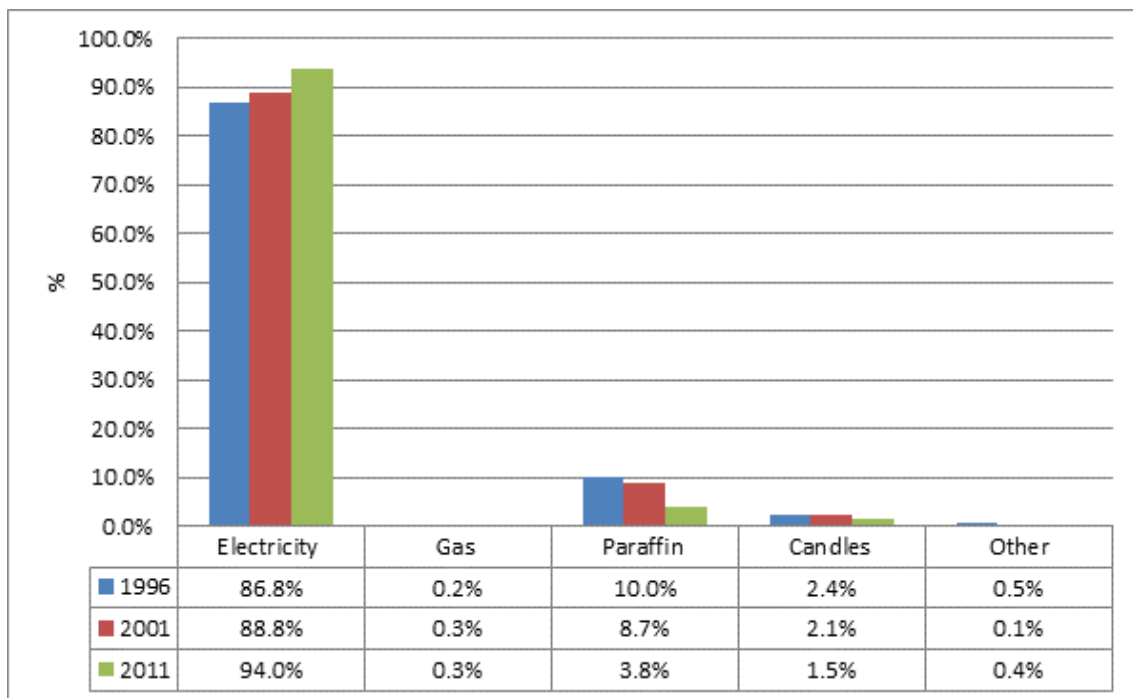
#### 4.2.1.1 PROFILE

All South Africans have the right to access to basic services. These rights are enshrined in Chapter 2 (i.e. the Bill of Rights) of the Constitution (Sections 24, 26 and 27) as well as being highlighted in the NDP (NPC, 2012:260). By improving access to these basic services citizens are enabled to be sufficiently nourished, healthy and gradually skilled thereby empowering the poor to take advantage of various social and economic opportunities which may exist in and around the City of Cape Town (NPC, 2012:218). The following profile provides a snapshot of access to basic services in the City of Cape Town using Stats SA’s Census data for 1996, 2001, and 2011.

#### I. ENERGY SOURCE FOR LIGHTING

In 2011, electricity was the main source of lighting used by 94% of all households in the City of Cape Town for lighting followed by paraffin (i.e. 3.8%). Access to electricity for lighting has increased significantly from 86.8% to 94% in 1996 and 2011, respectively. During the same period, the utilisation of other sources (e.g. paraffin) of lighting, with the exception of gas, has decreased, as highlighted by the figure below.

Figure 3: Energy source for lighting for 1996, 2001 and 2011

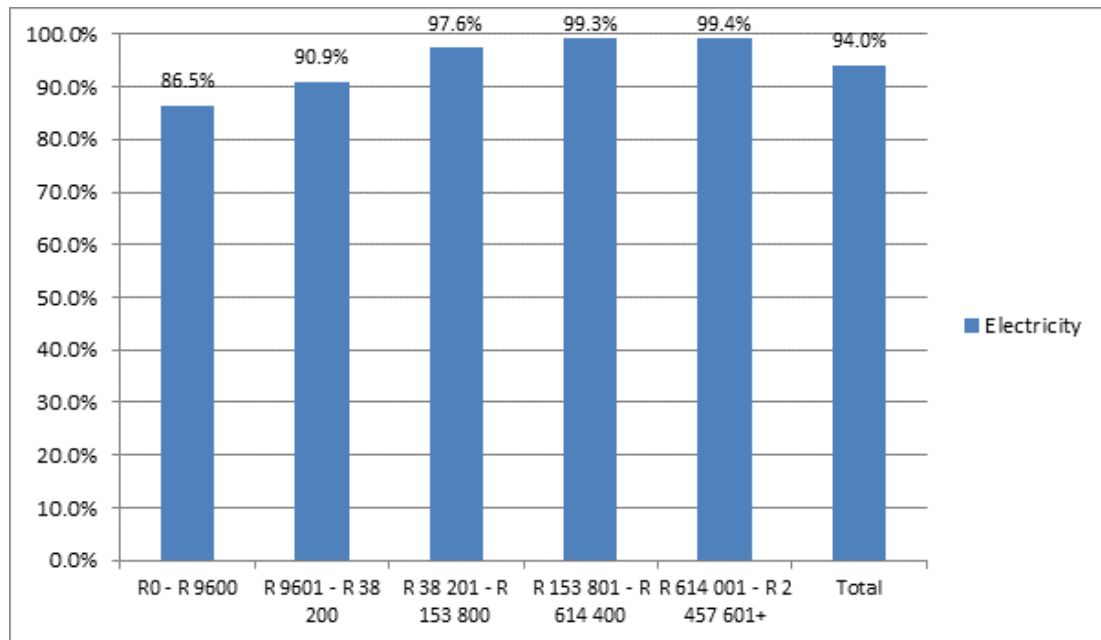


Source: Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

In addition, the figure below demonstrates access to electricity as a source of energy for lighting by household income. It shows that while 86.5% of households earning an income of less than R9 600

per annum have access to electricity for lighting, services still continue to fail the poor. These inequalities place strain on citizens' abilities to achieve their necessary capabilities

Figure 4: Electricity as the main source for lighting by household income in 2001

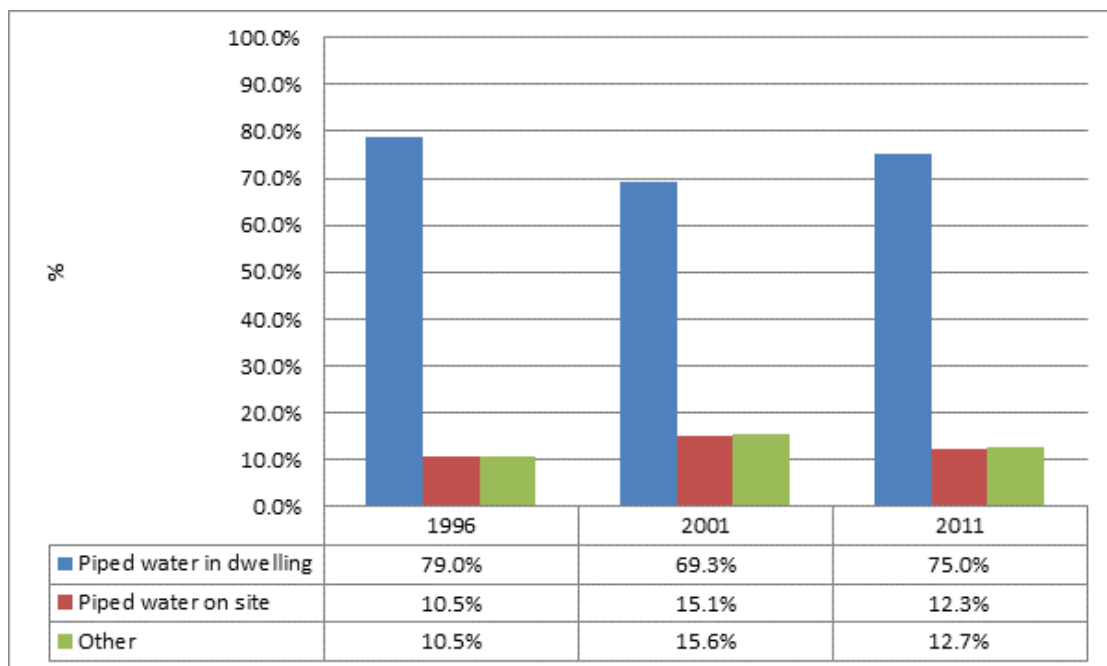


Source: Statistics South Africa, 2011, coupled with own calculations

## II. ACCESS TO PIPED WATER

In 2011, approximately 87.3% of households had access to piped water. This shows a slight drop of 2.2% in household access to piped water between 1996 and 2011.

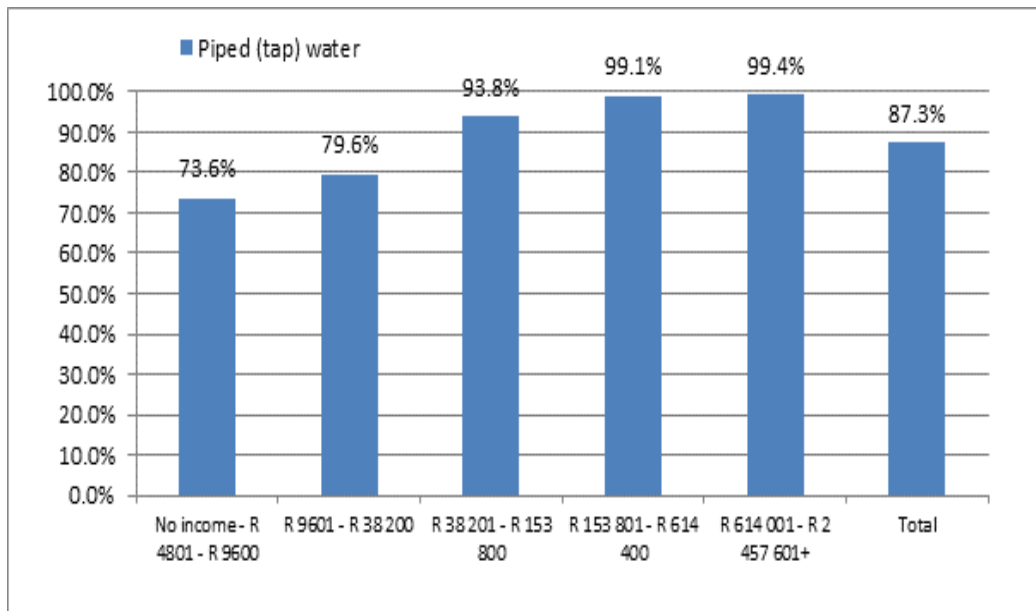
Figure 5: Access to piped water for 1996, 2001 and 2011



Source: Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

The figure below confirms the notion that poorer communities still have less access to piped water. For instance, it highlights that only 73.6% of households with an annual income of less than R9 600 has access to piped water as compared to 99.4% of households with an annual income of more than R2.5-million.

Figure 6: Access to piped water by annual income level in 2011

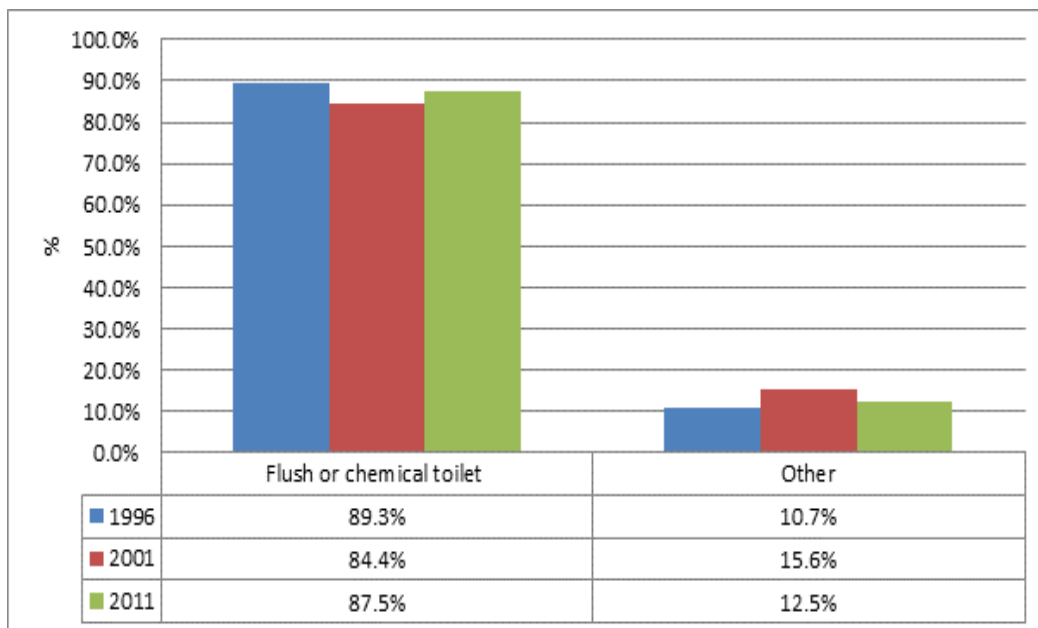


Source: Statistics South Africa, 2011, coupled with own calculations

### III. ACCESS TO SANITATION

In 2011, approximately 87.5% of households had proper sanitation services. This signifies a decrease from 89.3% in 1996, and only a slight increase from 84.4% in 2001.

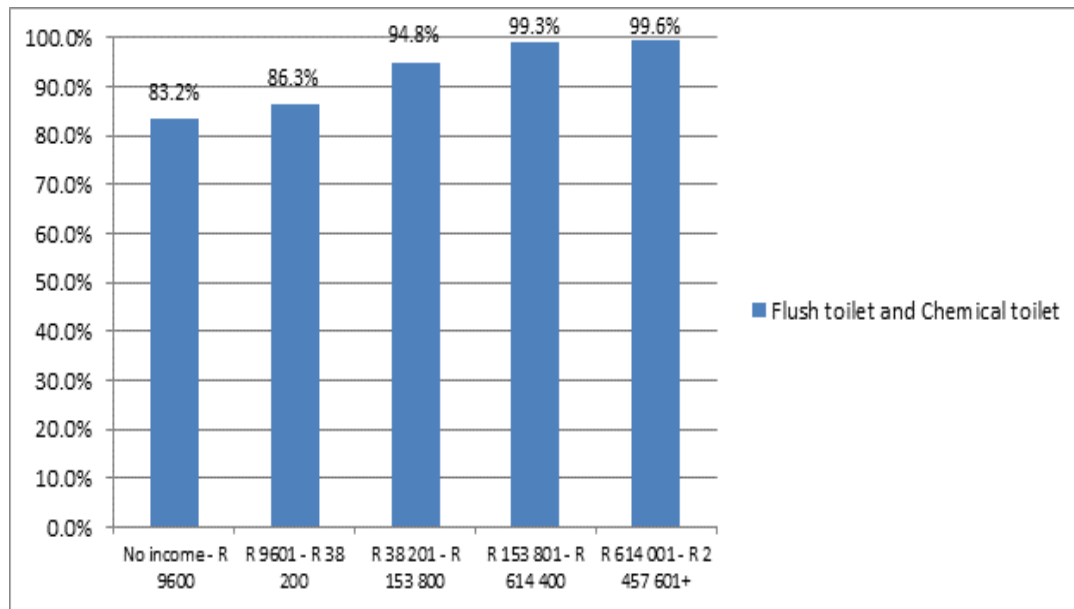
Figure 7: Access to sanitation services for 1996, 2001 and 2011



Source: Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

The figure below shows that access to proper sanitation services remain a significant issue for poorer communities. The figure shows that for all households earning an annual income of less than R9 600 per annum; only 83.2% has access to flushing or chemical toilets compared to 99.6% of households with an annual income of more than R2.5million.

Figure 8: Access to proper sanitation by annual income levels in 2011

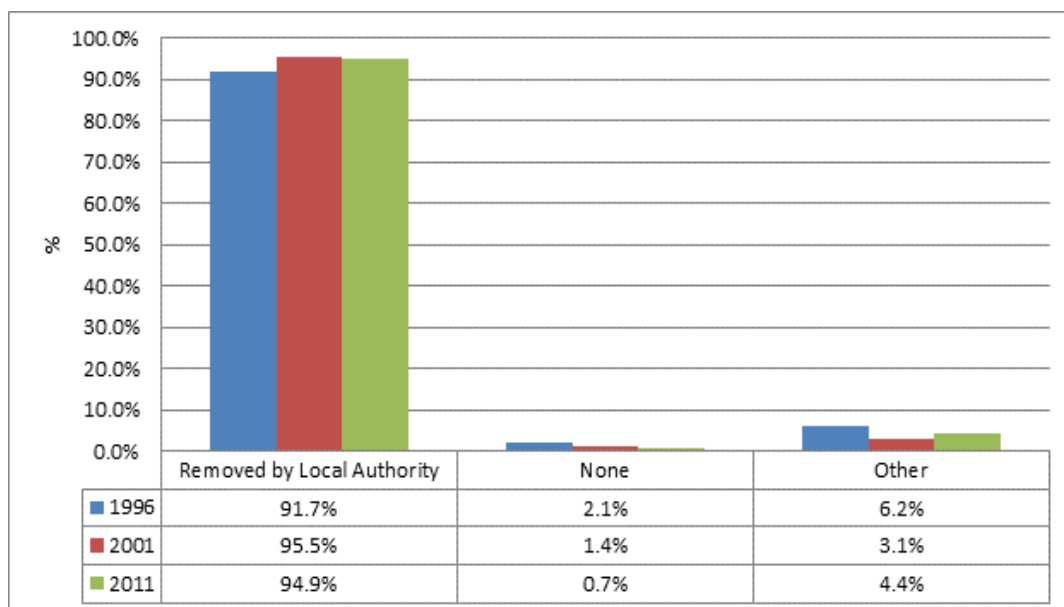


Source: Statistics South Africa, 2011, coupled with own calculations

#### IV. REFUSE REMOVAL

According to the figure below, access to refuse removal has improved slightly from 91.7% in 1996 to 94.9% in 2011, although there was a minor decrease between 2001 and 2011, i.e. from 95.5% to 94.9%.

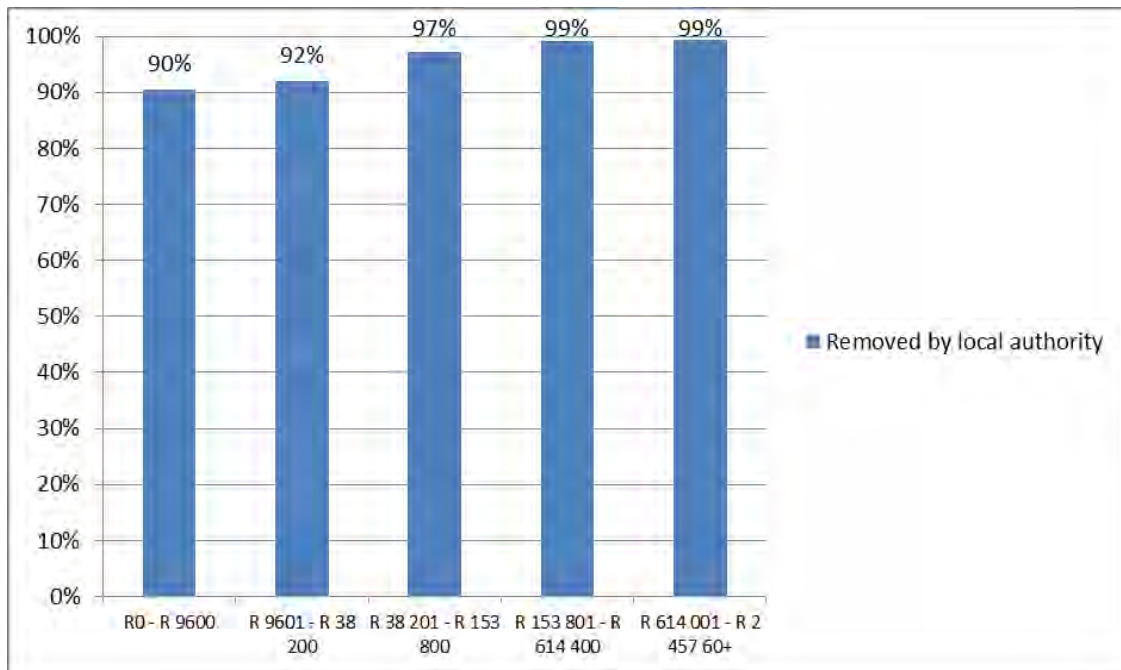
Figure 9: Refuse removal for 1996, 2001 and 2011



Source: Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

The figure below shows refuse removal by local authority by household annual income. It demonstrates that approximately 99% of households earning an annual income of more than R614 000 has their refuse removed by local authorities as compared to 90% of households earning less than R9 600 per annum.

Figure 10: Refuse removal by annual income in 2011

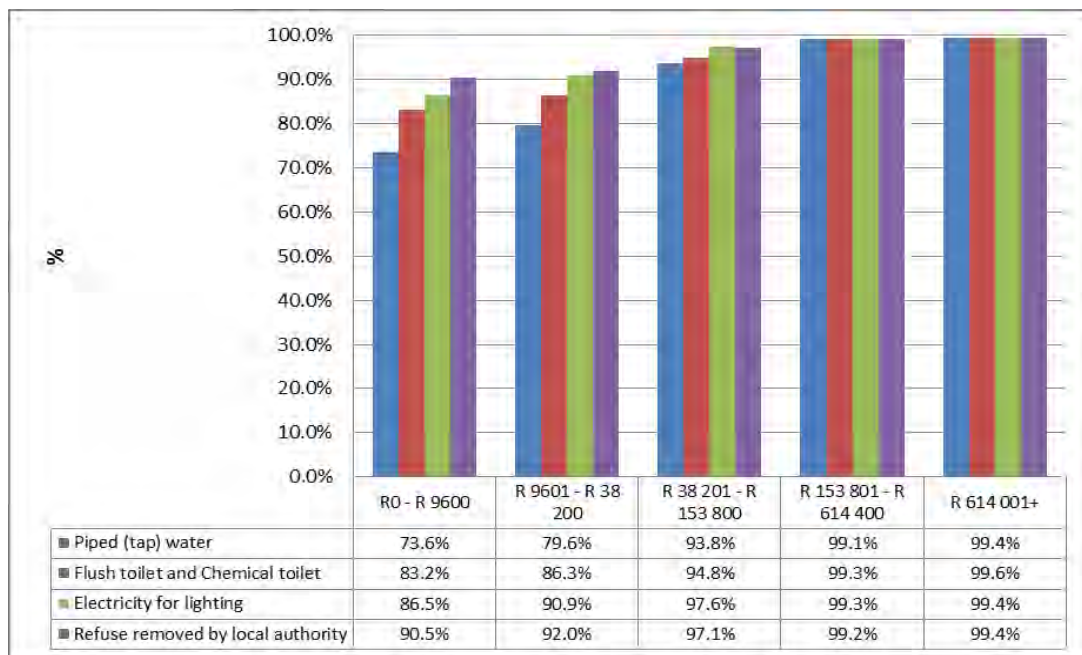


Source: Statistics South Africa, 2011, coupled with own calculations

With the economic effects of the global recession of 2008 still being felt by most of the developing countries, rising public deficits and forever shrinking government budgets and resources prompt policy and decision makers to develop new and more cost-effective policies and strategies. These policies and strategies are developed to comprehensively address the constant rise in poverty and inequality levels using the limited fiscal budgets available for resource planning. These government policies and strategies are typically homogenous in nature and often cover both the poor and non-poor populations. The result of these homogeneous policies and strategies is the intended programme benefits going disproportionately to the non-poor communities. (NPC, 2012:270).

The results of these skewed resource distributions can be seen in the figure below, which shows that despite the majority of the more wealthy households living in the City of Cape Town enjoying comprehensive access to certain basic services, the most poor households, i.e. households earning an annual income of less than R9 600, has less than adequate access to the same basic services. These results validate the research findings of Parker; Kirkpatrick, *et al* (2008:180) regarding the features and causes of household poverty in developing countries. The results suggest that poorer households in less developed countries typically endure both severe levels of exclusion from basic infrastructure services and from the inadequate quality of the limited basic infrastructure services to which the poor households do not have access to.

Figure 11: Levels of access to certain basic services by annual household income in 2011



Source: Statistics South Africa, 2011, coupled with own calculations

The above-mentioned lack of adequate access to basic services of poorer households can be addressed through the use of more rigorous service delivery procedures. These procedures can prevent decision makers from making mediocre investment decisions that commit government to unnecessary incessant project funding, which ultimately hampers the progress of other critical service delivery projects (NPC, 2010:160). This could be achieved through better application of public-private funding, which could ultimately result in improved decision making (NPC, 2010:160).

#### 4.2.1.2 IDENTIFICATION OF DECISION CRITERIA FOR BASIC SERVICES

##### I. CONSTRUCTING THE DECISION MAKING MATRIX

Spatial-MCDM procedures can be used by government to better inform public-private funding. However, in order to optimise the targeting of public-private spending, the Spatial-MCDM model requires specific criteria that can be used to effectively identify appropriate communities that require government intervention hence reducing costs of government interventions. For the criteria theme basic services, four evaluation criteria were derived and used to construct a decision making matrix, which is used to assess the joint evolution of basic services rendered in the City of Cape Town between 2001 and 2011. The following four evaluation criteria are used to compile the basic services capability set and amalgamated to construct the decision making matrix. These criteria are the percentage of persons:

- Who do not use electricity as a source for lighting;
- Who has access to piped water in their dwellings;
- Who do not have their refuse removed by local authorities, and;
- Not using the bucket system (including no toilets).

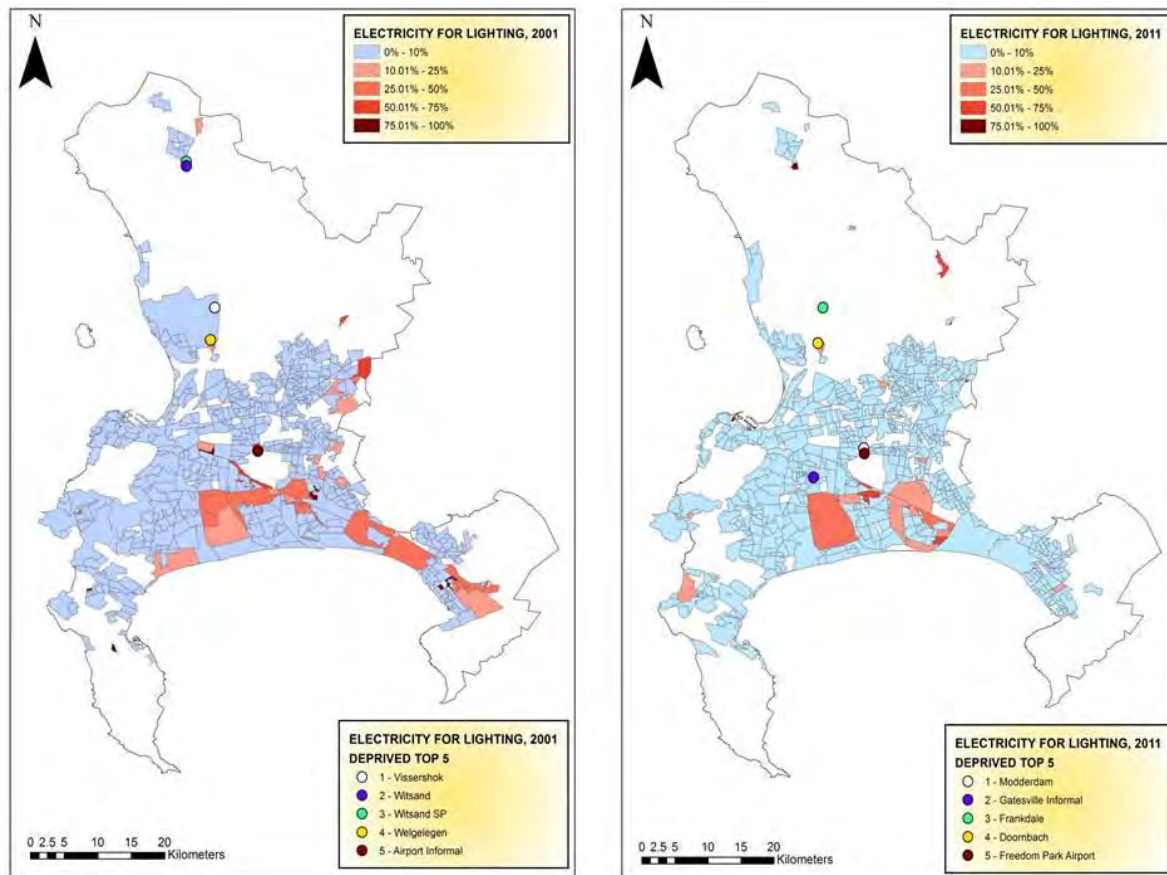
The decision making matrix can be defined at various geographical levels and is important for policy implementation since it impact the poor. For the purposes of this study, the above-mentioned criteria were evaluated at a sub–place level. The reason for that is that smaller communities characteristically have added homogeneous socio–economic characteristics as compared to other larger geographical regions, thus reducing programme intervention leakages (Bigman and Fofack, 2000:135).

## II. SPATIAL ANALYSIS OF EVALUATION CRITERIA

### a. ELECTRICITY AS A SOURCE FOR LIGHTING

The NDP affirms that by 2030, more than 90% of the total population must have adequate access to grid connected or off-grid electricity (NPC, 2012:163). Map 6 below shows that since 2001 more citizens living in the City of Cape Town Metropolis has been connected to the electricity grid. The map also shows the progress made by government in terms of meeting the 2030 target of connecting more than 90% of persons to grid connected or off-grid electricity. The map highlights specific communities such as Modderdam, Gatesville informal, Frankdale, Doornbach and Freedom Park where electricity related interventions are required to be implemented over the next 15 years to meet the NDP’s electricity objectives.

Map 6: Percentage of persons with no access to electricity for lighting in 2001 and 2011

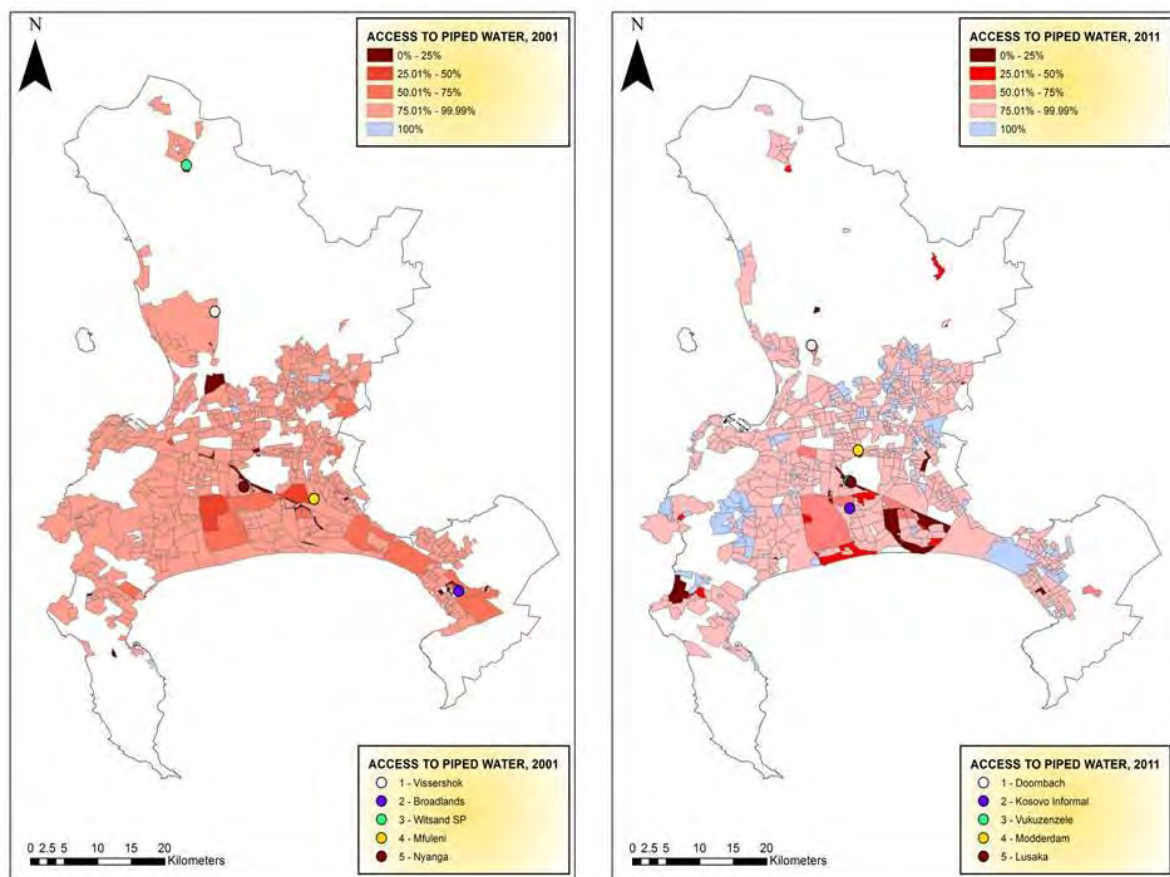


Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

## b. ACCESS TO PIPED WATER IN DWELLINGS

The water resources and services vision underpinning the NDP is to provide adequate and affordable access to clean, potable water by 2030 to all South Africans (NPC, 2012:65). Map 7 below shows the progress made by government in terms providing access to clean, potable water for all citizens. The maps highlights access to piped water in dwellings as a critical policy issue as very few communities in the City of Cape Town has all of its households connected to piped water infrastructure. The map also identifies regions and communities where urgent government interventions are required, specifically in the Khayelitsha and Philippi regions and in communities such as Doornbach, Kosovo Informal, Vukuzenzele, Modderdam and Lusaka.

Map 7: Percentage of persons with access to piped water (inside dwelling or yard) for 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

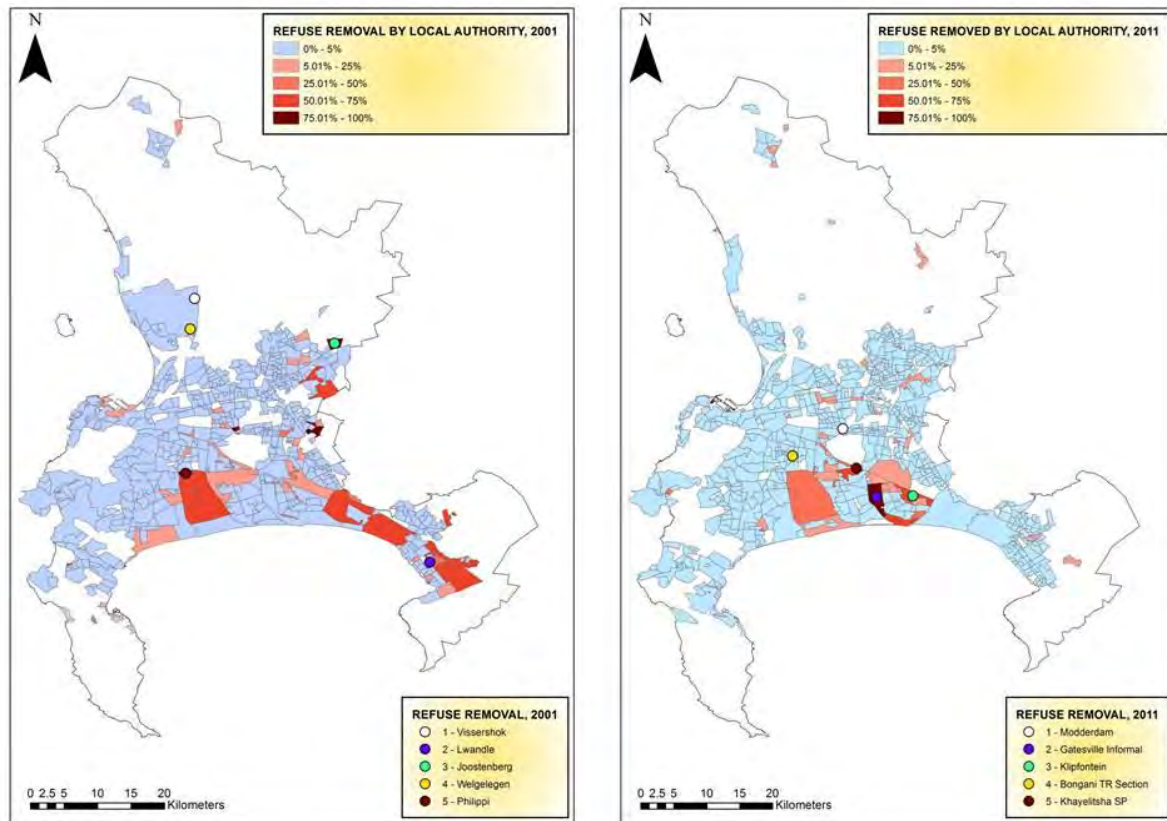
## c. REFUSE REMOVAL BY LOCAL AUTHORITIES

While the NDP does not make explicit mention of the linkages between refuse removal and poverty eradication, goal two of the National Waste Management Strategy states that government should ensure the efficient and effective delivery of waste (removal) services. The key indicator target for this goal is 95% of persons having access to satisfactory levels of waste collection services (Department of Environmental Affairs, 2011:9). Map 8 below shows the spatial distribution change of all persons who do not have their refuse removed by local authorities. The map draws the attention to



the fact that while conditions have improved, pocket areas within the City of Cape Town still exist where high percentages of persons do not have their refuse removed by local authorities. This is of concern to both the Health and Safety sectors, given the high correlations between infectious diseases and crime and poor refuse removal.

Map 8: Percentage of persons who do not have their refuse removed by local authorities for 2001 and 2011

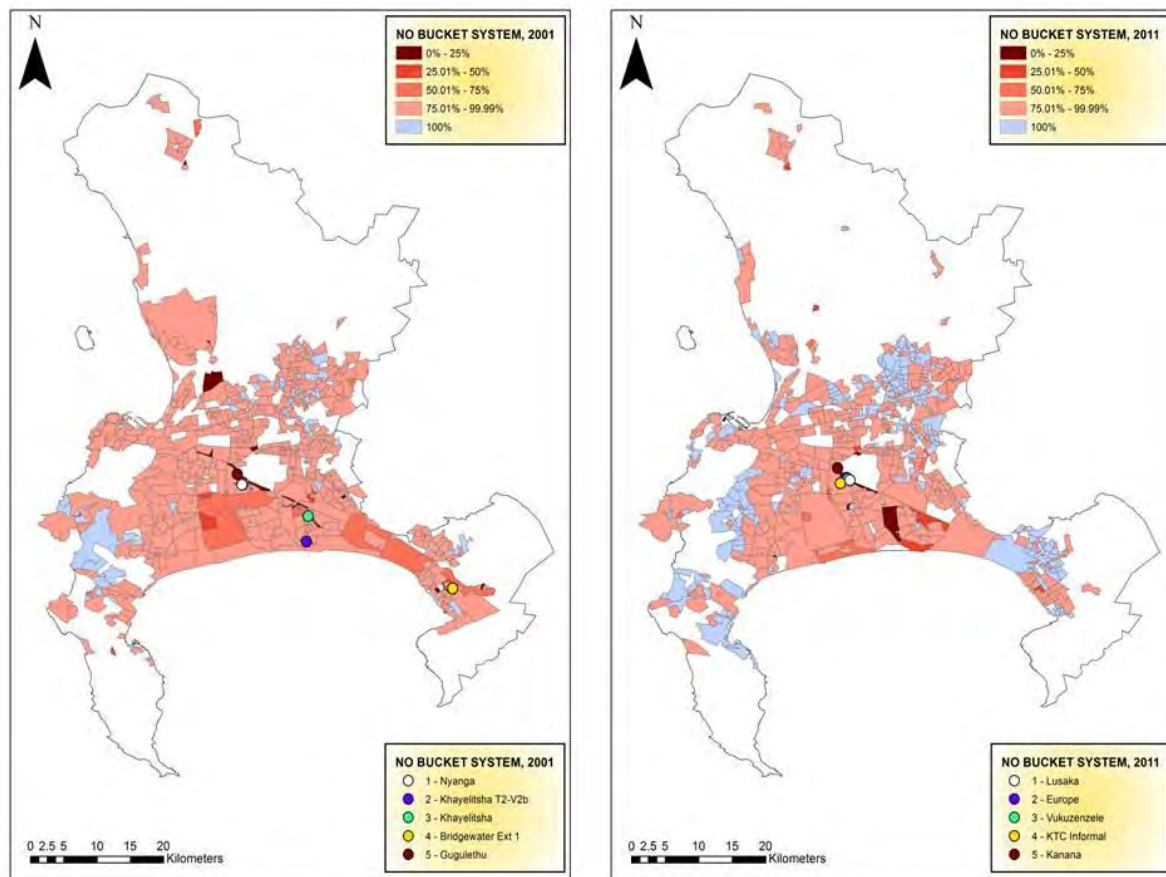


Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

#### d. SANITATION SERVICES

Improved access to affordable and hygienic sanitation services is considered by the NDP as a critical capability needed to eradicate poverty (NPC, 2012:177). Post 1994, the eradication of the bucket system has been identified as a key developmental goal on all service delivery agendas for local municipalities. The map below shows the spatial change of communities in the City of Cape Town between 2001 and 2011 not using the bucket system (including no toilets) as a form of sanitation services. This spatial analysis shows that while eradicating the bucket system is high on the development agenda for all three spheres of government, progress made over the last decade has been too slow resulting in multiple service delivery protests, and most notably the series of so-called “poo protests” conducted around the City of Cape Town (Hutchison, Internet source: 26 June 2013). Map 9 also identifies certain communities such as Lusaka, Europe, Vukuzenzele, KTC informal and Kanana where urgent infrastructure related interventions are required to address the lack of proper sanitation services.

Map 9: Percentage of persons not using the bucket system for 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### III. CONSTRUCTING THE WEIGHTED DECISION MAKING MATRIX

The determination of criteria weighting schemas is considered to be the most important phase in the construction of the decision making matrix. These schemas are used to unambiguously assign criteria importance to each of the evaluation criteria included in the MCDM model, and to develop a basic services index used to identify hotspots where several features of basic service deprivation occur. The average weighting schema used to derive the basic services index is determined by calculating the average Principal Component one (PC1) using the PC1 values for both 2001 and 2011. All PC1 were derived using a statistical program called STATA 12.

Before the PC1's can be determined, the presence of multi-collinearity must be tested for. To do this, a pairwise correlation matrix between the initial basic services index and its four related evaluation criteria is constructed to test for the presence of multi-collinearity and to substantiate the extent of association between the initial basic services index and its related criteria. The table below shows that water, lights and toilets being highly correlated ( $p > 0.80$ ) with the initial basic services index while sanitation is only mildly correlated. These high correlations indicate the likely presence of multi-collinearity in the spatial dataset for 2001.

When evaluating the relationships between the criteria and the basic services index both piped water and toilets have an inverse (i.e. negative) relationship with the initial basic services index. This shows that with the improvement in access to piped water and adequate sanitation facilities the basic services deprivation levels of communities will be improved.

Table 7: Pearson correlation matrix for the four criteria used for the initial basic services index in 2001

<b>CRITERIA</b>	<b>INDEX</b>	<b>TOILETS</b>	<b>REFUSE</b>	<b>LIGHT</b>	<b>WATER</b>
<b>INDEX</b>	1.0000				
<b>TOILETS</b>	-0.8423**	1.0000			
<b>REFUSE</b>	0.6417**	-0.4930**	1.0000		
<b>LIGHT</b>	0.8759**	-0.7898**	0.5786**	1.0000	
<b>WATER</b>	-0.9386**	0.8673**	-0.5811**	-0.8895**	1.0000

\*\* Statistically significant at  $p < 0.01$

The pairwise correlation matrix developed for 2011 between the initial basic services index and its four related evaluation criteria (i.e. toilets, refuse, light and water) used in the PCA analysis is shown in the table below. Statistically significant correlations were observed for all coefficients ( $\rho < 0.01$ ) and high correlation coefficients ( $p > 0.80$ ) were observed for improved access to proper sanitation services, and access to piped water in a dwelling/yard. Also, when evaluating the relationships between the four criteria and the initial basic services index, both piped water and toilets have an inverse (i.e. negative) relationship with the initial basic services index, thus basic services deprivation levels decreases with increased access to piped water in a dwelling/yard and eradication of the bucket system. These high correlations values in both Tables six and seven gives a strong indication of the presence of multi-collinearity. To address this issue, Variance Inflation Factor (VIF) techniques are applied to only the 2001 basic service criteria to identify the criteria which will be removed.

Table 8: Pearson correlation matrix for the four criteria used for the basic services index in 2011

<b>CRITERIA</b>	<b>INDEX</b>	<b>TOILETS</b>	<b>REFUSE</b>	<b>LIGHT</b>	<b>WATER</b>
<b>INDEX</b>	1.0000				
<b>TOILETS</b>	-0.8569*	1.0000			
<b>REFUSE</b>	0.7348*	-0.5892*	1.0000		
<b>LIGHT</b>	0.6919*	-0.4570*	0.5337*	1.0000	
<b>WATER</b>	-0.9653*	0.8343*	-0.7118*	-0.6756*	1.0000

\*\* Statistically significant at  $p < 0.01$

The correlation matrices presented in the Tables 6 and 7 above corroborate the presence of multi-collinearity in the initial model and that one or more variables are interrelated with one another. The existence of multi-collinearity will not only result in repeatability errors, but will also add complexity

into the model development process. Thus, VIFs are derived to ascertain which of the four criteria can be removed from the spatial-MCDM models without hindering the model's capabilities. The table below presents the results of the VIF analysis for 2001, highlighting that all VIFs are below the VIF threshold of 10. For that reason, all four criteria will be retained for the spatial-MCDM models for 2001 and 2011.

Table 9: VIF scores for each criterion

<b>CRITERIA</b>	<b><i>VIF</i><sub>2001</sub></b>	<b><i>1/VIF</i></b>
<b>TOILETS</b>	7.53	0.1328
<b>REFUSE</b>	4.96	0.2016
<b>LIGHT</b>	4.07	0.2458
<b>WATER</b>	1.56	0.6430

The results of the multi-collinearity testing have shown that all basic services related criteria for both 2001 and 2011 can be retained in the spatial-MCDM models. The tables and results below will show the PCA results and how these results were applied to derive the average weight schema to be applied to both spatial-MCDM models. Table 10 shows the results of the PCA for 2001 and 2011. It is observed that Principal Component 1 (PC1) accounts for more than 83% and 81% of the total variation in both the 2001 and 2011 models, respectively, whereas the other PC's only accounted for less than 20% of the variation. Due to these variations in percentages, the eigenvectors relating to the first PC are used as to derive the average weighting schema to be applied to both spatial-MCDM models.

Table 10: Results of the PCA for 2001 and 2011 applied to the basic services domain

<b>COMP</b>	<b>YEAR</b>	<b>EIGENVALUE</b>	<b>DIFFERENCE</b>	<b>PROPORTION</b>	<b>CUMULATIVE</b>
PC1	2001	0.0930	0.0821	0.8264	0.8264
	2011	0.0659	0.0571	0.8083	0.8083
PC2	2001	0.0109	0.0055	0.0973	0.9237
	2011	0.0088	0.0049	0.1079	0.9162
PC3	2001	0.0055	0.0023	0.0485	0.9722
	2011	0.0039	0.0010	0.0478	0.9640
PC4	2001	0.0031	0.0000	0.0278	1.0000
	2011	0.0029	0.0000	0.0360	1.0000

The eigenvectors of the four criteria used to develop the basic services index are shown in Table 11 below. It is observed that the coefficients for Principal Component 1 relating to the criteria: proper sanitation services, and access to piped water in dwelling/yard are both positive. These results imply, considering that all things are considered equally, that communities with greater access to piped water

in dwelling and proper sanitation services will be ranked lower in terms of the government priority for basic services upgrades or improvements.

Table 11: Eigenvector values for 2001 and 2011 for each of the criteria

CRITERIA	YEAR	COMP1	COMP2	COMP3	COMP4
TOILET	2001	0.4810	0.3156	0.7071	-0.4111
	2011	0.4858	0.5705	0.3759	-0.5452
REFUSE	2001	-0.2885	0.9351	-0.2034	0.0303
	2011	-0.2625	0.0871	0.8520	0.4446
LIGHT	2001	-0.5195	-0.0309	0.6728	0.5258
	2011	-0.3340	0.8163	-0.3507	0.3149
WATER	2001	0.6446	0.1582	-0.0766	0.7441
	2011	0.7639	0.0240	-0.0996	0.6371

Keeping in mind that Principal Component 1 accounts for more than 80% of the total variation in the basic service data model, its related normalised eigenvectors ( $\sum_{i=1}^n |\varphi| = 1$ ) is used to derive the average weighting schema that is applied to develop the final basic services deprivation index. The mathematical sequences below show the individual weighting schemas used to derive the average schema and the related 2001 and 2011 basic services indices. Both weighting schemas for 2001 and 2011 show that the criteria, i.e. access to piped water in dwelling/yard (37%), proper sanitation services (26%) and electricity for lighting (22%) have been assigned priority in both spatial-MCDM models.

$$BASIC\ SERVICES\ INDEX_{2001} = \{TOILET(0.24876), REFUSE(0.14920), LIGHTING(0.26867), WATER(0.33337)\}$$

$$BASIC\ SERVICES\ INDEX_{2011} = \{TOILET(0.26314), REFUSE(0.14218), LIGHTING(0.18091), WATER(0.41377)\}$$

$$BASIC\ SERVICES\ INDEX_{average} = \{TOILET(0.2559), REFUSE(0.1457), LIGHTING(0.2248), WATER(0.3736)\}$$

#### 4.2.1.3 IDENTIFICATION OF IDEAL SOLUTION

In MCDM, various alternatives are evaluated using multiple and often conflicting criteria to determine preferential decision choices. This often results in no solution being found that concurrently placates the set of evaluation criteria, and results in a compromised solution being found between policy planners and decision makers. TOPSIS is considered as the most suitable MCDM technique to be used under these types of conditions. This TOPSIS technique work on the premise of selecting the most preferred alternative with the shortest distance from the Positive Ideal solution ( $S_i^+$ ) and the farthest from the Negative Ideal solution ( $S_i^-$ ). The alternative ranking is done by means of a closeness index derived using both the positive and negative ideal solutions (Behzadian; Otaghsara, *et al*, 2012:13052). For the purposes of this study, the final alternative ranking is done based on an inverse calculation that subtracts the closeness index value from one.

The table below displays the  $S_i^+$  and  $S_i^-$  values used in deriving the basic services deprivation index for 2001 that ranks the identified communities within the City of Cape Town using the basic services capability set. This index unanimously identifies communities that are severely deprived of basic services capabilities ( $I_{basic\ services} > 80\%$ ). This can guide the City of Cape Town's resource allocation plans i.e. Integrated Development Plans (IDP) so as to ensure that the municipality upholds its constitutional obligations of safeguarding the delivery of basic services to all citizens in a sustainable way. The basic services deprivation index can also be used as a baseline to assess the progress made by government in terms of improving access to basic services. According to the 2001 ranking deprivation index, Lwandle was ranked as the most severely deprived community in the City of Cape Town Metropolis in terms of basic services capabilities followed by Welgelegen, Wallacedene, Nomzamo and Langa. The table also highlights the City of Cape Town's inability to effectively arbitrate various communities' service delivery expectations by exploiting the wider network of state and other non-government resources (COGTA, 2009:35).

Table 12: The distance values and the final rankings for basic services in 2001

<b>ALTERNATIVE</b>	<b><math>S_i^+</math></b>	<b><math>S_i^-</math></b>	<b><math>C_i</math></b>	<b><math>1 - C_i</math></b>	<b>RANK</b>	<b>PLACE</b>
$A_1$	0.01	0.51	0.979	0.021	349	Acacia Park
....						
$A_{291}$	0.46	0.14	0.232	0.768	5	Langa
$A_{306}$	0.48	0.04	0.078	0.922	1	Lwandle
$A_{347}$	0.43	0.12	0.216	0.784	4	Nomzamo
$A_{543}$	0.50	0.13	0.202	0.798	5	Wallacedene
$A_{548}$	0.49	0.05	0.091	0.909	2	Welgelegen
.....						
$A_{580}$	0.01	0.51	0.972	0.028	270	Zonnebloem

The table below presents the  $S_i^+$  and  $S_i^-$  values used in deriving the basic services index for 2011, which similarly ranks the identified communities within the City of Cape Town using the four evaluation criteria. It highlights the progress made by government in terms of redressing certain constitutional rights as enshrined in the Bill of Rights. According to the 2011 basic services rank index, Modderdam was identified as the most severely deprived community in terms of access to adequate basic services followed by Boys Town, Frankdale, Freedom Park Airport and Khayelitsha SP. When analysing and comparing the spatial pattern of the results for 2001 with 2011, the top five deprived communities identified in 2001 were more spatially dispersed as compared with the deprived communities 2011, which is more spatially clustered.

Table 13: The distance values and the final rankings for basic services in 2011

ALTERNATIVE	$S_I^+$	$S_I^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.00	0.52	0.996	0.004	497	Acacia Park
....						
$A_{94}$	0.45	0.14	0.240	0.760	2	Boys Town
$A_{220}$	0.47	0.16	0.250	0.750	3	Frankdale
$A_{221}$	0.45	0.15	0.254	0.746	4	Freedom Park
$A_{316}$	0.41	0.16	0.283	0.717	5	Khayelitsha SP
$A_{398}$	0.49	0.07	0.119	0.881	1	Modderdam
.....						
$A_{705}$	0.02	0.51	0.963	0.037	110	Zwartdam

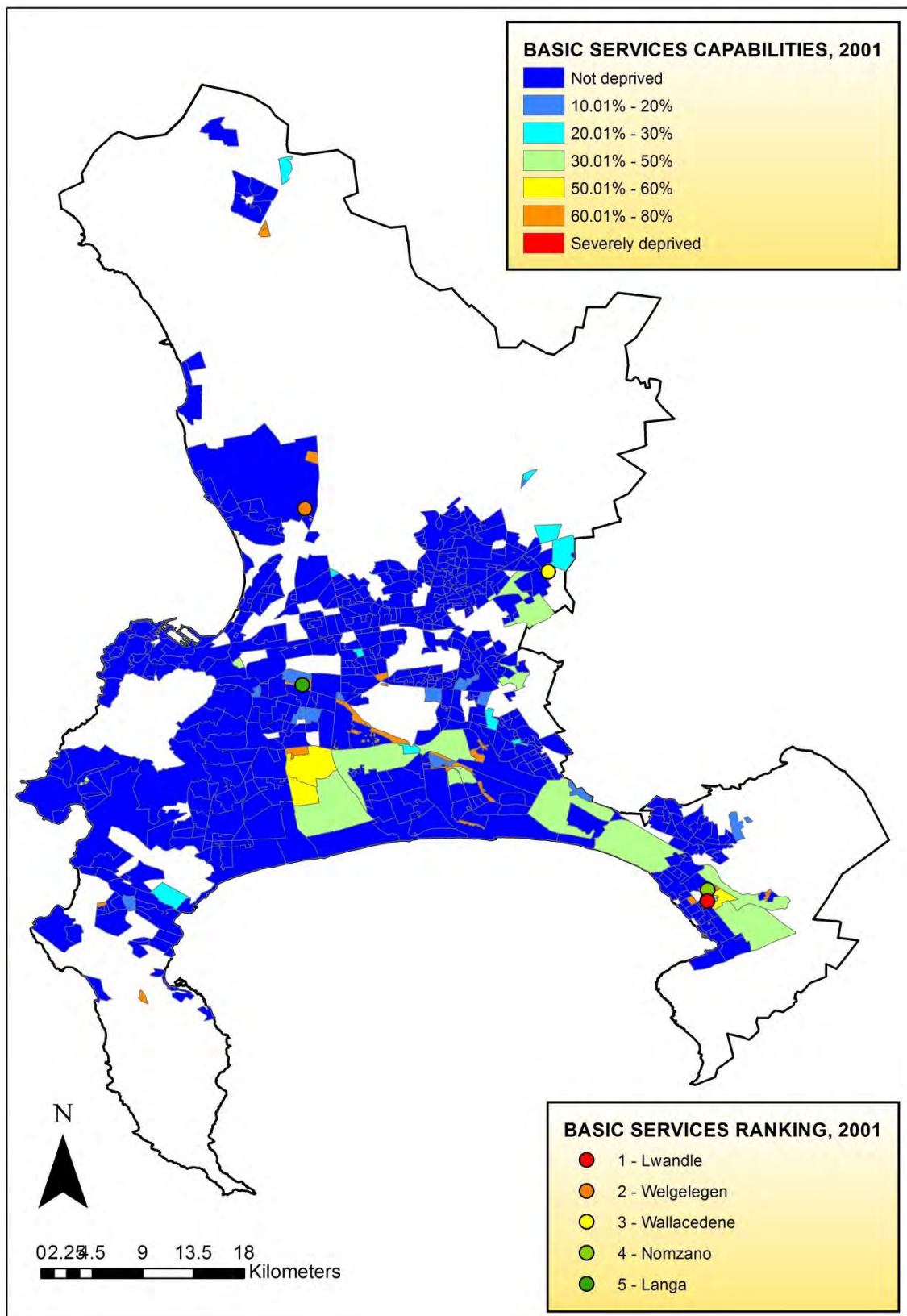
Table 14 below presents the summarised statistics of the basic services deprivation scores in the City of Cape Town for 2001 and 2011. Regarding basic services capability deprivation, it shows a decrease between 2001 and 2011, both for the mean (i.e. 7.7% to 5%, respectively) and standard deviation (i.e. 15.9% to 13.8%, respectively). These results support highly documented increased efforts by both the provincial and local governments to improve access to fundamental basic services such as water and sanitation in the City of Cape Town. Furthermore, the decrease in the large standard deviations between 2001 and 2011 highlights to a certain degree the narrowing basic services capabilities identified in the City of Cape Town.

Table 14: Summary statistics for basic services deprivation scores for 2001 and 2011

CAPABILITIES	OBS	MEAN	STD. DEV	MIN	MAX
Basic services index 2001	580	0.07657	0.158698	0	0.92227
Basic services index 2011	705	0.04980	0.138168	0	0.88104

Maps 10 and 11 below demonstrate the spatial distribution and local variability of basic services capability deprivation for 2001 and 2011. These maps show that between 2001 and 2011, government has succeeded in keeping pace with the growing demand for basic services. Nevertheless, the spatial results for 2011 shows that while government has done well in terms of redress, this progress could still not match the increase in the number of communities receiving poor services in specifically the southern parts of the City of Cape Town, including Khayelitsha, Crossroads, Gugulethu and so forth.

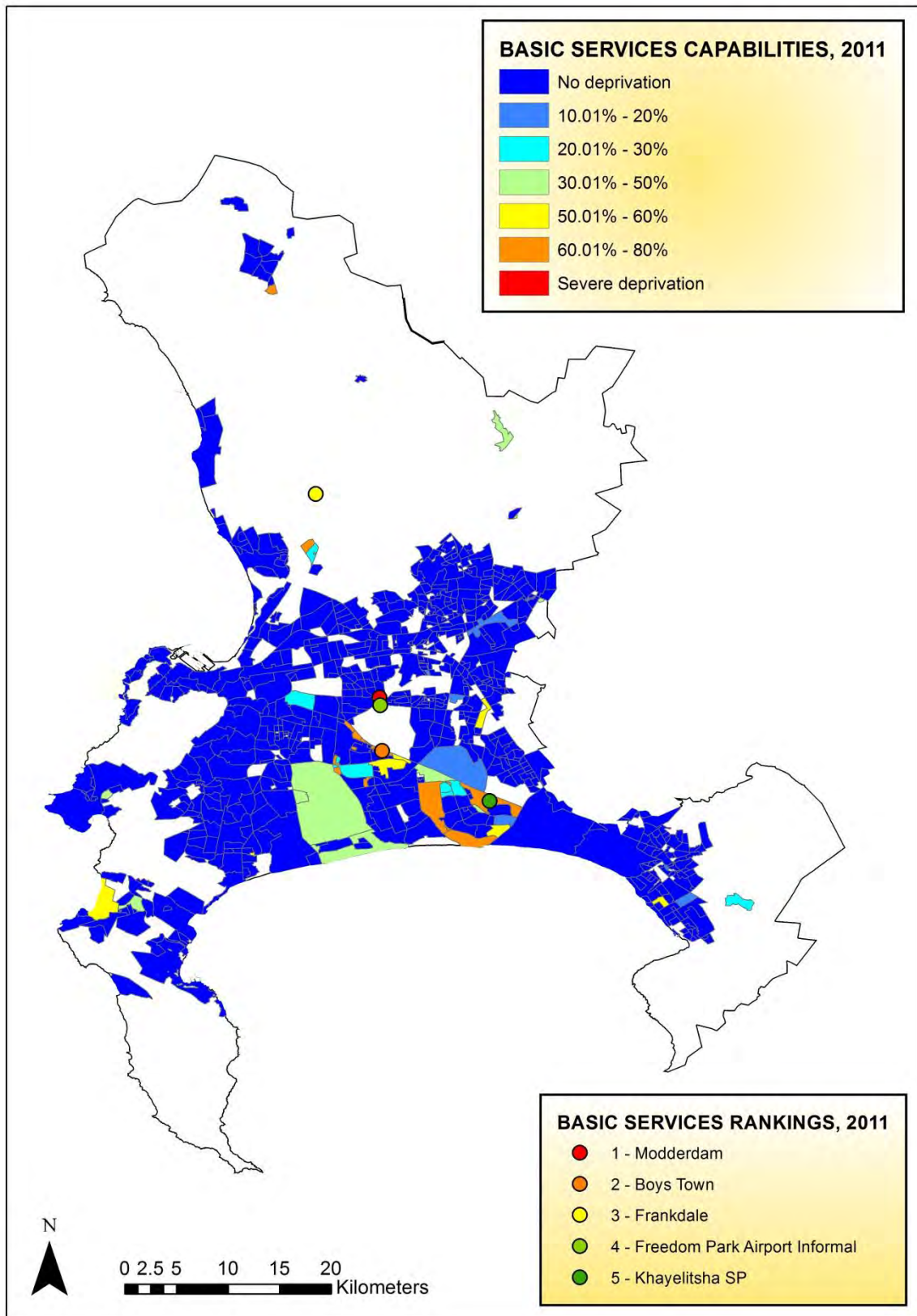
Map 10: Spatial pattern of levels of basic services in the City of Cape Town in 2001



Source: Own calculations



Map 11: Spatial pattern of levels of basic services in the City of Cape Town in 2011



Source: Own calculations

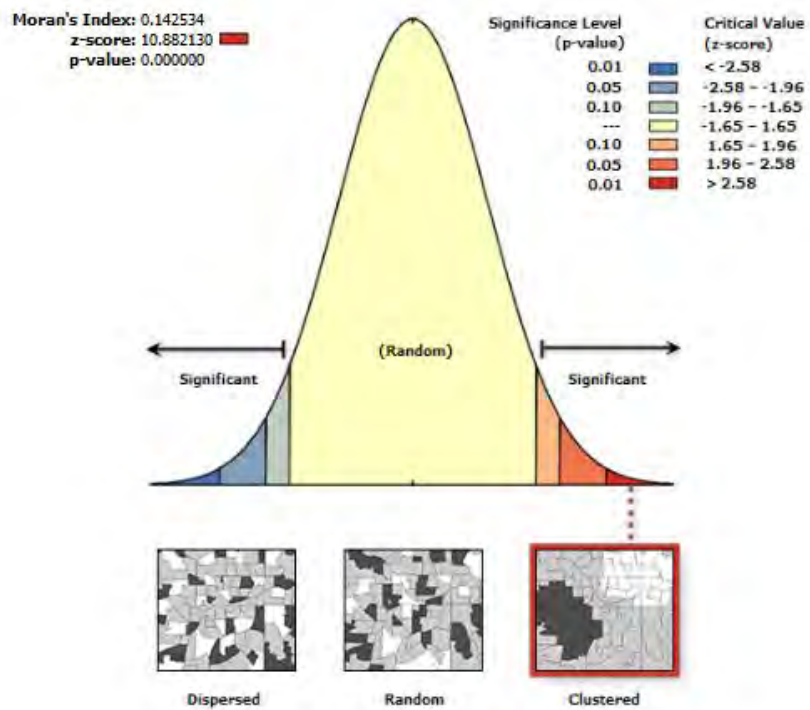
According to COGTA's (2009:39) State of Local Government in South Africa Report 2009, the increase in the number of (poor) communities receiving poor basic services are negatively associated with local governments' inability to keep pace with the growing demands for adequate infrastructure required for improved access to certain fundamental basic services. A Report by The World Bank (1994:2) argues that to combat increasing levels of poverty, infrastructure must develop fast enough to accommodate for population growth. To do this, municipalities must incorporate spatial statistical analysis into their basic infrastructure services decision making processes to ensure that the intended programme and intervention beneficiaries (i.e. ideally poor communities) actually benefit. Within the scope of this study, three spatial statistics, namely Global Moran's I; Local Moran's I (Anselin), and Getis-Ord  $G_i^*$  will be applied to analyse the extent of spatial association with regards to basic services capability deprivation, thus assisting to better understand the multiple facets of its spread and evolution. This type of understanding will allow decision makers to develop more meaningful policies that, when implemented, will significantly address the multiple aspects of adequate basic services provision in the City of Cape Town.

#### I. GLOBAL MORAN'S INDEX (I)

The analysis of spatial patterns of levels of basic services provision in the City of Cape Town focuses on communities that receive inadequate to severely inadequate levels of basic services. Much of the basic services mapping in this study is applied with the objective of identifying communities who experience high levels of multiple capability deprivation in the City of Cape Town. These communities are referred to as hot spots. The first type of analysis relating to the measurement of spatial associations or communities receiving poor basic services is done using one of the G 'family' statistics, namely Global Moran's I statistic. The Global Moran's I statistic is a descriptive measure used to assess the global spatial autocorrelation (Zhanga; Luob, *et al*, 2008:212). It is a helpful statistic used to test for the presence of dispersion, randomness and clustering in the overall spatial pattern of basic services capabilities deprivation between 2001 and 2011 in the City of Cape Town. Notwithstanding, the biggest disadvantage of the Global Moran's I is that the statistic does not show where the clustering of communities with poor basic services are located.

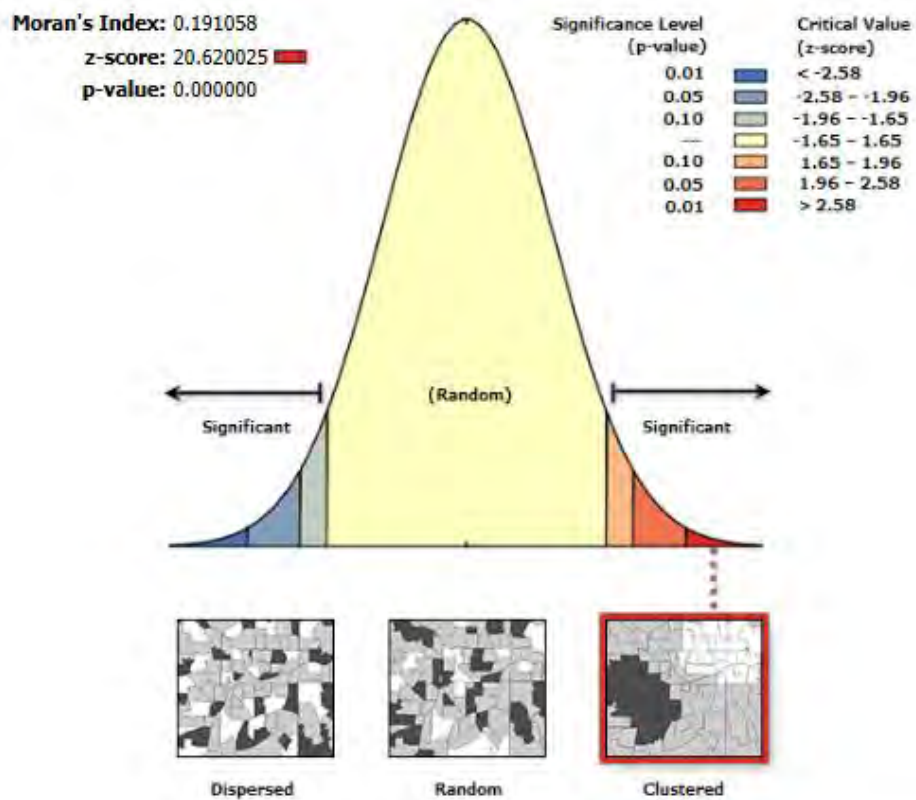
To execute this analysis, two Global Moran's I coefficients were computed, namely Global Moran's Index and its associated Z-score using the basic services index values derived from the MCDM process as the input data. The results of the analysis as presented in Figures 12 and 13 below display positive Moran's I of 0.14 and 0.19 for 2001 and 2011, respectively. These results quantitatively prove the existence and slight expansion of a clustering pattern in poor basic services between 2001 and 2011 across the City of Cape Town. The high positive Z score of 10.9 and 20.6 for 2001 and 2011, respectively indicate that the null hypothesis of 'no spatial clustering' of basic services capability deprivation can be rejected and there exist a less than one percent likelihood that this clustered pattern could be the result of random chance.

Figure 12: Moran's I classification for the basic services in the City of Cape Town for 2001



Source: Own calculations

Figure 13: Moran's I classification for the basic services in the City of Cape Town for 2011



Source: Own calculations

## II. LOCAL INDICATOR OF SPATIAL ASSOCIATION (LISA)

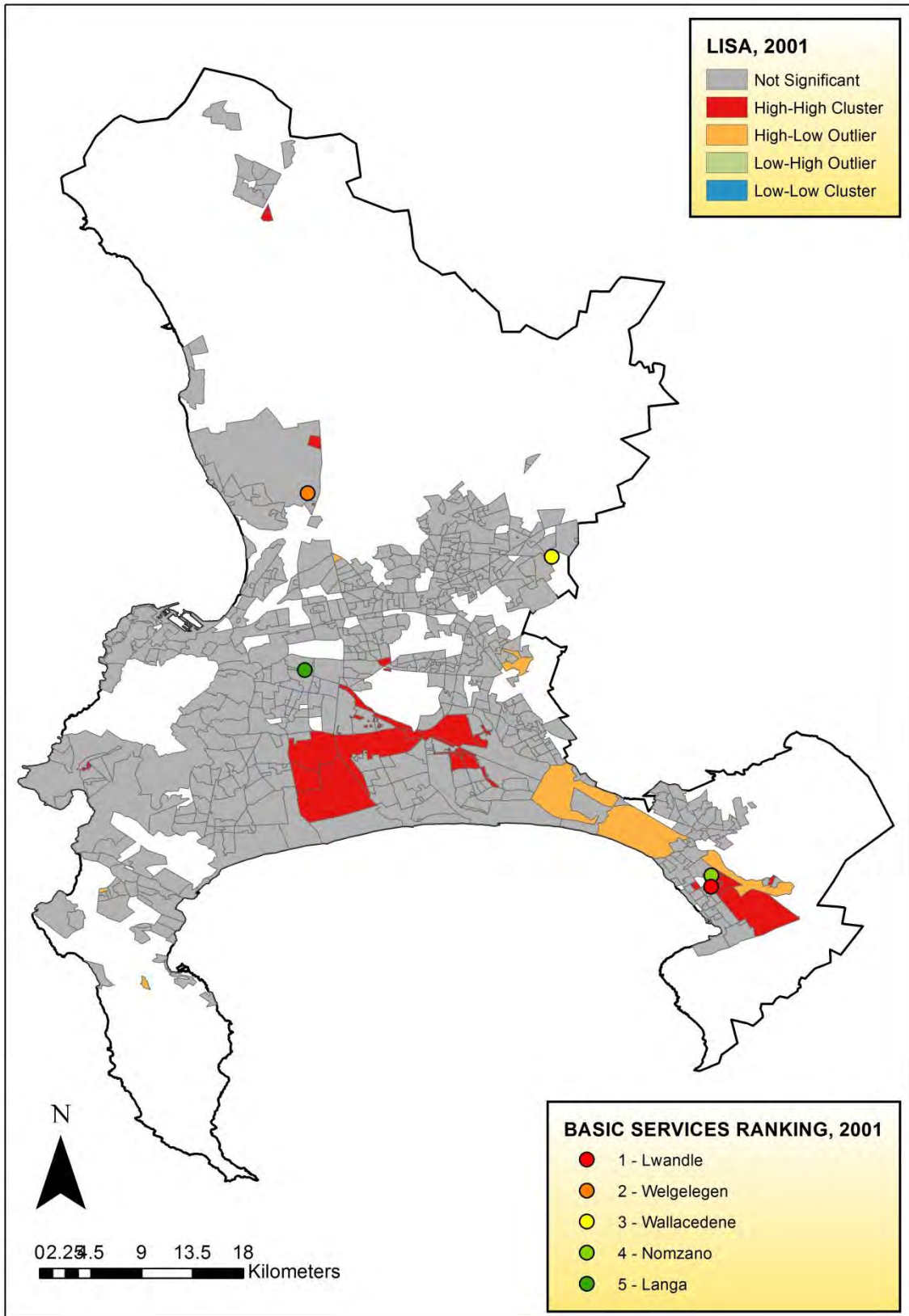
Maps 12 and 13 below demonstrate the spatial clusters of basic services capability deprivation at a 0.05 significance level for the City of Cape Town in 2001 and 2011. The LISA statistic gives an indication of the degree of significant spatial clustering of similar index scores in the neighbourhood of the *i*-th community located in the City of Cape Town. These communities are categorised into four classes, namely communities:

- (1) That are characterised by the high basic services deprivation scores derived from the MCDM model bordered by communities with high basic services capability deprivation scores (i.e. High–High or H–H);
- (2) With low basic services capability deprivation scores bordered by communities with low basic services capability deprivation scores (i.e. Low–Low or L–L);
- (3) With high basic services capability deprivation values and surrounded by communities with low basic services capability deprivation (i.e. High–Low or H–L), and;
- (4) With low basic services capability deprivation scores bordered by communities with high basic services capability deprivation scores (i.e. Low–High or L–H).

In 2001, there were two major spatial clusters of the H–H type, including the surrounding Strand area (i.e. Lwandle and Nomzamo) and the surrounding Philippi area. Map 12 below shows the existence of an H–L type cluster that indicates the presence of spatial uncertainties in the manner causing the spatial configuration of basic services capability deprivation in the City of Cape Town. These results reveals firstly, the presence of spatial heterogeneity and secondly, a common spatial characteristic found in South Africa, which was predominantly brought about through Apartheid planning, where communities characterised by high basic services capability deprivation levels are surrounded by communities that are predominantly characterised by low basic services capability deprivation levels.

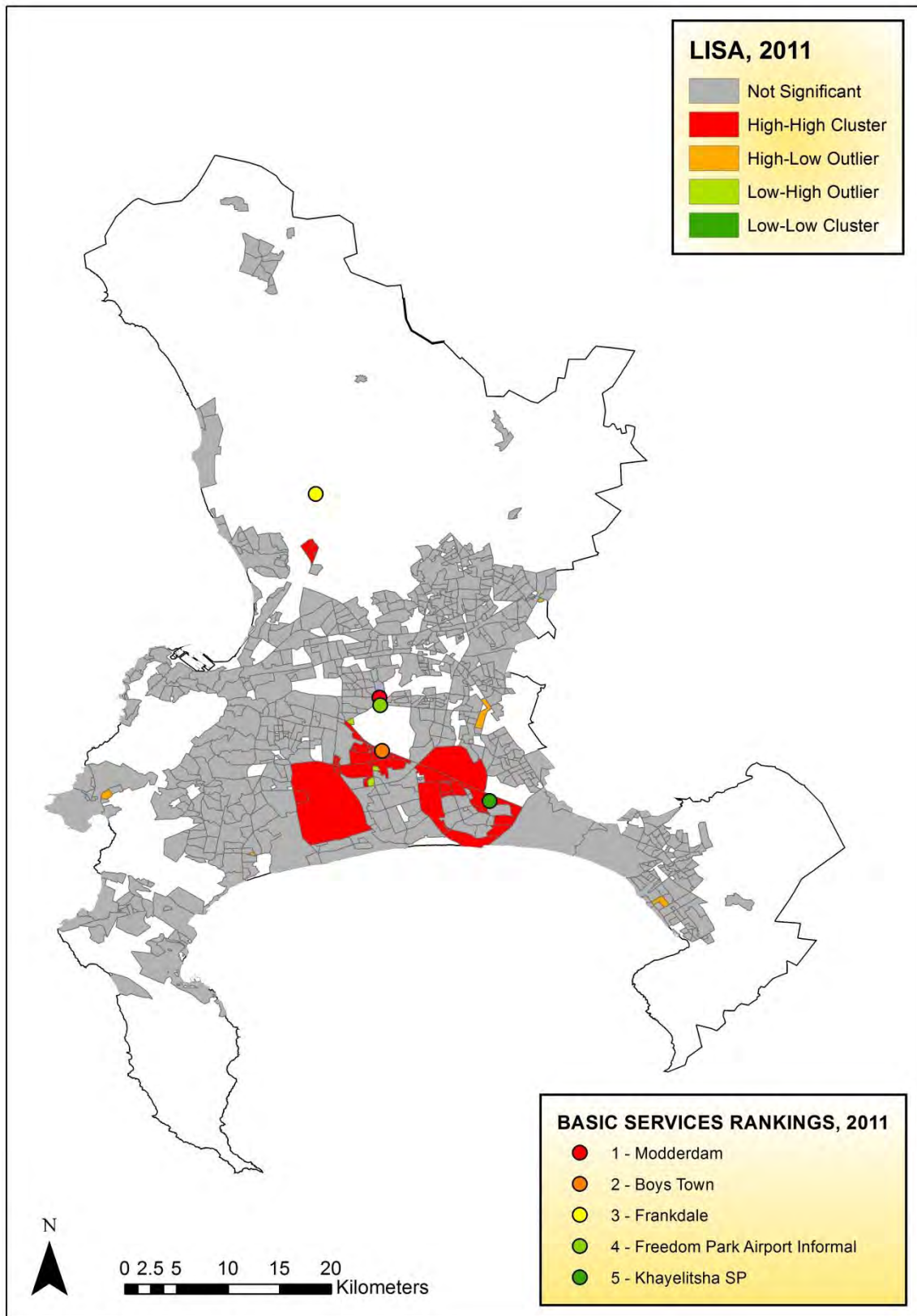
In addition, Map 13 below demonstrates two major H–H cluster types in the Khayelitsha and Philippi areas. When comparing these results with Map 12, it is evident that between 2001 and 2011 government has made strides in terms of improving citizen access to certain fundamental basic services in the City of Cape Town. Notwithstanding, Map 13 also shows that between 2001 and 2011, the H–H cluster in the Khayelitsha and Philippi areas has expanded significantly. This expansion is the result of two types of exclusion policies implemented in the City of Cape Town, namely active and passive. Sen (2000:15) refer to policies intended to improve access to certain basic services, but that unintentionally increase the basic services deprivation levels in other communities as passive policies, while active policies refer to policies implemented with the intention of increasing deprivation levels. The implementation of both these policy types has resulted in the situation where communities receiving adequate access to basic services are segregated from communities like Khayelitsha and Philippi who experience inadequate to severely inadequate levels of basic services.

Map 12: LISA for 2001



Source: Own calculations

Map 13: LISA for 2011



Source: Own calculations

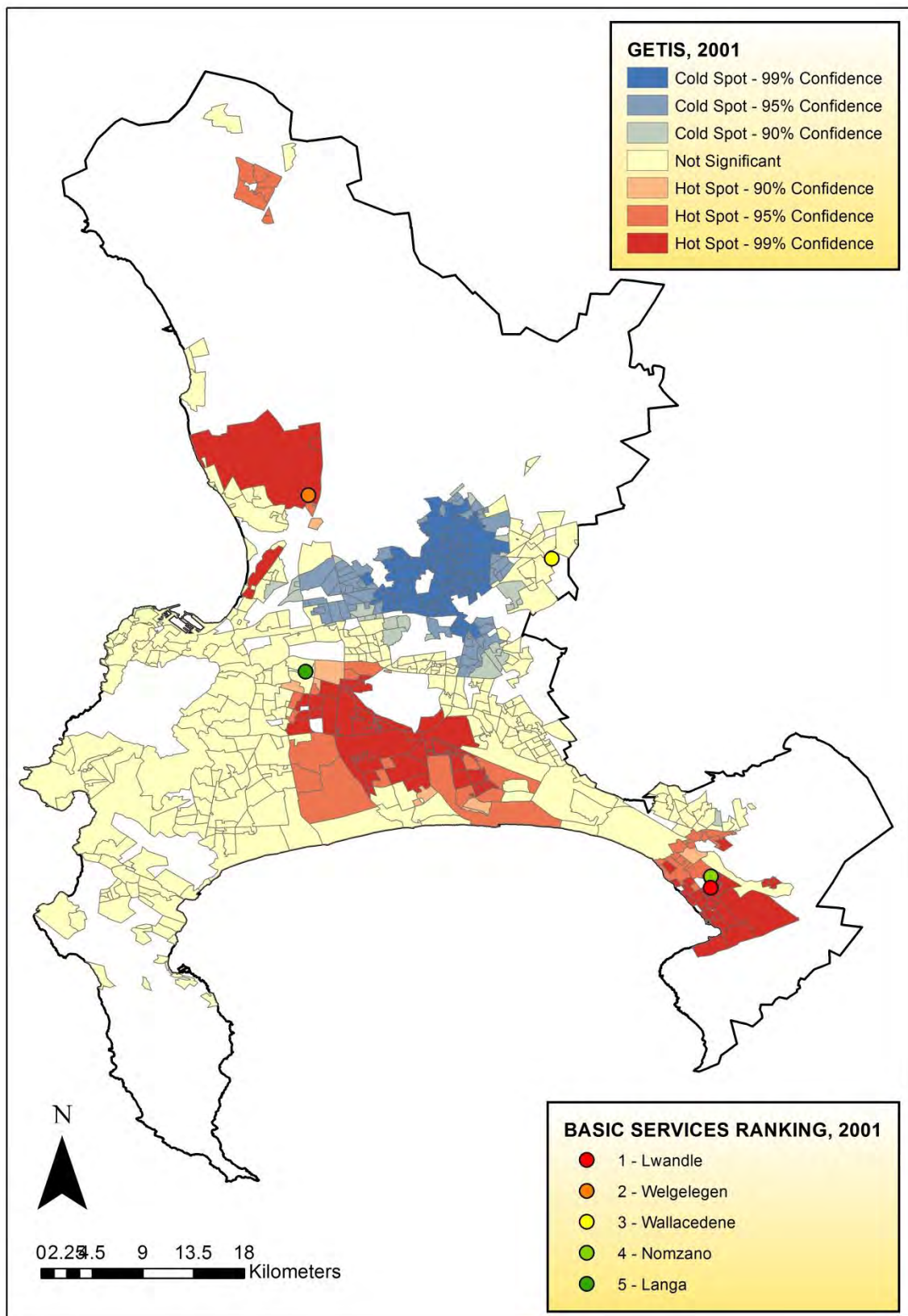
### III. GETIS – ORD $G_i^*$

A hotspot assessment for 2001 and 2011 using the levels of access to basic services in the City of Cape Town was performed using the spatial statistical tool called Getis-Ord  $G_i^*$  to investigate any indication for spatial patterning of inadequate to severely inadequate levels of basic services. This statistical tool identifies spatial clusters of high values (i.e. hotspots) and low values (i.e. cold spots) using the  $G_iZ$  scores and  $G_iP$  scores for each community. Maps 14 and 15 below demonstrate the clustering of both positive and negative scores of  $Z[G_i^*(d)]$  that is significant at a 0.01, 0.05 and 0.1 level. Referring to Map 14 below, the clustering of positive scores highlighted in red indicates the spatial association of high values ( $Z[G_i^*(d)] > 1.96$ ) and the negative clustering in blue shows the spatial association of low values ( $Z[G_i^*(d)] < -1.96$ ).

In 2001, the Getis-Ord  $G_i^*$  analysis of communities receiving inadequate to severely inadequate levels of basic services identifies multiple clustered communities with significantly increased incidences in the Khayelitsha/Philippi areas and Strand/Lwandle area, thus making these areas so-called hotspots. These areas with high levels of basic services capability deprivation are completely enclosed by communities with no elevated or lowered deprivation levels (i.e. regions coloured in beige). This region is then bordered by a fragmented band of communities with low levels of basic services capability deprivation in the northern part of the City of Cape Town, also referred to as so-called cold spots.

The  $G_i^*$  analysis for basic services capability deprivation for 2011 is done to assess the shift in spatial patterns between 2001 and 2011. The results of basic services capability deprivation for 2011, as shown in Map 14 below, display one main cluster of raised incidences (Philippi and Khayelitsha and its surrounding areas) and multiple clusters with lowered incidences, with distinctive pattern changes between 2001 and 2011. Furthermore, Map 15 also displays that between 2001 and 2011 the number of clusters with raised incidences decreased if compared with 2001, but the spatial cluster size for basic services deprivation for the surrounding Philippi and Khayelitsha communities has increased. These results reinforce the notion of social exclusion/ segregation, and how the implementation of passive infrastructure development initiatives by government has exacerbated basic services capability deprivation in the southern parts of the City of Cape Town. If government was to effectively eradicate basic service capability deprivation in the City of Cape Town by 2030, then efforts between the three spheres of government must be revitalised to restructure the built environment through the improvement of basic services related infrastructure in the City of Cape Town in order to attain impartial development and redress major social exclusion factors (NPC, 2010:44). Factors such as a lack of access to proper sanitation services; no piped water in a dwelling/yard; not using electricity as the primary source for lighting; and inadequate refuse removal services can all be viewed as exacerbating the issue of social exclusion, which in turn increases capability deprivation.

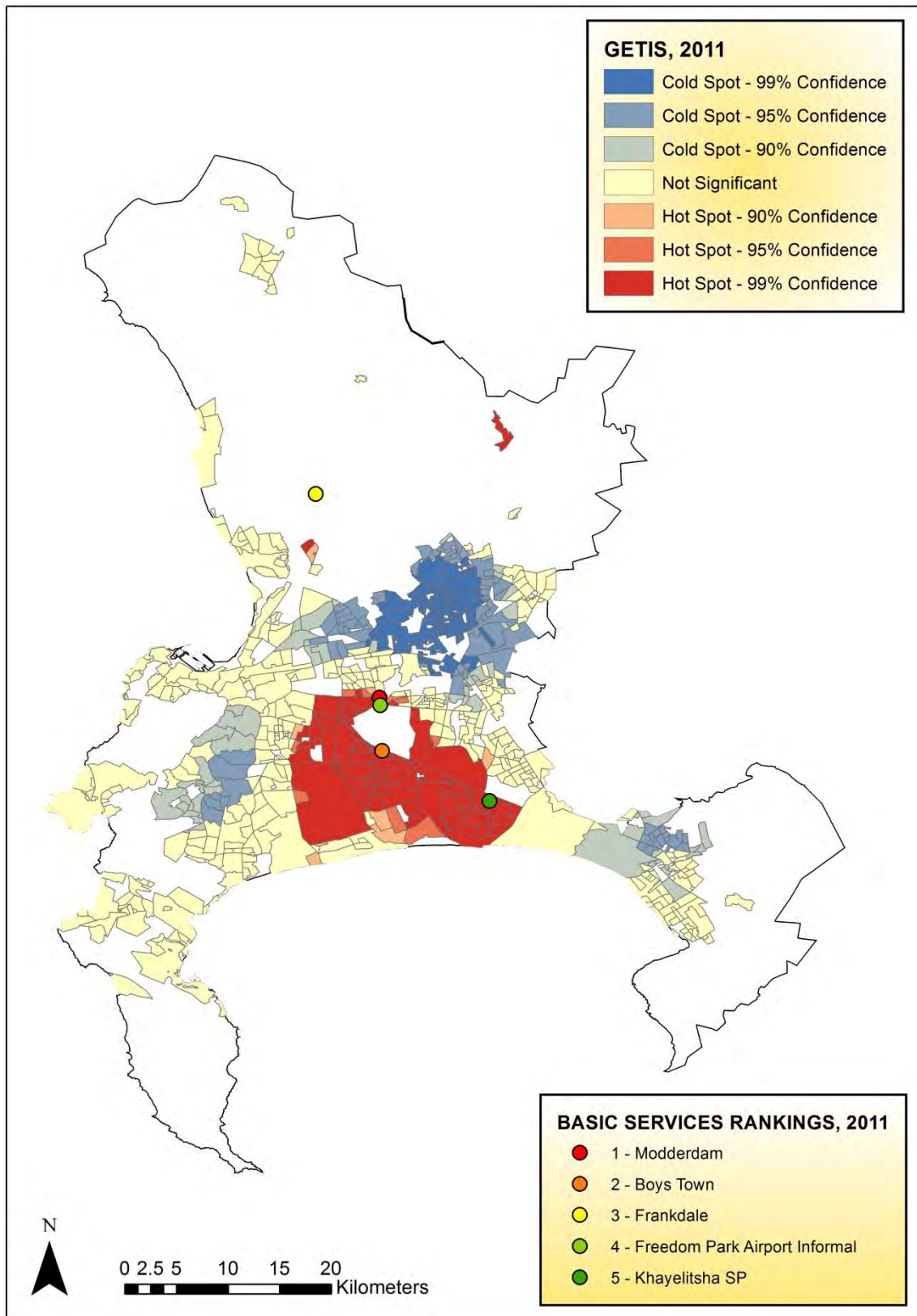
Map 14: Getis-Ord significance at the 1%, 5% and 10% significance level in 2001



Source: Own calculations



Map 15: Getis-Ord significance at the 1%, 5% and 10% significance level in 2011

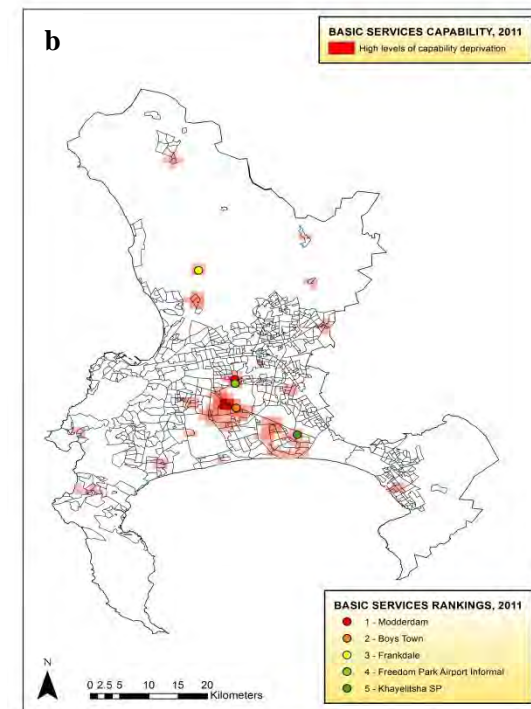
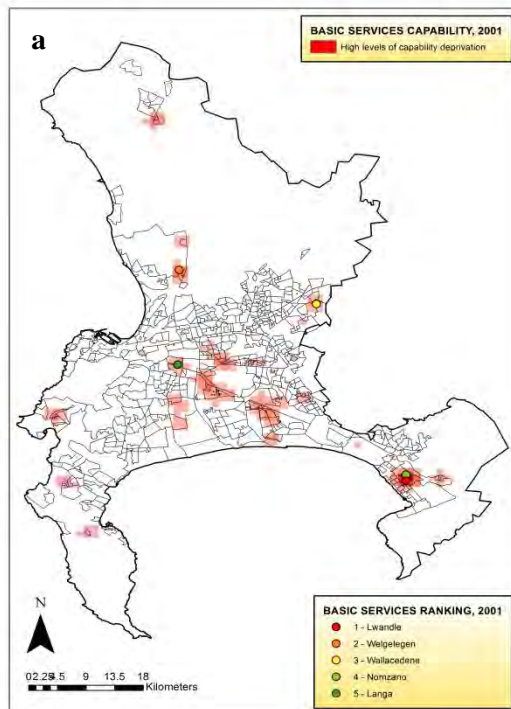


Source: Own calculations

#### IV. KERNEL DENSITY ESTIMATION (KDE)

As another method of hotspot analysis, Kernel Density Estimation (KDE) was done to validate the spatial outputs of the Moran  $I$ 's. The results for 2001 and 2011 as shown in Maps 16 a and b below and derived from the basic services hotspots (basic services index), alludes to variability in the spatial distribution of inadequate to severely inadequate levels of basic services hotspots and cold spots in the City of Cape Town. KDE was used as a secondary spatial statistical measure to quality assures the results produced using the  $G_i^*$  'family' spatial statistics. The results of the KDE analysis validate two key points concluded from the  $G_i^*$  analysis, i.e. (1) the spatial distribution of basic services capability deprivation is concentric, therefore perpetuating social exclusion and community segregation along racial and/ or class lines, and (2) between 2001 and 2011 the deprivation cluster for Khayelitsha, Philippi and the surrounding areas has increased.

Map 16: Kernel Density Estimation for basic services in 2001(a) and 2011(b)



## **4.2.2 EDUCATION**

According to the NPC (2012:28), the South African Government has identified education as a vital component in attempts to effectively eradicate poverty by 2030. The UNDP (1997:2) notes that poverty is much more than just income deprivation; it is also considered to be the repudiation of values and opportunities needed to lead a valued life. In this regard, education is commonly considered to be one of the primary opportunities required to lead a valued life.

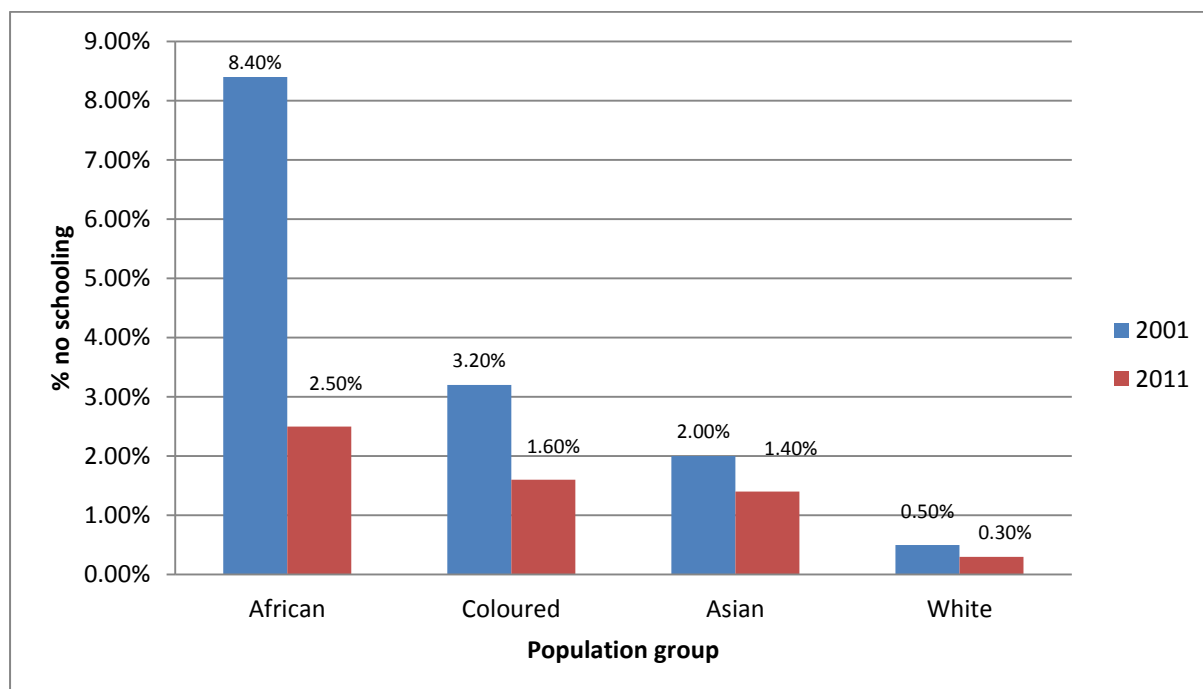
Two central paradigms are commonly used to conceptualise the relationship between poverty and education. On the one hand, the human capital approach focuses on the development of productive agents, while on the other hand, the human development or capabilities approach incorporates valued functionings such as being able to calculate, read, write and select and follow one's valued functionings (Sen, 1999:293). Thus, unlike the human capital approach that perceives education as an economic growth instrument, the capabilities approach positions education as a requirement for human resource development and poverty eradication (McClure, 2014:477). The operationalisation of the capabilities approach can provide decision makers with an integrated framework used to conceive education as an exact measure of poverty and well-being and as an unintended effect on social change (Tilak, 2002:196). For example, individuals who attain a certain level of basic education are empowered enough to protect and defend themselves from ill treatment and abuse, and apply for any work opportunities that might exist.

Bearing the above in mind, this section of the study will utilise the capabilities approach to operationalise and evaluate the importance of educational capabilities since this is a fundamental part of capability poverty (Tilak, 2002:196). Educational capability indices for 2001 and 2011 are derived using the two identified evaluation criteria as inputs into the two MCDM models used to rank each of the communities within the City of Cape Town according to their educational capability levels, and to assess the educational capability changes between 2001 and 2011. These results will assist planners and decision makers in identifying communities within the City of Cape Town that require additional educational programmes and interventions relating to improving access to quality Early Childhood Development (ECD) programmes, basic education, Further Education and Training (FET), and Higher Education so as to improve the educational capabilities of the deprived community.

### **4.2.2.1 PROFILE OF EDUCATION**

The Bill of Rights (i.e. Chapter 2 of the Constitution of the Republic of South Africa) highlights the right to basic education of all South Africans. Given that these rights have been preserved for all South Africans, the figure below shows the percentage changes between 2001 and 2011 for the number of persons older than 20 years and older with no schooling for the four main ethnic groups. Most notably, it shows a significant decrease in the percentage amongst the African population.

Figure 14: Persons aged 20 years and older with no formal schooling, 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

Tilak (1999:518) argues that an inverse relationship exists between poverty and education, thus the higher the citizen's educational level, the lower the proportion of poor citizens in the total population because as more knowledge and relevant skills are imparted onto citizens the higher the monthly or annual income levels. This notion is supported by the positive correlations between monthly income levels and higher education levels, as demonstrated in Table 15 below. It shows that the majority of those with a Grade 12 or higher fall within the higher monthly income group, while the converse is also true, i.e. that the majority of those with lower than Grade 12 or no schooling fall within the lower monthly income group.

Table 15: Monthly income breakdown by level of highest education in 2011

Highest education level	No income	R 1 - R 800	R 801 - R 6 400	R 6 401 - R 25 600	R 25 601 - R 204 801 or more	Total
No schooling	35.5%	9.9%	52.4%	1.7%	0.5%	100.0%
Less Grade 12	41.9%	6.9%	44.2%	6.1%	0.9%	100.0%
Grade 12	33.2%	4.3%	38.2%	21.2%	3.1%	100.0%
Higher education	17.7%	1.7%	17.3%	43.3%	20.1%	100.0%
Other	25.5%	3.9%	33.6%	25.1%	12.0%	100.0%
Total	35.2%	5.3%	38.1%	16.6%	4.7%	100.0%

Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

#### 4.2.2.2 IDENTIFICATION OF DECISION CRITERIA

##### I. CONSTRUCTING THE DECISION MAKING MATRIX

In this section, the main features that characterise educational capability are described, and how it can be operationalised through the use of a spatial-MCDM model. Of particular concern for this assessment is the development and estimation of the educational capability indices for 2001 and 2011 that will ultimately provide a measure of educational levels of communities in a capability space.

According to Wigley and Akkoyunlu–Wigley (2006:292), the initial educational capabilities (i.e. to read, write and calculate) that are attained through the completion of basic education are the essential elements needed to achieve valued functionings. While these basic educational capabilities may not be directly link to income progression or material wealth (i.e. valued functionings), these educational capabilities provide citizens with the fundamental elements needed to, for example, escape socially oppressive environments or participate more meaningfully in political and public decision making. Thus, the provisioning of basic education for all citizens living in the City of Cape Town could ideally ensure that the indirect benefits gained from various social and economic growth opportunities may be extensively shared amongst all members of society and not just an elite few (Wigley & Akkoyunlu–Wigley, 2006:288). It was thus critical for the South African Government through the promulgation of the NDP, to acknowledge the importance of education in terms of citizen capability progression to achieve certain valued functionings rather than just the role of education in income progression or material wealth. In terms of the NDP (2012:296), the South African Government strives to ensure that all citizens of South Africa has adequate access and opportunities to education and skills training.

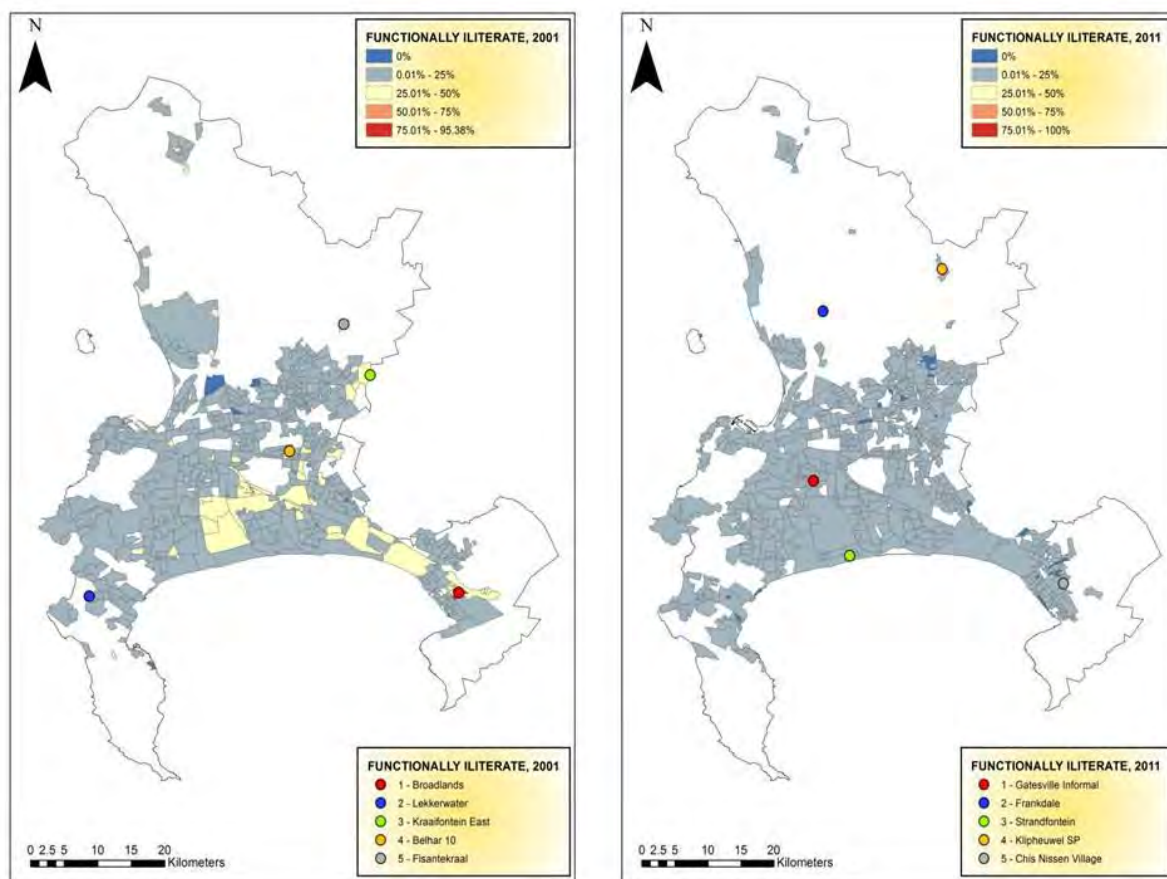
Due to paucity in accurate and reliable education data and information, for the purposes of this study, it is extremely challenging to operationalise the capability approach within the educational context. Also, as indicated in Chapter 3, there is no agreed framework for the assessment of any dimensions of the capability approach. In an attempt to overcome these data, information and methodological challenges, a robust spatial-MCDM methodology is used as it takes into account the different interactions amongst the multiple capability related evaluation criteria. This methodology is used to derive educational capability measures to identify communities within the City of Cape Town that lacks the necessary educational resources, programmes and interventions needed to achieve valued educational functionings. As input into this spatial-MCDM methodology, two evaluation criteria relating to educational capabilities are sourced from Census 2001 and 2011 data, and are used to develop the initial decision making matrices. The evaluation criteria used to develop these decision making matrices are (i) the percentage of persons aged 15 years and older who are functionally illiterate, and (ii) the percentage of persons aged 15 years and older who has attained a Grade 12 or higher as the highest level of education.

## II. SPATIAL ANALYSIS OF EVALUATION CRITERIA

### a. FUNCTIONAL ILLITERACY

Under the South African Schools Act, 1996 (Act No. 84 of 1996) education is compulsory for all South African citizens aged between seven (grade one) and fifteen years of age (Department of Basic Education, 1996:6). This Act has signals government's intent to effectively eradicate illiteracy in country. The maps below show the spatial change of functional illiteracy rates in the City of Cape Town between 2001 and 2011. The spatial analysis shows that while government has made significant strides in terms of reducing illiteracy, additional educational interventions are required to effectively eradicate illiteracy in the City of Cape Town. Map 17 also identifies individual communities that require additional educational interventions such as Gatesville Informal, Frankdale, Strandfontein, Klipheuwel SP and Chris Nissen Village.

Map 17: Functionally illiterate rate in 2001 and 2011



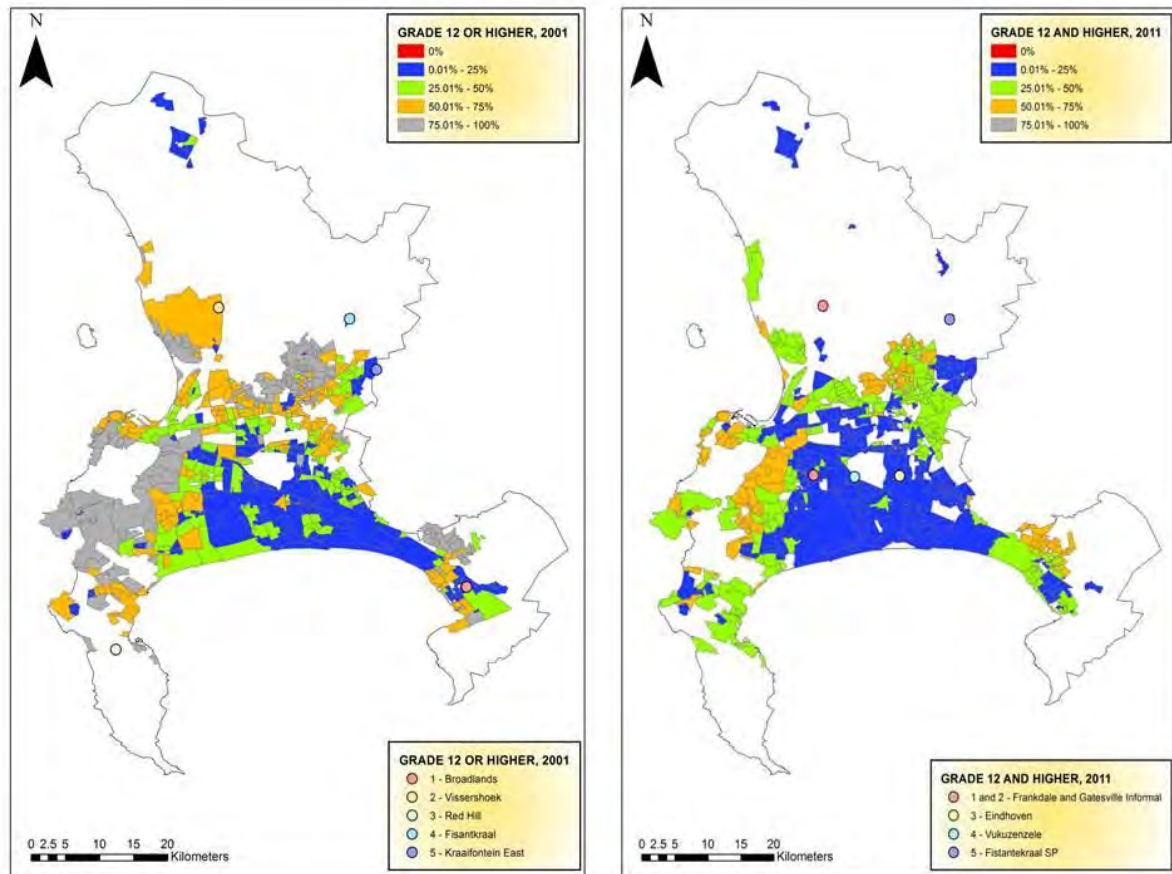
Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### b. GRADE 12 AND HIGHER AS THE HIGHEST EDUCATIONAL LEVEL

The South African Government (NPC, 2012:296) envisages that education for all children in South Africa should be made compulsory until Grade 12. The NDP (2012:317) focuses on four broad educational redress themes, including higher education, and emphasises this educational sector and access thereto as well attainment thereof, as vital in terms of improving the capabilities of

communities and promoting economic development thereby eradicating poverty. Map 18 below shows the spatial distribution change of persons with Grade 12 and higher. It also highlights the segregation issue where communities with high percentages of Grade 12 and higher are isolated from regions with low percentages of Grade 12 and higher. Likewise, Map 18 identifies communities such as Frankdale, Gatesville Informal, Eindhoven, Vukuzenzele and Fisantekraal SP where additional educational resources are required to improve the higher educational levels.

Map 18: Grade 12 and higher, 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### III. CONSTRUCTING THE WEIGHTED DECISION MAKING MATRIX

Before the construction of the weighted decision matrix, an investigation into the relationships between the initial educational capability indices and their related components are undertaken to establish the presence of multi-collinearity. Table 16 below provides the related correlation coefficients for the educational capability index and the scores for its two components (i.e. illiteracy and Grade 12 and higher). The table firstly shows that all criteria are highly correlated ( $\rho > 0.80$ ) with the education index. It also shows that illiteracy is positively correlated (i.e. income and unemployment) and Grade 12 and higher has a strong negative relationship with the education index. These correlation results raise the issue of repeatability in the model, which could significantly impair the MCDM model results, and thus the need to test for multi-collinearity.

Table 16: Pearson correlation matrix for the two criteria used for the education index for 2001

COMPONENT	EDUCATION	ILLITERACY	MATRICMORE
EDUCATION	1.000		
ILLITERACY	0.8184**	1.000	
MATRICMORE	-0.9990**	-0.8113**	1.000

\*\* Statistically significant at  $p < 0.01$

The pairwise correlation matrix developed for 2011 between the initial education index and its two related evaluation criteria used in the PCA analysis is shown in Table 17 below. Statistically significant correlations were observed for all coefficients ( $\rho < 0.01$ ) and a high correlation coefficient ( $\rho > 0.80$ ) was observed for the criterion Grade 12 and higher. Also, when evaluating the relationships between the two evaluation criteria and the initial education index, illiteracy has a positive relationship while the criterion Grade 12 and more has a negative relationship. The former underlines that the educational capabilities of a community increase significantly as more persons achieve Grade 12 and higher. These significantly higher correlations are an indication of the presence of multi-collinearity, which will be addressed through the use of the Variance Inflation Factor (VIF) technique to identify criteria that can be removed from the MCDM models.

Table 17: Pearson correlation matrix for the two criteria used for the education index for 2011

CRITERIA	EDUCATION	ILLITERACY	MATRICMORE
EDUCATION	1.0000		
ILLITERACY	0.7474**	1.0000	
MATRICMORE	-0.9987**	-0.7519*	1.0000

\*\* Statistically significant at  $p < 0.01$

These Pearson correlation matrices for 2001 and 2011 present significant findings for policy planners and decision makers. The correlation matrices support the suggestion of the NDP to extend compulsory schooling up to Grade 12. In doing so, the South African Government could effectively eradicate illiteracy and improve the basic educational capability levels of all communities across South Africa. Improving the educational capability levels of communities would provide for the expansion of core capabilities such as problem solving and making moral decisions. This will indirectly benefit the economy and South Africa as a whole as fewer people would be dependent on the welfare of the state.

Table 16 and 17 both corroborate the presence of multi-collinearity in the two spatial-MCDM models and that one or more criteria are interrelated with one another. The existence of multi-collinearity will not only result in repeatability errors, but will also add intricacies into the model development process. Thus, VIF's are derived to ascertain which of the two criteria can be removed from the



spatial-MCDM model without hindering the model’s capabilities. Table 18 presents the results of the VIF analysis for 2001 and shows all VIFs to be less than 10. These factors indicate that although the criteria are highly correlated with each other, the presence of multi-collinearity can be negated and both criteria can remain in the final MCDM model.

Table 18: VIF scores for each criterion for 2001

<b>CRITERIA</b>	<b><i>VIF<sub>all</sub></i></b>	<b><i>1/VIF</i></b>
<b>ILLITERATE</b>	2.93	0.3419
<b>MATRICMORE</b>	2.93	0.3419
<b>MEAN VIF</b>	2.93	

The results of the multi-collinearity testing have shown that all education related criteria for both 2001 and 2011 can be retained in the MCDM models. The following tables and results will show the PCA results for these two criteria and how these results were applied to derive the average weighting schema for the final education capability indices. Table 19 below shows the results of the PCA for 2001 and 2011. It is observed that Component 1 accounts for more than 95% and 96% of the total variation in both the 2001 and 2011 models, respectively. Due to these variations, the eigenvectors relating to the first PC are used to derive the average weighting schema for both 2001 and 2011.

Table 19: Results of the PCA for 2001 and 2011 applied to the education domain

<b>COMP</b>	<b>YEAR</b>	<b>EIGENVALUE</b>	<b>DIFFERENCE</b>	<b>PROPORTION</b>	<b>CUMULATIVE</b>
PC1	2001	0.0760	0.0721	0.9502	0.9502
	2011	0.0450	0.0435	0.9682	0.9682
PC2	2001	0.0040	0.0000	0.0498	1.0000
	2011	0.0015	0.0000	0.0318	1.0000

The eigenvectors of the two criteria used to develop the education indices for 2001 and 2011 are shown in Table 20 below. It is observed that the coefficients for PC 1 relating to the criterion Grade 12 and higher is positive. This result implies, considering that all factors remain constant, that communities with higher proportions of persons with Grade 12 and higher will be ranked lower in terms of the government priority for improving educational levels.

Table 20: Eigenvector values for 2001 and 2011 for each of the criteria

<b>CRITERIA</b>	<b>YEAR</b>	<b>COMP1</b>	<b>COMP2</b>
<b>ILLITERATE</b>	2001	-0.3590	0.9333
	2011	-0.2192	0.9757
<b>MATRICMORE</b>	2001	0.9333	0.3590
	2011	0.9757	0.2192

Bearing in mind that the PC 1 for 2001 and 2011 accounts for more than 95% and 96%, respectively of the total variation in the education model, its related normalised eigenvectors ( $\sum_{i=1}^n |\varphi| = 1$ ) are used as the preferred weighting schema for the development of the education capability indices. The mathematical sequences below shows the weighting schemas for 2001 and 2011 used to derive the average weighting schema to be applied to the decision making matrices. The three weighting schemas show that the criterion, i.e. Grade 12 and higher has been assigned priority in the MCDM models.

$$EDUCATION\ INDEX_{2001} = \{ILLITERATE(0.28), MATRICMORE(0.72)\}$$

$$EDUCATION\ INDEX_{2011} = \{ILLITERATE(0.18), MATRICMORE(0.82)\}$$

$$EDUCATION\ INDEX_{average} = \{ILLITERATE(0.23), MATRICMORE(0.77)\}$$

Now that the average weighting schema is developed, it is applied to the MCDM models to derive the education capability deprivation rank indices. The following section highlights the results generated from the education models.

#### 4.2.2.3 IDENTIFICATION OF IDEAL SOLUTION

The objective of the following section is to derive the appropriate education deprivation indices for 2001 and 2011 used to rank each of the community alternatives based on education capability and assess change in deprivation levels. These rankings will be based on the inverse calculation that subtracts the closeness index value from one. Table 21 below displays the  $S_i^+$  and  $S_i^-$  values for 2001 that are used in deriving the education capability deprivation index that ranks the 580 communities within the City of Cape Town using the two evaluation criteria, namely illiteracy and Grade 12 and higher. According to the 2001 ranking index, Broadlands was ranked as being the most educational capability deprived community in the City of Cape Town followed by Lekkerwater, Kraaifontein East, Red Hill, and Fisantekraal.

Table 21: The distance values and the final rankings for education capability deprivation for 2001

ALTERNATIVE	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.16	0.60	0.78	0.22	402	Acacia Park
....						
$A_{90}$	0.75	0.00	0.00	1.00	1	Broadlands
$A_{178}$	0.68	0.11	0.14	0.86	5	Fisantekraal
$A_{285}$	0.68	0.10	0.13	0.87	3	Kraaifontein East
$A_{298}$	0.68	0.09	0.12	0.88	2	Lekkerwater
$A_{410}$	0.70	0.12	0.14	0.86	4	Red Hill
.....						
$A_{580}$	0.24	0.52	0.69	0.31	335	Zonnebloem

The table below presents the  $S_i^+$  and  $S_i^-$  values used in deriving the education capability deprivation index for 2011 that similarly ranks the identified communities within the City of Cape Town using the two evaluation criteria (i.e. illiteracy and Grade 12 and higher). According to the 2011 education rank index, Gatesville Informal was identified as the most deprived community in terms of education capabilities followed by Frankdale, Europe in Gugulethu, Kalksteefontein, and Philippi SP1. When comparing the results for 2001 with 2011, it is noted that none of the top five education capability deprived communities identified for 2001 resurfaced in the top five for 2011.

Table 22: The distance values and the final rankings for education capability deprivation for 2011

<b>ALTERNATIVE</b>	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	<b>RANK</b>	<b>PLACE</b>
$A_1$	0.25	0.33	0.564	0.436	4977	Acacia Park
....						
$A_{194}$	0.56	0.04	0.07	0.93	3	Europe
$A_{220}$	0.57	0.02	0.03	0.97	2	Frankdale
$A_{227}$	0.58	0.00	0.00	1.00	1	Gatesville Informal
$A_{304}$	0.57	0.04	0.07	0.93	4	Kalksteefontein
$A_{466}$	0.55	0.04	0.07	0.93	5	Philippi SP1
.....						
$A_{705}$	0.42	0.17	0.29	0.71	303	Zwartdam

Table 23 below presents the summary statistics of the education capability deprivation scores in the City of Cape Town for 2001 and 2011. With respect to education capabilities, Table 21 shows an increase between 2001 and 2011 for both the mean (i.e. from 43 to 60%) and standard deviation (i.e. from 24.5 to 25.5%). These summary statistics show perturbing trends for the state of education in the City of Cape Town and the inability of government to keep pace with the growing demands for quality education.

Table 23: Summary statistics for Education capability deprivation scores for 2001 and 2011

<b>CAPABILITIES</b>	<b>OBS</b>	<b>MEAN</b>	<b>STD. DEV</b>	<b>MIN</b>	<b>MAX</b>
Education index 2001	580	0.4280	0.24496	0.0055	1
Education index 2011	705	0.6025	0.25476	0.0024	1

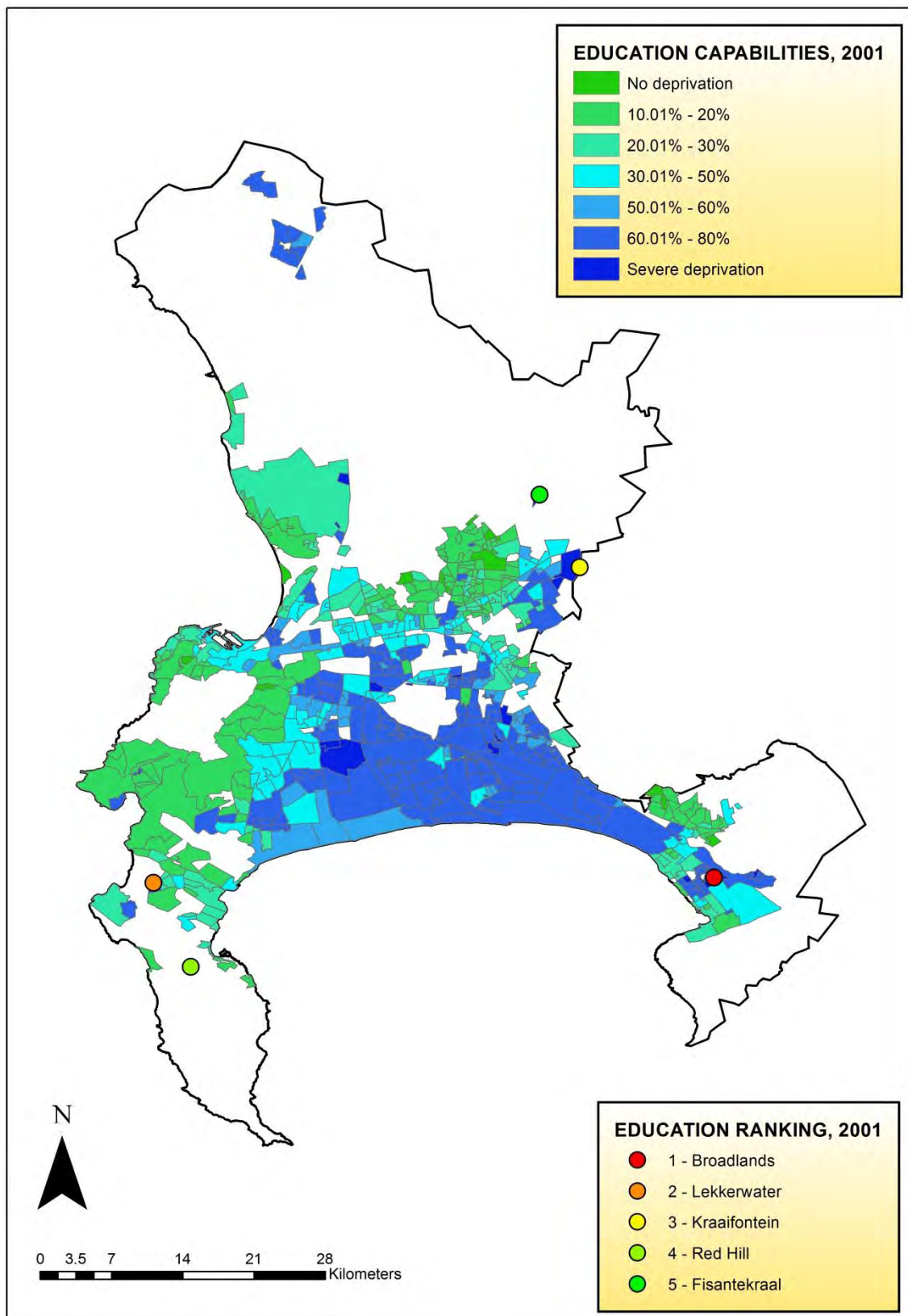
Maps 19 and 20 below show the spatial distribution of education capability deprivation in the City of Cape Town for 2001 and 2011. These maps highlight specific communities that require urgent government intervention relating to human capacity, school management, school district support, infrastructure and outcomes-related responsibility between different schools and communities so as to improve education capabilities. The maps below also highlight the spatial change in education deprivation over the period in question. Map 19 illustrate the spatial distribution of education

capability deprivation for the various communities in the City of Cape Town for 2001 and how certain communities are isolated based on education capabilities. The 2001 spatial results confirm social theories and research findings that firstly, socio-economic problems specifically related to urban cities are spatially clustered in concentrated regions of poverty and deprivation, and secondly, that social environments (e.g. schools) do affect the development of children (Niles and Peck, 2008:307). Map 20 further shows that spatial distribution of education capability deprivation in 2011 and demonstrates the spatial change in education capability across the City of Cape Town. Map 20 shows worrying spatial trends because while all three spheres of government strives for higher literacy rates and Grade 12 pass rates and thus allocates billions of Rands towards different infrastructure, resource allocation and capability building initiatives, other external factors such as emigration and immigration plays a tangible role in lowering the effects of education related interventions, and further reaffirm segregation theories.

Socio-economic segregation is a critical social theory for education experts and planners to understand because segregated arrangements or communities result in differentiated outcomes and more robust linkages between social status levels and life expectancies (Klasen, 2001:425). For instance, a student's academic performance can be significantly influenced by the social and economic circumstances of the school he or she attends as well as the student's own socio-economic environments. Thus, a poor learner from a segregated community such as Gatesville Informal attending a school characterised by the exact environmental conditions faced by all community members residing in Gatesville Informal will be exposed to a so-called double disadvantage due to the poor school conditions, coupled with the student's own disadvantaged background. Thus, educational policies can play a prominent role in promoting socio-economic segregation and academic performance. These adverse educational policies typically fail to empower disadvantaged learners to be completely integrated into both the social and economic existence of adulthood (Klasen, 2001:423).

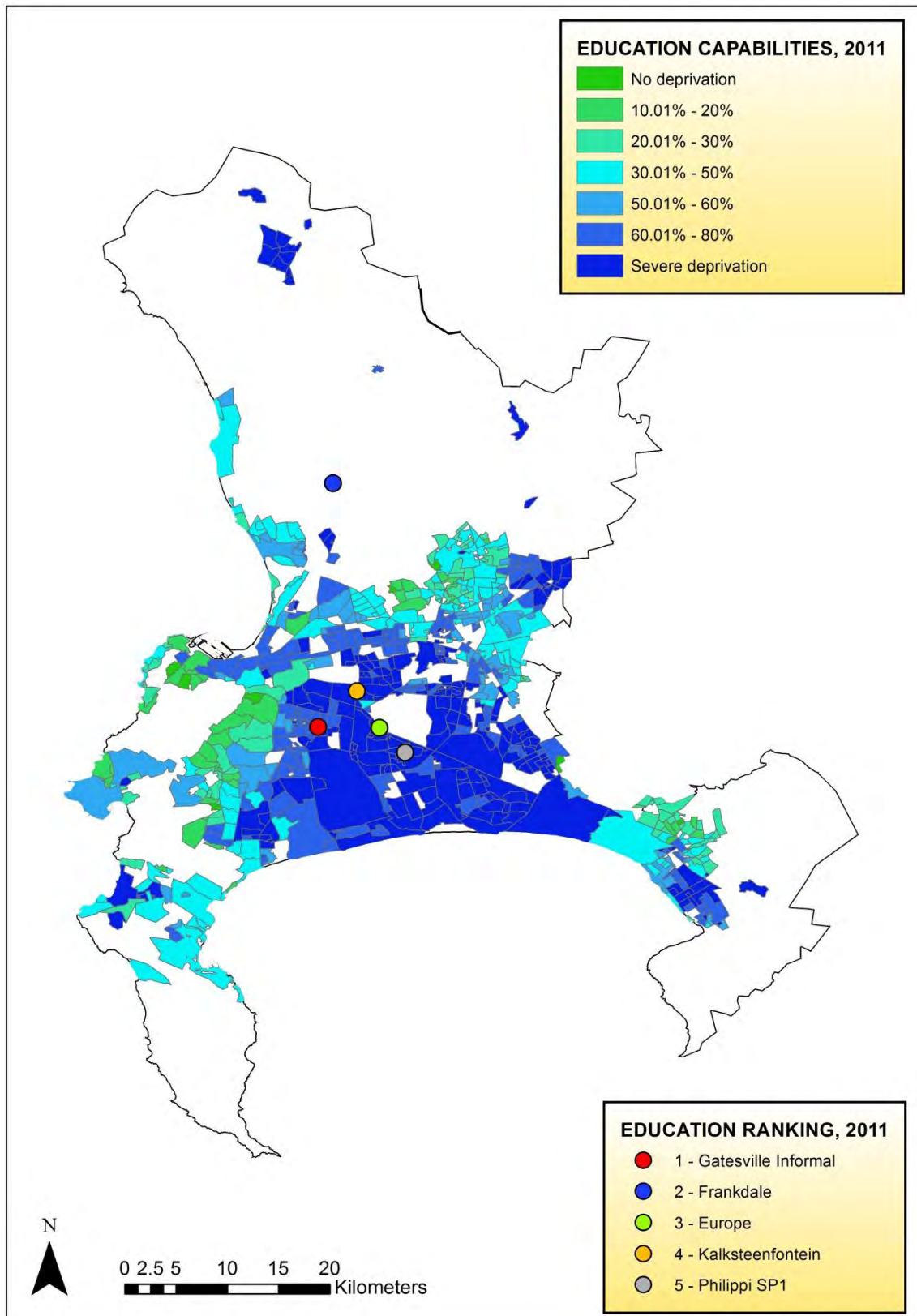
To address these learner adversities, the NDP highlights Early Childhood Development (ECD), basic education, higher education and research and innovation as critical driving factors in the improvement of education standards. These driving forces are mainly focused on improving the average educational achievement as there are increasing pressures in the labour market which enforces greater premiums on human capital as the important factor for unremitting upsurges of per capita income (Klasen, 2001:424). The NDP fails to address the issue of distribution in terms of educational outcome as it neglects the importance of having a reliable learner transport system in South Africa. These learner transport systems could assist poorer communities in accessing quality education opportunities such as schools with better academic results and academic resources, which in turn could assist learners, and ultimately their families, and communities as a whole, to achieve valued functionings.

Map 19: Spatial pattern of education capability deprivation in the City of Cape Town for 2001



Source: Own calculations

Map 20: Spatial pattern of education capability deprivation in the City of Cape Town for 2011



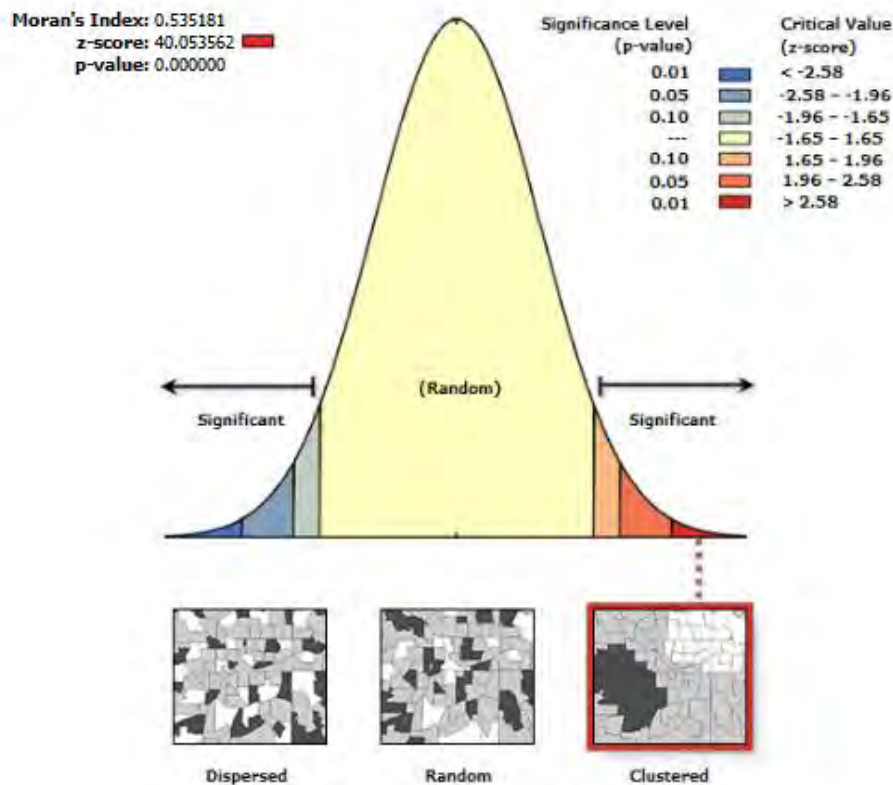
Source: Own calculations

## I. GLOBAL MORAN'S INDEX (I)

The analysis of spatial patterns of education capability deprivation in the City of Cape Town focuses on the extent to which communities that experience severe levels of basic education capability deprivation are segregated from more affluent communities with higher levels of education capabilities. The first spatial analysis of the spatial segregation was done using a spatial autocorrelation method called Global Moran's I. To execute this analysis, two spatial autocorrelation coefficients were computed, namely the Global Moran's I and its associated Z-score using the education index values derived from the MCDM process as the input.

The results of the 2001 analysis are presented in the figure below. The results show a high positive Z score of 40.05 and a statistically significant Moran's I score of 0.53. These results generated from the spatial autocorrelation method indicate that the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance. This statistically validates the notion of an entrenched segregated pattern along an education capability line as presented in Maps 19 and 20, which had resulted from the implementation of Apartheid spatial planning policies and also current education policies.

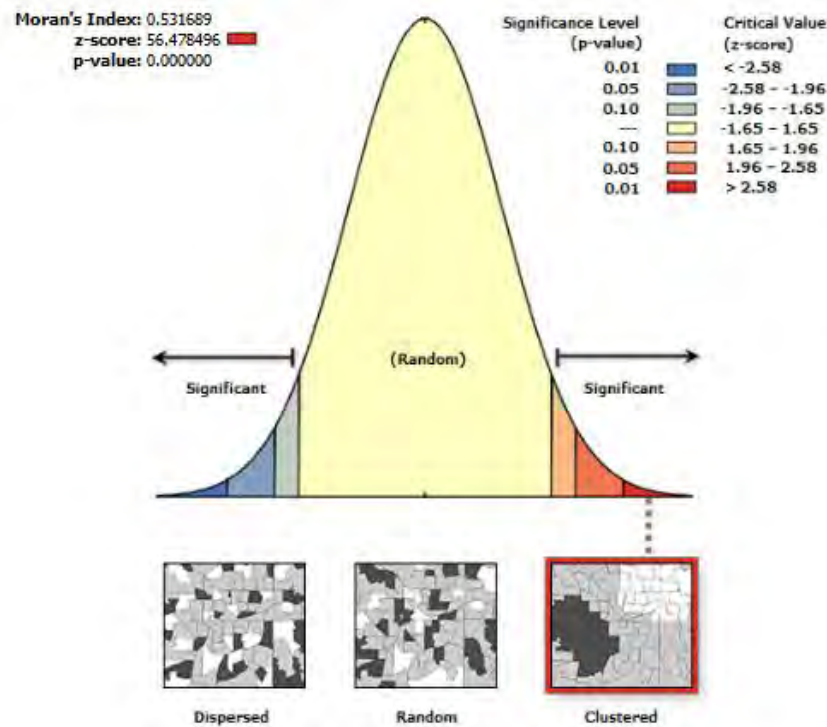
Figure 15: Moran's I classification for education capability in the City of Cape Town for 2001



Source: Own calculations

The results for 2011 as shown in the figure below display similar trends as compared with the results of 2001. The outcome of the spatial autocorrelation analysis show a high positive Z score of 56.5 and a Global Moran's Index score of 0.53. As was the case with the 2001 results, the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance.

Figure 16: Moran's I classification for education capability in the City of Cape Town for 2011



Source: Own calculations

In this study, significant spatial dependence of education capability deprivation is evident for both 2001 and 2011. The positive spatial autocorrelations for both years indicate that education capability deprivation is clustered in such a manner that communities entrenched in high levels of deprivation are surrounded by neighbouring communities with similar high levels of education capability deprivation, while communities with low levels of deprivation are neighbored by communities with similar low levels of deprivation. It is essential that policy planners and decision makers begin to understand these education segregation patterns in the City of Cape Town. Nonetheless, very little is mentioned on the topic of education segregation in the NDP. Thus, attempting to comprehend and explain the Global Moran's I results in terms of education segregation and how to address this issue are challenging. Research by Tilak (2002:199) indicates that parents from deprived communities do not have sufficient resources to send their children to better performing schools and this often leads to negative community education capabilities. To address this, the South African government has, since the advent of democracy in 1994, initiated multiple redress education programmes and interventions.



## II. LOCAL INDICATOR OF SPATIAL ASSOCIATION (LISA)

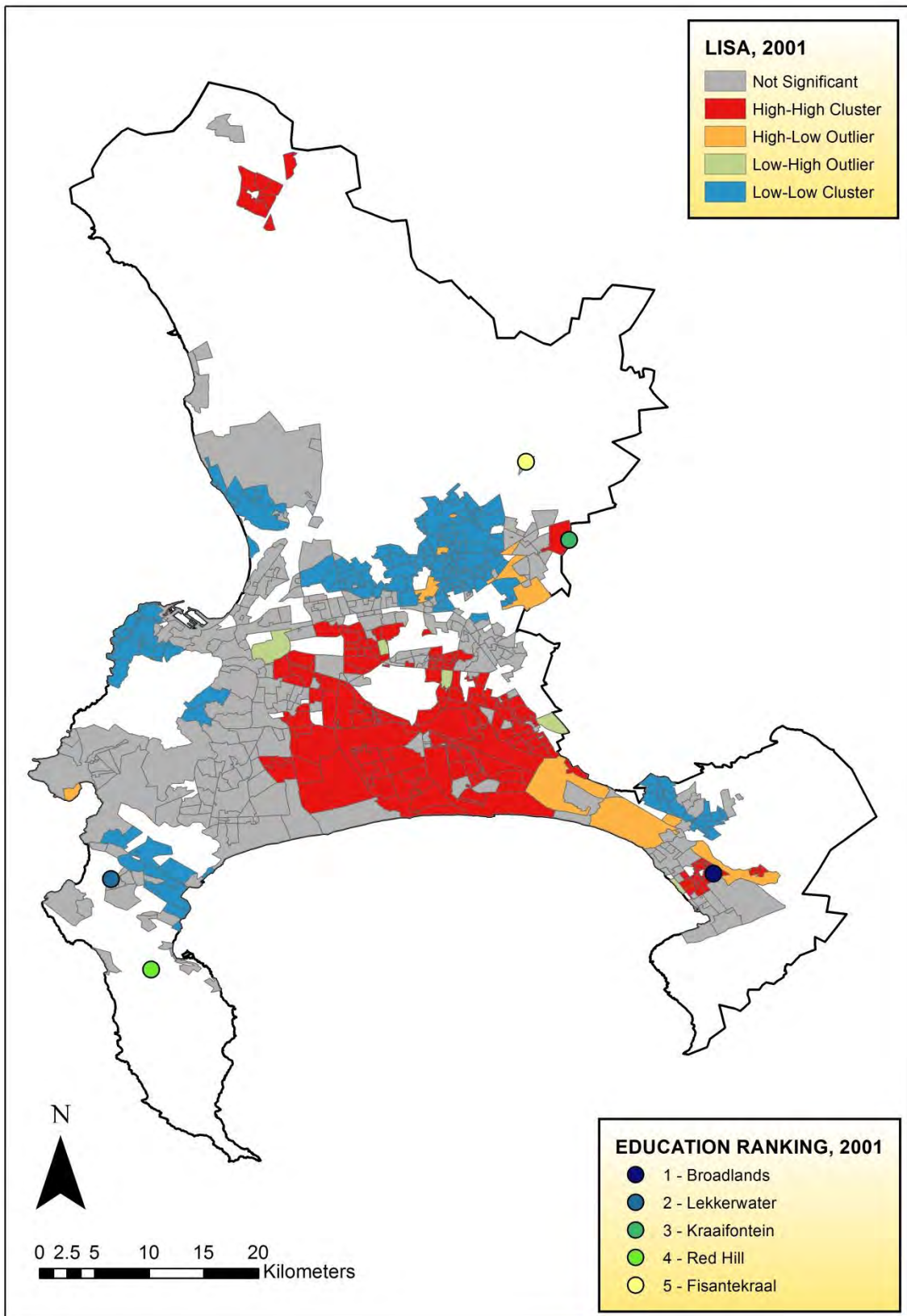
Maps 21 and 22 below display the spatial clustering for the education capability deprivation residuals. The Local Moran's I is classified into four categories, namely communities characterised by:

- (1) High levels of education capability deprivation surrounded by communities with high levels of education capability deprivation (i.e. High–High or H–H);
- (2) Low levels of education capability deprivation surrounded by communities with low levels of education capability deprivation (i.e. Low–Low or L–L);
- (3) High levels of education capability deprivation surrounded by communities with low levels of education capability deprivation (i.e. High–Low or H–L), and;
- (4) Low levels of education capability deprivation surrounded by communities with high levels of education capability deprivation (i.e. Low–High or L–H).

Map 21 below shows that in 2001, there was one major spatial cluster of the H–H type in the surrounding areas of Philippi; Khayelitsha; Crossroads, and Guguelthu. It also shows the existence of an H–L as well as an L–L cluster type, which indicates the presence of spatial uncertainties in the manner causing the spatial configuration of education capability deprivation in the City of Cape Town. These results reveal the presence of spatial heterogeneity and a common spatial characteristic found in South Africa, which was predominantly brought about through Apartheid led spatial planning policies where communities characterised by high education capability deprivation levels are surrounded by communities that are predominantly characterised by low education capability deprivation levels.

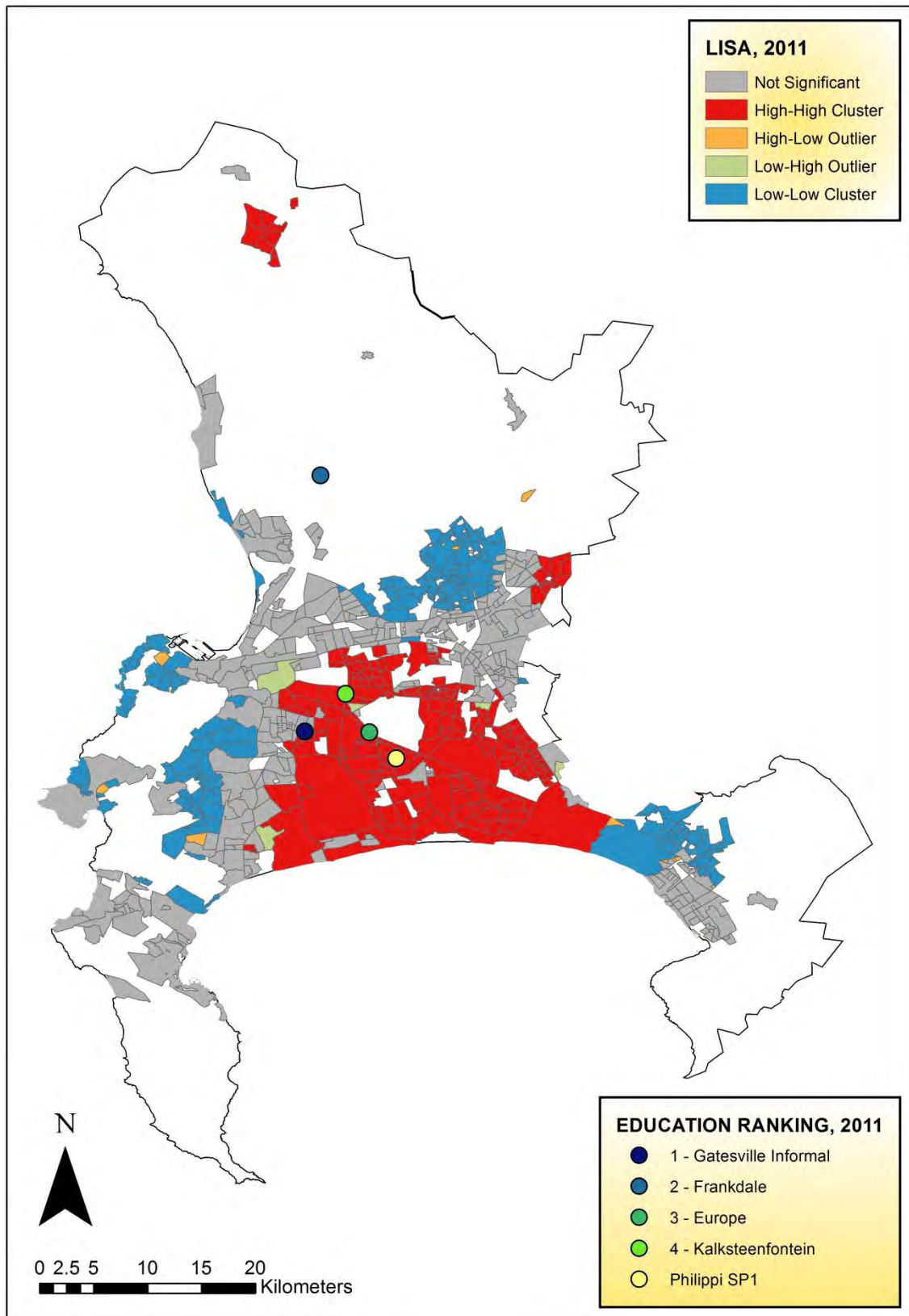
Map 22 shows the presence of one major H–H cluster type, which includes communities such as Khayelitsha, Philippi, Crossroads, Delft, Mitchells Plain and Elsies River. When comparing these results with Map 21, it is evident that between 2001 and 2011, the South African government's redress programmes and interventions have done very little to address the poor educational outcomes created by Apartheid policies in the City of Cape Town. One factor which might have impacted on these entrenched spatial patterns is the enrolment policies of schools based on learner catchment areas. These catchment policies imply that parents and learners must live within a certain distance of a school before a learner can enrol at a school. Keeping this in mind, one could argue that such types of enrolment policies further reinforce segregation patterns. However, it should be stressed that the spatial-MCDM model utilised for the purposes of this study does not incorporate learner enrolment, and for this reason, it would be difficult to prove such an assumption. Notwithstanding, what the two maps below do demonstrate is that the implementation of both active and passive redress education policies like the enrolment and school fees policies in the City of Cape Town has indirectly resulted in stagnated levels of social inclusion along education capability lines between 2001 and 2011, and especially in communities such as Khayelitsha, Philippi, Crossroads, Gugulethu and Delft.

Map 21: LISA for 2001



Source: Own calculations

Map 22: LISA for 2011



Source: Own calculations

### III. GETIS – ORD $G_i^*$

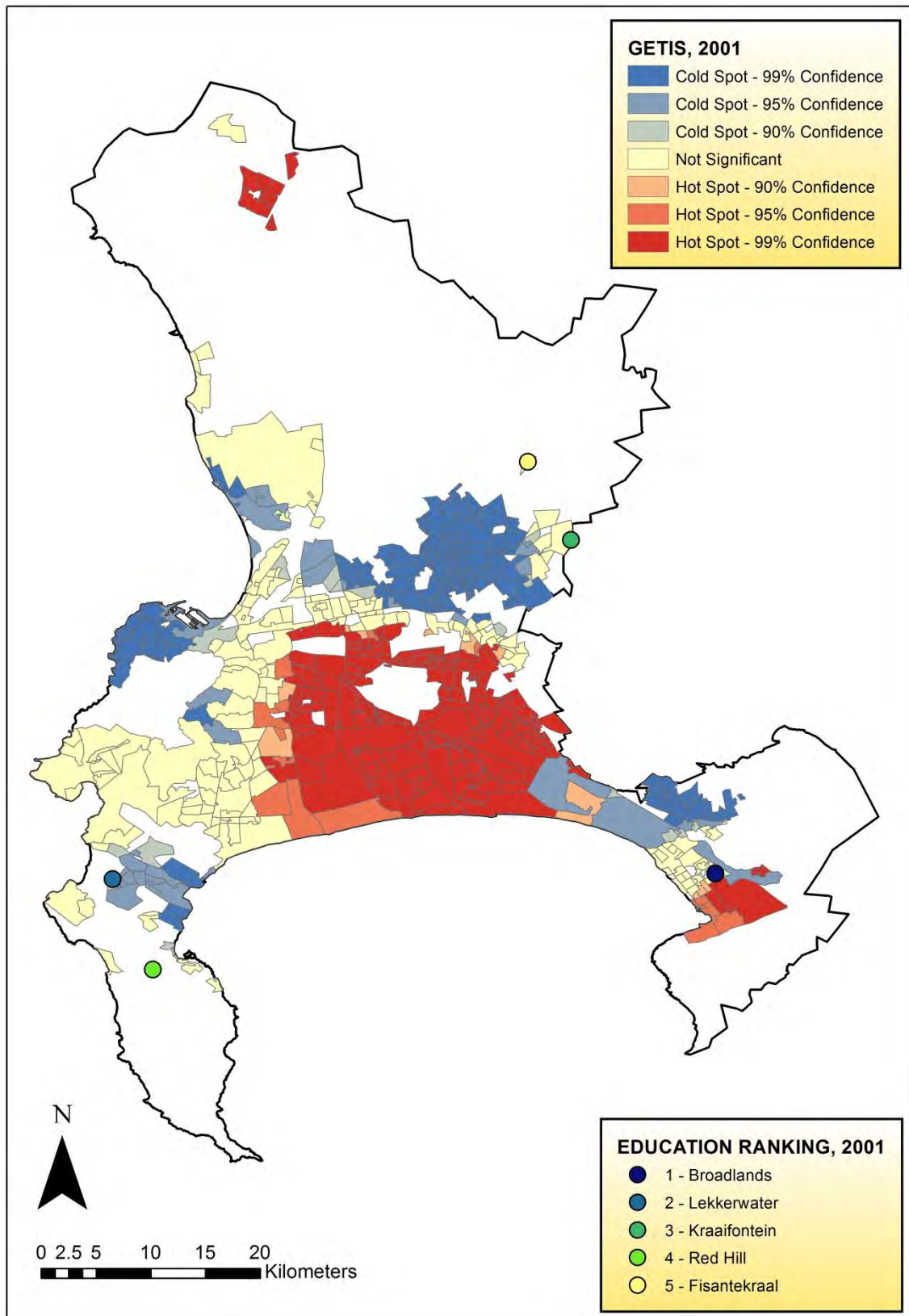
A hotspot assessment using the education capability deprivation scores for 2001 and 2011 was done using the spatial statistical tool called Getis-Ord  $G_i^*$  to investigate any indication for spatial patterning of education deprivation. The  $G_i^*$  statistics identify spatial clusters of high values (i.e. hotspots) and low values (i.e. cold spots) using the  $G_iZ$  scores and  $G_iP$  scores for each community. Maps 23 and 24 below show the clustering of both positive and negative scores of  $Z[G_i^* (d)]$  that are significant at a 0.01, 0.05 and 0.1 level. The clustering of positive scores highlighted in red indicates the spatial association of high values ( $Z[G_i^* (d)] > 1.96$ ), while the negative clustering highlighted in blue shows the spatial association of low values ( $Z[G_i^* (d)] < -1.96$ ).

In 2001, the Getis-Ord  $G_i^*$  analysis of communities entrenched in severe levels of education capability deprivation is shown in Map 23 and identifies three major clusters of communities with significantly raised incidences (i.e. hotspots). The first major cluster includes communities such as Khayelitsha, Mitchells Plain, Philippi, Guguelthu, Delft, Belhar, and Elsies River areas. The second cluster includes areas such as Broadlands and Nomzamo, while the third significant cluster includes communities like Saxsonsea, Avondale, Robinvale and Beacon Hill. These areas with high levels of education capability deprivation are completely enclosed by communities with no elevated or lowered deprivation levels (i.e. regions coloured in beige). This region is then bordered by a fragmented band of communities with low levels of education capability deprivation in the northern part of the City of Cape Town (i.e. cold spots).

The  $G_i^*$  analysis for education capability deprivation was also done for 2011 to assess the shift in spatial patterns between 2001 and 2011. The results of the deprivation analysis for 2011, as shown in Map 24, similarly display three main clusters. The first major cluster includes communities such as Khayelitsha, Mitchells Plain, Philippi, Guguelthu, Delft, Belhar and Elsies River areas. The second cluster includes areas such as Bloekombos, Kraafontein East, Wallacedene and Scottsdene, while the third significant cluster includes communities like Saxsonsea, Avondale, Robinvale and Beacon Hill. Map 24 also displays how the number of clusters with raised incidences has remained the same between 2001 and 2011. These results reinforce the notion of social exclusion/ segregation, and how the implementation of inadequate education reform policies has further concentrated education capability deprivation in certain segregated parts of the City of Cape Town.

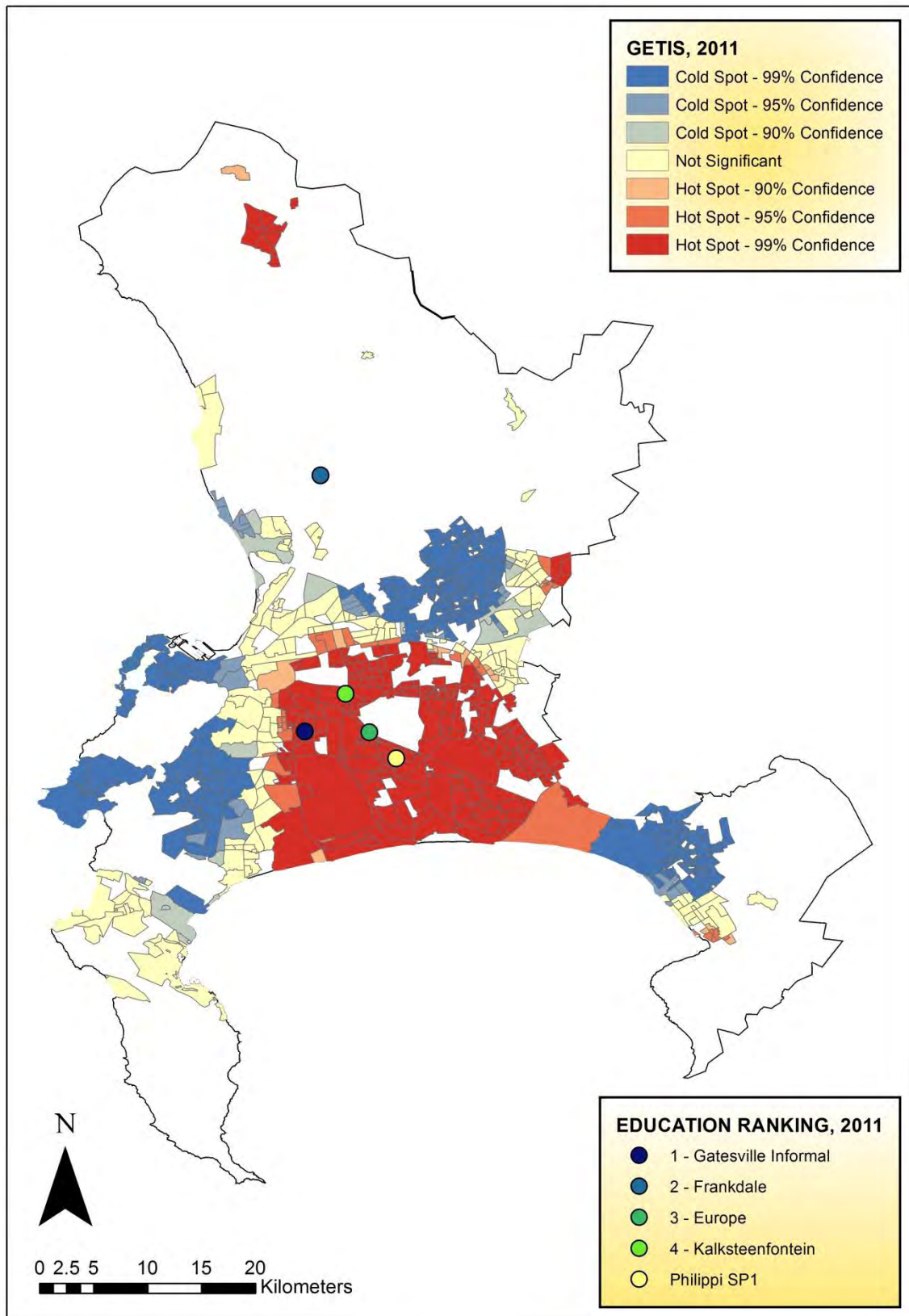
In order for the South African Government to effectively address the insufficient education reform and concentrated education deprivation regions within the City of Cape Town, the spatial MCDM model underlines the importance of, and need to reform especially the higher education system (model priority assigned to Grade 12 and higher). A reformed higher education system could ensure more graduates from communities such as Gatesville Informal, enabling them to have access to broader areas of work opportunities, and in turn offering them with opportunities to lead valued lives.

Map 23: Getis-Ord significance at the 1%, 5% and 10% significance level in 2001



Source: Own calculations

Map 24: Getis-Ord significance at the 1%, 5% and 10% significance level in 2011

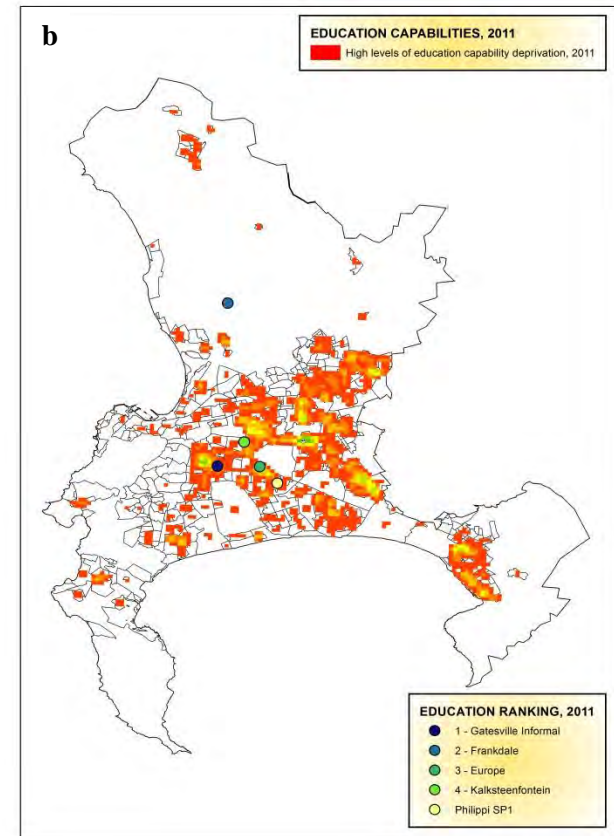
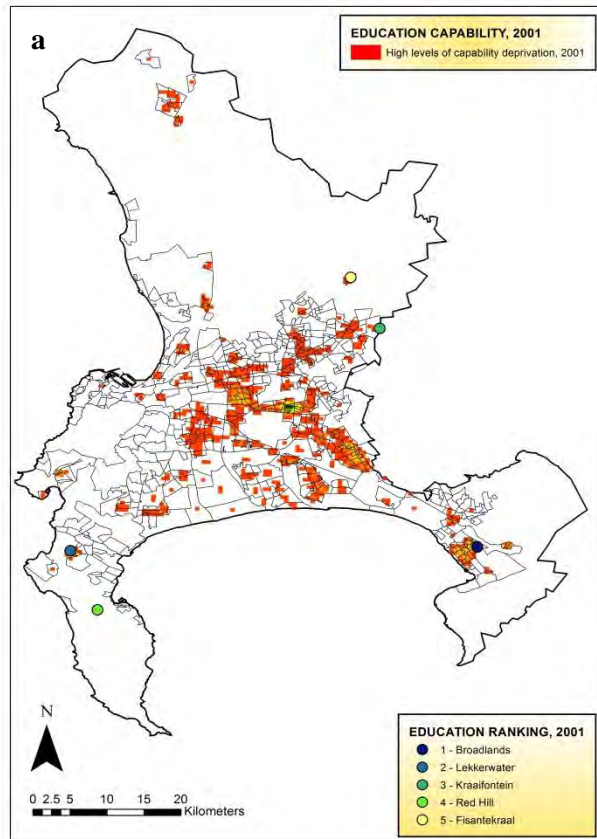


Source: Own calculations

#### IV. KERNEL DENSITY ESTIMATION (KDE)

As another form of hotspot analysis, the Kernel Density Estimation (KDE) was done to quality assures the spatial outputs of the  $G_i^*$  ‘family’ spatial statistics. The results of 2001 and 2011 KDE are shown in the maps below, and derived from the education capability deprivation scores; allude to variability in the spatial distribution of levels of education deprivation in the City of Cape Town. The maps below show similar trends when compared with the Moran I’s maps. These results demonstrate the rigidity of ArcGIS capabilities in terms of performing spatial analysis.

Map 25: Kernel Density Estimation for education in 2001(a) and 2011(b)



### **4.2.3 LABOUR FORCE**

To eradicate poverty and reduce inequality by 2030, the South African Government has identified economic reform and employment as decisive factors. It aims at creating employment for all; ensuring decent work opportunities for the labour active population, and promote sustainable livelihoods for all persons living in South Africa (NPC, 2012:131). To achieve these goals, government proposes a more dynamic labour market environment that promotes economic growth and development, while still supporting a more active labour market with high labour absorption rates (NPC, 2010:131). These premeditated proposals will reduce the cost of living for all poorer households and businesses by implementing targeted micro-economic policies that will bring about economic reform especially in sectors such as transport, health care and education (NPC, 2010:132).

According to the NPC, the reduction in the cost of living is a critical factor for increasing the standard of living for all South Africans. To create this environment, the South African Government must develop extensive labour force capabilities to take advantage of various labour market opportunities across South Africa. The following labour force index is derived for 2001 and 2011 to firstly, identify communities in the City of Cape Town that are entrenched in high levels of labour force capability deprivation, and secondly, to assess the progress made in terms of creating an enabling labour market environment between 2001 and 2011.

#### **4.2.3.1 PROFILE OF LABOUR FORCE**

The South African Government believes that full employment must be considered as a decisive factor within which the 5.4% Gross Domestic Product (GDP) growth in the economy is translated into poverty eradication and inequality reduction (NPC, 2012:118). To achieve this, South Africa must grow an inclusive economy in which sufficient opportunities are presented to all South Africans that are able to participate in the labour market irrespective of social status, creed, race or gender. Key elements of this inclusive economy is increasing exports, providing better skills development programmes, reducing the cost of living for the poor, investing in infrastructure development and improve labour market performance so as to provide sufficient access to youth and the unskilled work force (NPC, 2012:109).

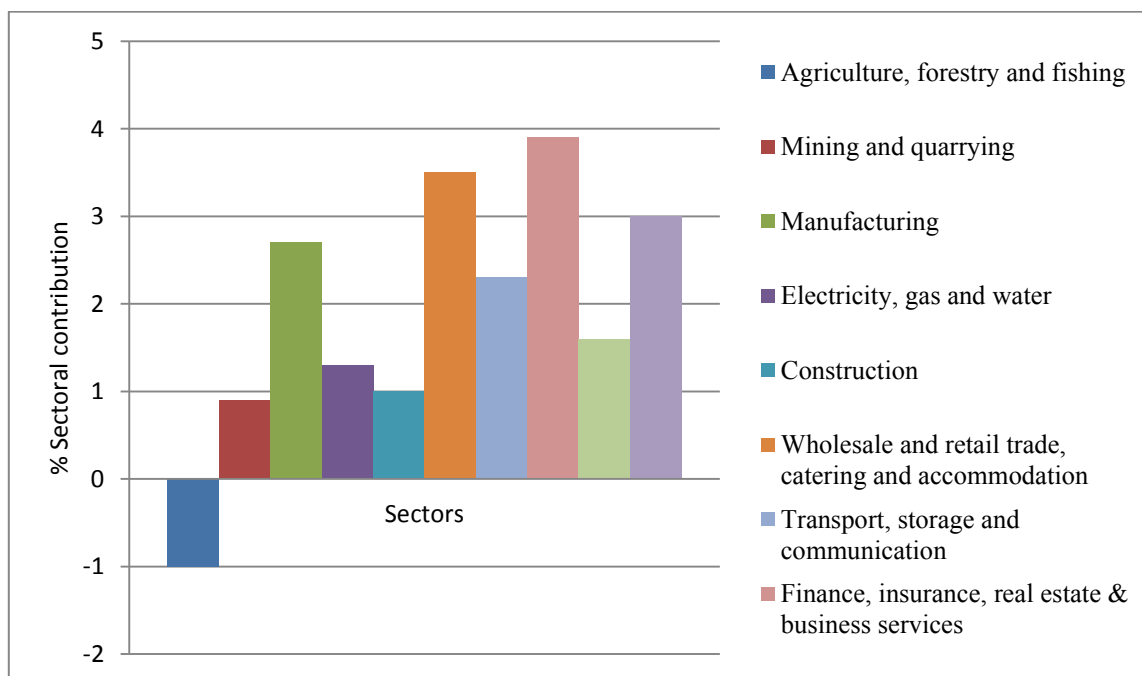
According to the NDP (2012:296), the 5.4% GDP growth is an essential prerequisite for the eradication of poverty, but progressive economic growth alone may not be enough to meet the labour market demands of the South African economy. For the levels of poverty to be effectively eradicated, significant increases in real wages and labour outputs must be achieved to improve the levels of income for the poor. In the statistical analysis below, a review of economic growth, income and labour market outputs using the data produced by Quantec (a consultancy which provides economic and financial data) and Stats SA is done for the City of Cape Town. This analysis will provide an overview of the state of the City of Cape Town economy and its ability to create a conducive economic environment which promotes active labour market absorption.



## I. GROSS DOMESTIC PRODUCT PER REGION

Between the period 2010 and 2011, the real Gross Domestic Product Per Region (GDPR) growth for the City of Cape Town averaged at about 3% per annum (Western Cape Government Provincial Treasury, 2013:23). The largest contributors to the economic growth came from the financial and business services sector, while, albeit smaller yet significant contributions, came from the wholesale and retail trade sector, which includes the effects of the revived tourism activity. Figure 17 below shows that the other sectors except for agriculture, forestry and fishing had made significant contribution to the recovery growth in the City of Cape Town. In all, the figure below characterises the City of Cape Town's economy which includes robust economic contributions from the regional services sectors such as finance, real estate and business services (Western Cape Government Provincial Treasury, 2013:24).

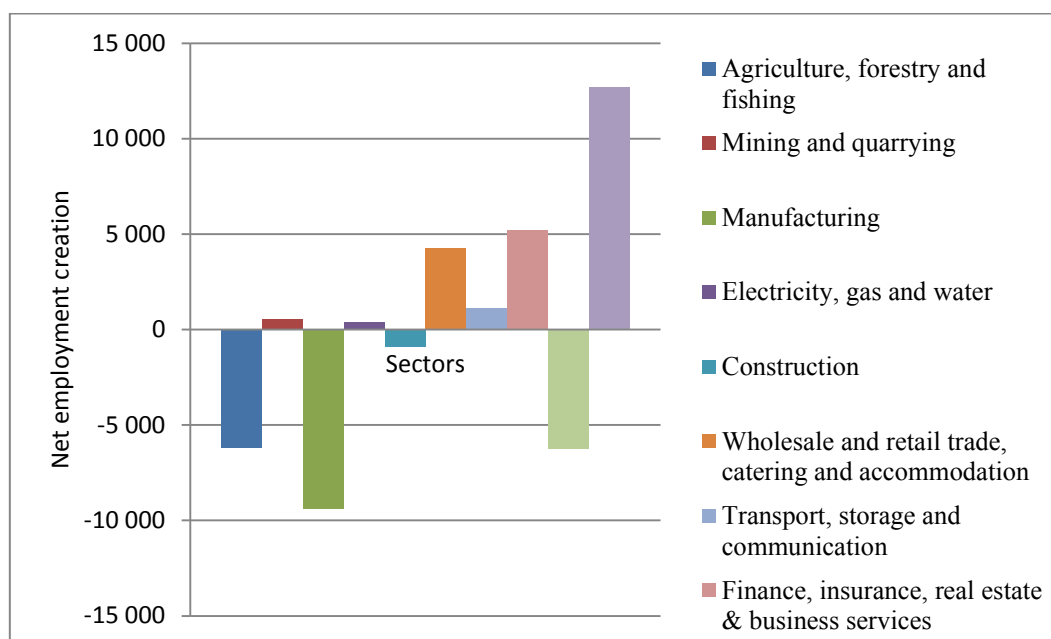
Figure 17: Average Real GDP growth 2010 – 2011 for the City of Cape Town



Source: Quantec Research/Corporation for Economic Research and Municipal Economic Review Outlook (2013:23)

Figure 18 below shows that the recessionary effects still linger in the City of Cape Town economy as in most regions across South Africa. It shows that between 2010 and 2011, only two of the ten sectors could create more than 5 000 new employment opportunities with the most being created in the finance, real estate and business services. The net job shedding still continues in major employment sectors such as Construction and Manufacturing. A prominent development is the net job deficits reported in the community, social and personal services sector between 2010 and 2011. This may be a result of employment developments surrounding the hosting of the 2010 FIFA World Cup (Western Cape Government Provincial Treasury, 2013:26).

Figure 18: Net employment creation 2010 – 2011 for the City of Cape Town



Source: Quantec Research/Corporation for Economic Research and Municipal Economic Review Outlook (2013:26)

## II. EMPLOYMENT STATUS

The table below shows the labour market trends for Census 1996, 2001 and 2011 datasets. It shows that between 1996 and 2011, narrow unemployment increased by 4.2% from 19.7% to 23.9%, respectively. As the City of Cape Town’s working age population continues to grow, i.e. from 1.6 million in 1996 to 1.8 million in 2011, labour markets are unable to accommodate the new labour force. This unemployment trend highlights the inability of government’s economic policies to address a lack of job creation.

Table 24: Narrow unemployment rate trends for the City of Cape Town for 1996, 2001 and 2011

<b>Unemployment</b>	<b>1996</b>	<b>2001</b>	<b>2011</b>
Rate	19.7	29.2	23.9

Source: Statistics South Africa, 1996, 2001 and 2011: own calculations

The Western Cape Government is committed to creating a dynamic labour market environment as proposed in the NDP (Provincial Treasury, 2013:21). This is done through implementing various economic policy reforms intended to support and grow the GDP and more than 250 000 infrastructure related work opportunities in the social, economic and environmental sectors. Various initiatives by the Western Cape Government to support a dynamic labour force environment include, for instance, investing R140 million in roads, education and health infrastructure and neighbourhood services; improving skills development training for unemployed youth by investing R112 million in different skills initiatives such as Artisan programmes and CAPACITY1000; and offering study

bursaries to students in the Engineering and built environment fields through the Masakh'iSizwe programme (Provincial Treasury, 2013:21).

#### 4.2.3.2 IDENTIFICATION OF DECISION CRITERIA

##### I. CONSTRUCTING THE DECISION MAKING MATRIX

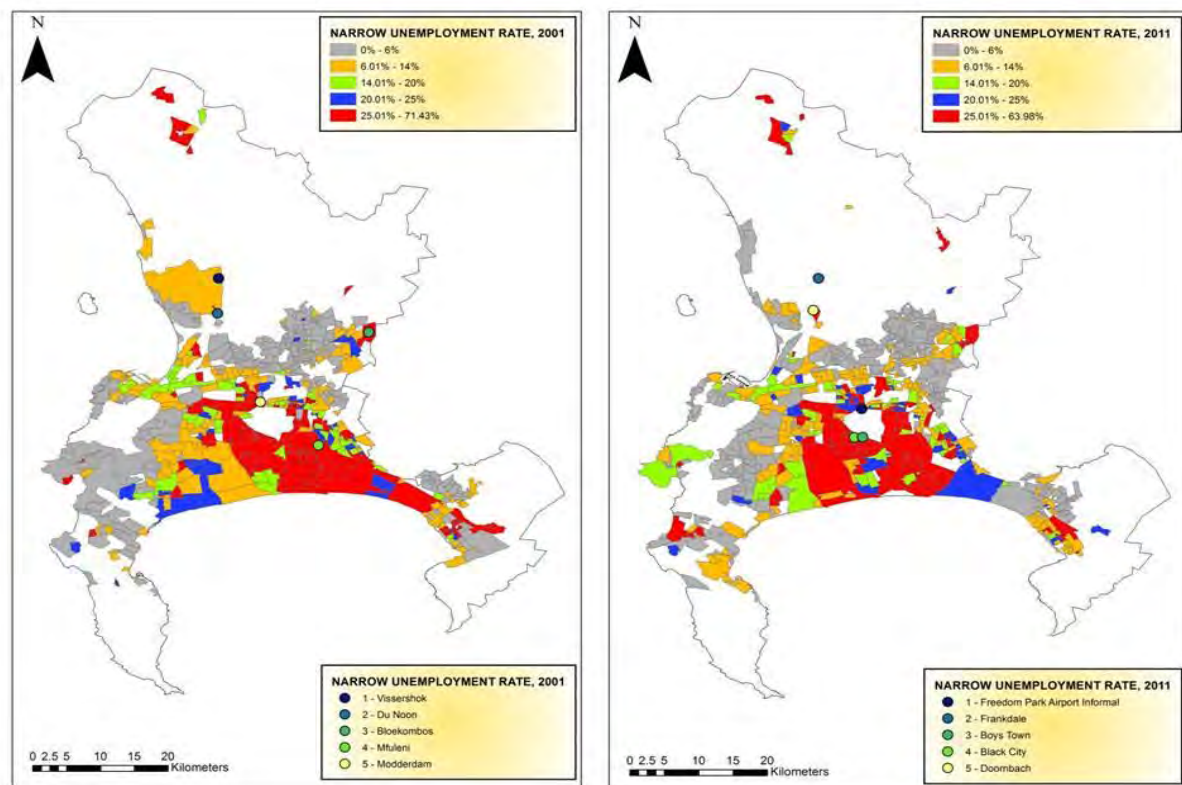
To extensively reduce unemployment to 6% by 2030, the NPC (2012:118) notes that the South African economy will have to double in size by 2030 to create sufficient employment opportunities for the country's economically active population. To do this the NDP proposes a binding constraint approach. This approach involves the identification of economic hindrances and purging them so as to proceed to newer and more insistent hindrances (NPC, 2012:125-126). To identify communities where economic hindrances may exist, three labour force related criteria will be used to assess the joint evolution of labour force capability deprivation in the City of Cape Town. The three evaluation criteria used to construct the decision making matrix include the percentage of economically active persons aged between 15 and 64 years who are (i) unemployed, (ii) earn a monthly income of less than R800, and (iii) employed females.

##### II. SPATIAL ANALYSIS OF EVALUATION CRITERIA

###### a. NARROW UNEMPLOYMENT RATE

Map 26 below shows the spatial distribution of unemployment in the City of Cape Town. It highlights where economic interventions are required to lower the overall unemployment rate.

Map 26: Narrow unemployment rate, 2001 and 2011

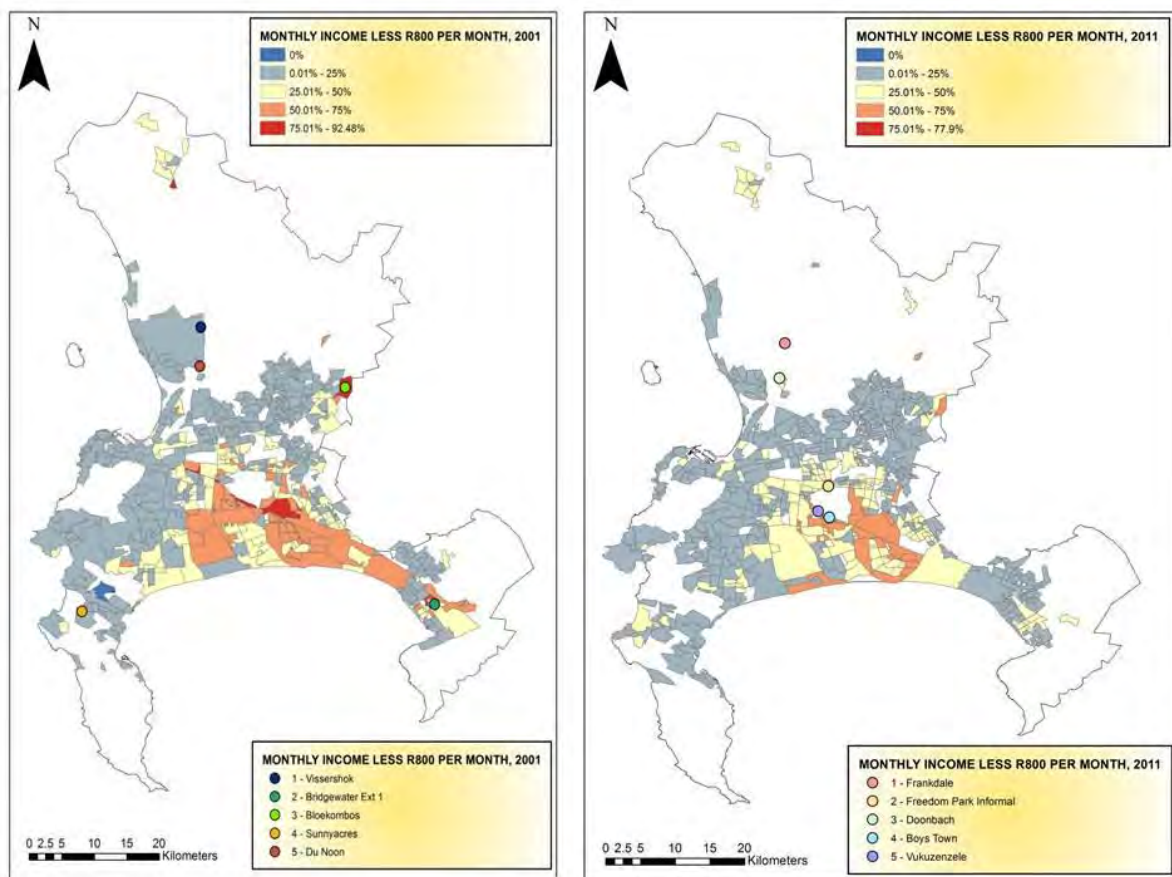


Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

b. MONTHLY INCOME LESS THAN R800 PER MONTH

The NDP (2012:24) obligates government to eliminate income poverty by 2030. It is envisaged that to eliminate income poverty, the cost of living should be reduced and productivity will have to increase in poorer communities (NPC, 2012:40). This should ideally entail the reduction in the cost of food, commuting, and an increase in the quality of free basic education and health services (NPC, 2012:40). Maps 27 below illustrates the topography change in terms of high levels of income poverty (R800 used as a Census proxy for R443 and poverty line as defined in the NDP)) across the City of Cape Town Metropolis. It highlights potential areas where economic interventions are required to reduce cost of living such as Frankdale, Freedom Park Informal, Doornbach, Boys Town and Vukuzenzele.

Map 27: Individual monthly income less than R800 in 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

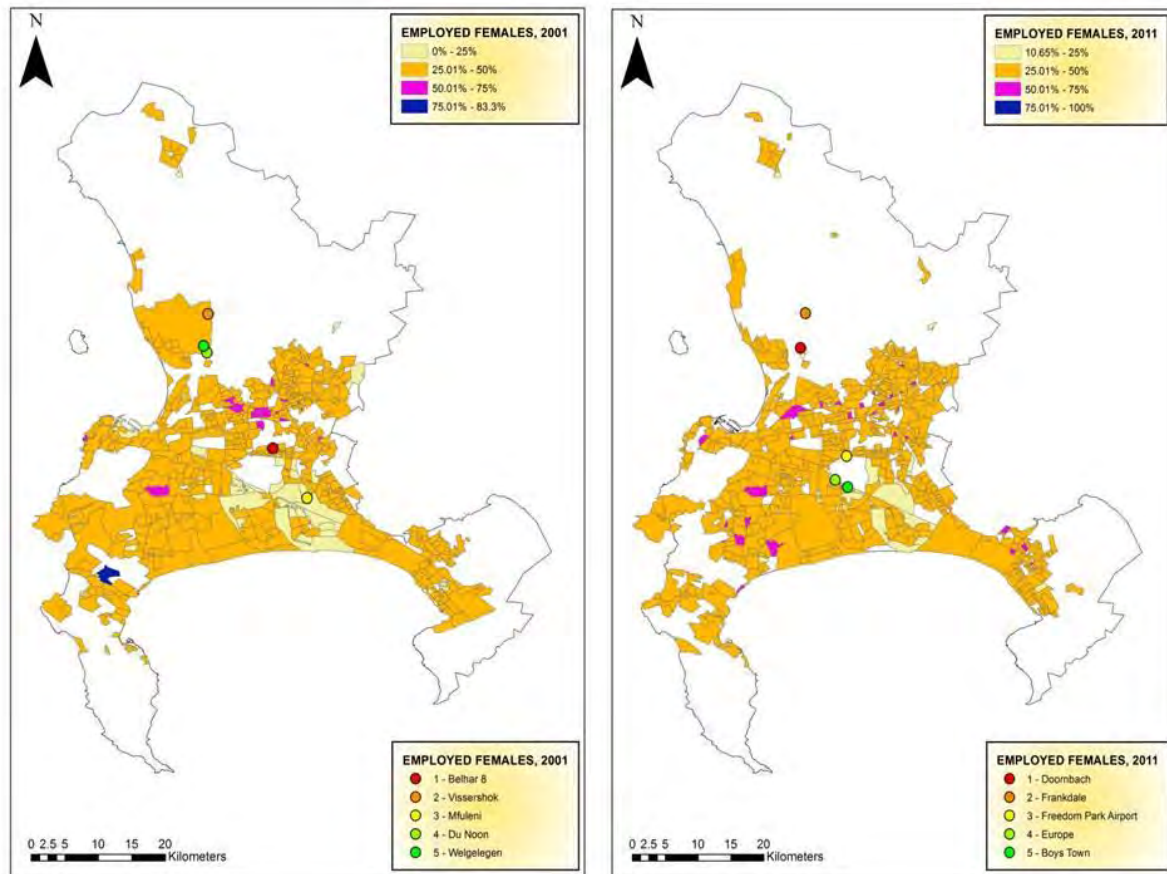
c. EMPLOYED FEMALES

The NDP (2012:459) notes that gender discrimination in both social and economic settings, which includes education institutions and workplace, remains a significant challenge in South Africa. To redress the issue of gender discrimination, concrete measures should be put in place to address discrimination barriers.

The maps below show the spatial distribution change of economically active females who are employed in the City of Cape Town for 2001 and 2011. Map 28 highlights communities such as

Doornbach, Frankdale, Freedom Park Informal, Europe and Boys Town where necessary government interventions are needed to tackle economic hindrances so as to provide equal work opportunities for females living in these communities to ensure that females living in these communities achieve valued lives.

Map 28: Employed economically active females in 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### III. CONSTRUCTING THE WEIGHTED DECISION MAKING MATRIX

Before the construction of the weighted decision matrix an investigation into the relationships between the initial labour force index and its related components is undertaken to establish the presence of multi-collinearity. The table below lists the correlation coefficients for the labour force index and the scores for its three components (i.e. income; unemployment, and female employment). It also shows that two coefficients, namely income and unemployment, are positively correlated, while one (i.e. female unemployment) is negatively correlated with the labour force index. Moreover, the table also shows that income, female employment, and unemployment are highly correlated ( $\rho > 0.80$ ) with the labour force index. This result raises the issue of repeatability, which significantly impairs the MCDM model output and thus the need to test for multi-collinearity.

Table 25: Pearson correlation matrix for the three criteria used for the labour force index for 2001

<b>COMPONENT</b>	<b>LABOUR</b>	<b>UNEMPLOY</b>	<b>INCOME</b>	<b>FEMPLOY</b>
<b>LABOUR FORCE</b>	1.0000			
<b>UNEMPLOY</b>	0.9721**	1.000		
<b>INCOME</b>	0.9914**	0.9453**	1.000	
<b>FEMPLOY</b>	-0.9281**	-0.9079**	-0.8992**	1.000

\*\* Statistically significant at  $p < 0.01$

The pairwise correlation matrix developed for 2011 between the initial labour index and its three related evaluation criteria used in the PCA analysis i.e. (unemployment, income and female employment) is shown in the table below. Statistically significant correlations were observed for all coefficients ( $\rho < 0.01$ ) and high correlation coefficients ( $\rho > 0.80$ ) were accounted for income less than R800, unemployment and female employment. Also, when evaluating the relationships between the three criteria and the initial labour force index, both income and unemployment has a positive relationship with the initial labour force index, thus indicating that labour force capabilities deteriorates with an increase in unemployment and income deprivation. These high correlations are an indication of the presence of multi-collinearity and the need for the application of Variance Inflation Factor techniques used to negate multi-collinearity

Table 26: Pearson correlation matrix for the four criteria used for the labour force index for 2011

<b>CRITERIA</b>	<b>INDEX</b>	<b>UNEMPLOY</b>	<b>INCOME</b>	<b>FEMPLOY</b>
<b>INDEX</b>	1.0000			
<b>UNEMPLOY</b>	0.9845**	1.0000		
<b>INCOME</b>	0.9946**	0.9640*	1.0000	
<b>FEMPLOY</b>	-0.9408*	-0.9337*	-0.9170*	1.0000

\*\* Statistically significant at  $p < 0.01$

Both these Pearson correlation matrices for 2001 and 2011 present significant finds for both policy planners and decision makers. The high correlation scores for unemployment and monthly income corroborates the findings of the NDP with regards to income poverty and states that in order for government to improve the standards of living for all, one of its main focus areas should be on improving the levels of employment and by improving levels of productivity, improve the income levels of the labour force population in the City of Cape Town (NPC, 2012:110). While this labour force model does not focus on capability sets that improve employability, it does however highlights communities in need and also where further investigation is needed to understand the labour force capability needs of communities

The above correlation matrices corroborate the presence of multi-collinearity in both models and that one or more variables are interrelated with one another. The existence of multi-collinearity will not only result in repeatability errors, but will also add intricacies into the model development process. Therefore, VIFs are derived to ascertain which of the three criteria can be removed from the MCDM model without hindering the model's capabilities. Table 27 presents the results of the VIF analysis for 2001 and shows that the criteria with respect to the percentage of unemployed persons and percentage of persons earning a monthly income of less than R800 has a VIF of 11.25 and 10.32, respectively. Through a process of elimination, once the criterion unemployment was removed from the model, the mean VIF decreased from 9.27 to 5.22. These VIF scores are an indication that the issue of multi-collinearity in the labour force MCDM model is addressed. Thus, to negate the issue of multi-collinearity in the final labour force MCDM models, only the criteria monthly income less than R800 and employed females will be included.

To further test the effects of removing unemployment from labour force MCDM model,  $R^2$  coefficients were calculated to assess model variability. In the initial labour force model in which all criteria were present, the  $R^2$  coefficients for 2001 and 2011 were 99.63% and 99.94%, respectively. Once the criterion unemployment was removed from the model, both the  $R^2$  coefficients remained above 99%. Therefore, by removing unemployment from the MCDM model the spatial variability is unlikely to change.

Table 27: VIF scores for each criterion in 2001

<b>CRITERIA</b>	<b><i>VIF<sub>all</sub></i></b>	<b><i>VIF<sub>unemployment</sub></i></b>
<b>UNEMPLOY</b>	11.25	
<b>INCOME</b>	10.32	5.22
<b>FEMLOY</b>	6.25	5.22
<b>MEAN VIF</b>	9.27	5.22

The table below shows the PCA results for the above-mentioned two criteria and how Principal Component 1 was used to derive the average weight schema for the final labour force capability deprivation indices. It shows the results of the PCA for 2001 and 2011, and highlights that Component 1 accounts for more than 97% of the total variation in both the 2001 and 2011 models, respectively, whereas the other PC only accounts for less than 3% of the total model variation. Due to these significant component variations, the eigenvectors relating to the first Component are used to derive the single average weighting schema to be applied to both the 2001 and 2011 labour force capability deprivation models so as to ensure comparability.

Table 28: Results of the PCA for 2001 and 2011 applied to the labour force domain

COMP	YEAR	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
COMP1	2001	0.0520	0.0504	0.9708	0.9708
	2011	0.0262	0.0254	0.9712	0.9712
COMP2	2001	0.0016	0	0.0292	1.0000
	2011	0.0008	0	0.0288	1.0000

The eigenvectors of the two criteria used to develop the labour force capability indices are shown in the table below. It is observed that the coefficients for principal component one relating to the criterion of income are positive. This result implies, considering that all factors remain constant, that communities with higher proportions of persons with monthly income levels less than R800 per month will be ranked higher in terms of the government priority for improving standards of living.

Table 29: Eigenvector values for 2001 and 2011 for each of the criteria

CRITERIA	YEAR	COMP1	COMP2
INCOME	2001	0.9159	0.4014
	2011	0.8882	0.4594
FEMPLOY	2001	-0.4014	0.9159
	2011	-0.4594	0.8882

Bearing in mind that the Principal Components 1 for 2001 and 2011 both account for more than 97% of the total variation in the labour force data models, its related normalised eigenvectors ( $\sum_{i=1}^n |\varphi| = 1$ ) are used to derive the average weighting schema. The mathematical sequences below show the weighting schemas for 2001 and 2011 used to derive the average weighting schema to be applied to the labour force decision making matrices. The average weighting schema shows that the criterion monthly income less than R800 has been assigned the highest priority within the labour force deprivation model (68%). The following section of the analysis shows the results of the labour force capability deprivation model.

$$LABOUR\ FORCE\ INDEX_{2001} = \{INCOME(0.70), FEMPLOY(0.30)\}$$

$$LABOUR\ FORCE\ INDEX_{2011} = \{INCOME(0.66), FEMPLOY(0.34)\}$$

$$LABOUR\ FORCE\ INDEX_{average} = \{INCOME(0.68), FEMPLOY(0.32)\}$$



#### 4.2.3.3 IDENTIFICATION OF IDEAL SOLUTION

The objective of the following section is to present the outputs of the labour force indices for 2001 and 2011 used to rank each of the community alternatives from no deprivation ( $I_{labour} < 0.10$ ) to severe deprivation ( $I_{labour} > 0.80$ ). These rankings are based on the inverse calculation that subtracts the closeness index value from one. Table 30 displays the  $S_i^+$  and  $S_i^-$  values for 2001 that are used in deriving the labour force index, which ranks the 580 communities within the City of Cape Town using the two evaluation criteria (i.e. monthly income and employed females). According to the 2001 ranking index, Vissershok was ranked as being the most labour force capability deprived community in the City of Cape Town followed by Bridgewater Ex 1, Bloekombos, Du Noon and Lwandle.

Table 30: The distance values and the final rankings for labour force deprivation in 2001

ALTERNATIVE	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.19	0.51	0.73	0.27	244	Acacia Park
....						
$A_{67}$	0.63	0.06	0.08	0.92	3	Bloekombos
$A_{87}$	0.66	0.04	0.06	0.94	2	Bridgewater Ext 1
$A_{126}$	0.62	0.06	0.09	0.91	4	Du Noon
$A_{360}$	0.61	0.07	0.11	0.89	5	Lwandle
$A_{534}$	0.68	0.01	0.02	0.98	1	Vissershok
.....						
$A_{580}$	0.20	0.50	0.71	0.29	231	Zonnebloem

The table below presents the  $S_i^+$  and  $S_i^-$  values used in deriving the labour force index for 2011 that similarly ranks the identified communities within the City of Cape Town using the two evaluation criteria (i.e. monthly income less than R800 and employed females). According to the 2011 basic services rank index, Frankdale was identified as the most severely deprived community in terms of labour force capabilities followed by Freedom Park Airport, Doornbach, Boys Town and Vukuzenzele. When comparing the spatial distribution of the results for 2001 with 2011, the top five deprived communities identified in 2001 were more spatially dispersed as compared with the deprived communities for 2011 that appear to be more spatially clustered.

Table 31: The distance values and the final rankings for labour force for 2011

ALTERNATIVE	$S_I^+$	$S_I^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.12	0.41	0.77	0.23	267	Acacia Park
....						
$A_{94}$	0.47	0.05	0.11	0.89	4	Boys Town
$A_{168}$	0.48	0.06	0.10	0.90	3	Doornbach
$A_{320}$	0.53	0.00	0.01	0.99	1	Frankdale
$A_{321}$	0.50	0.04	0.07	0.93	2	Freedom Park
$A_{657}$	0.41	0.12	0.22	0.78	5	Vukuzenzele
.....						
$A_{705}$	0.08	0.46	0.85	0.15	433	Zwartdam

Table 32 below presents the summary statistics of the labour force capability deprivation scores in the City of Cape Town for 2001 and 2011. With regards to labour force capabilities, it shows a decrease between 2001 and 2011 for both the mean (from 32.7% to 25.9%) and standard deviation (from 19.3% to 18.4%). While the global economy has experienced an economic recession over the last decade, labour markets have managed to reduce labour force related deprivation. These reductions highlight the role of formal and especially the informal sector in terms of accessing various labour force opportunities.

Table 32: Summary statistics for labour force capability deprivation scores for 2001 and 2011

CAPABILITIES	OBS	MEAN	STD. DEV	MIN	MAX
Labour force index 2001	580	0.3269	0.1929	0	0.9793
Labour force index 2011	705	0.2588	0.1841	0	0.9910

The above MCDM results are spatial enabled to demonstrate how spatial planning and labour force dynamics have infringed on the economic rights of certain communities in the City of Cape Town to achieve specific functionings and capabilities needed to improve citizens' economic well-being. The maps below highlight the communities in the City of Cape Town for 2001 and 2011 that are severely deprived of the necessary labour force capabilities and require urgent economic interventions so as to address the economic hindrances preventing citizens from lives which they have reason to value.

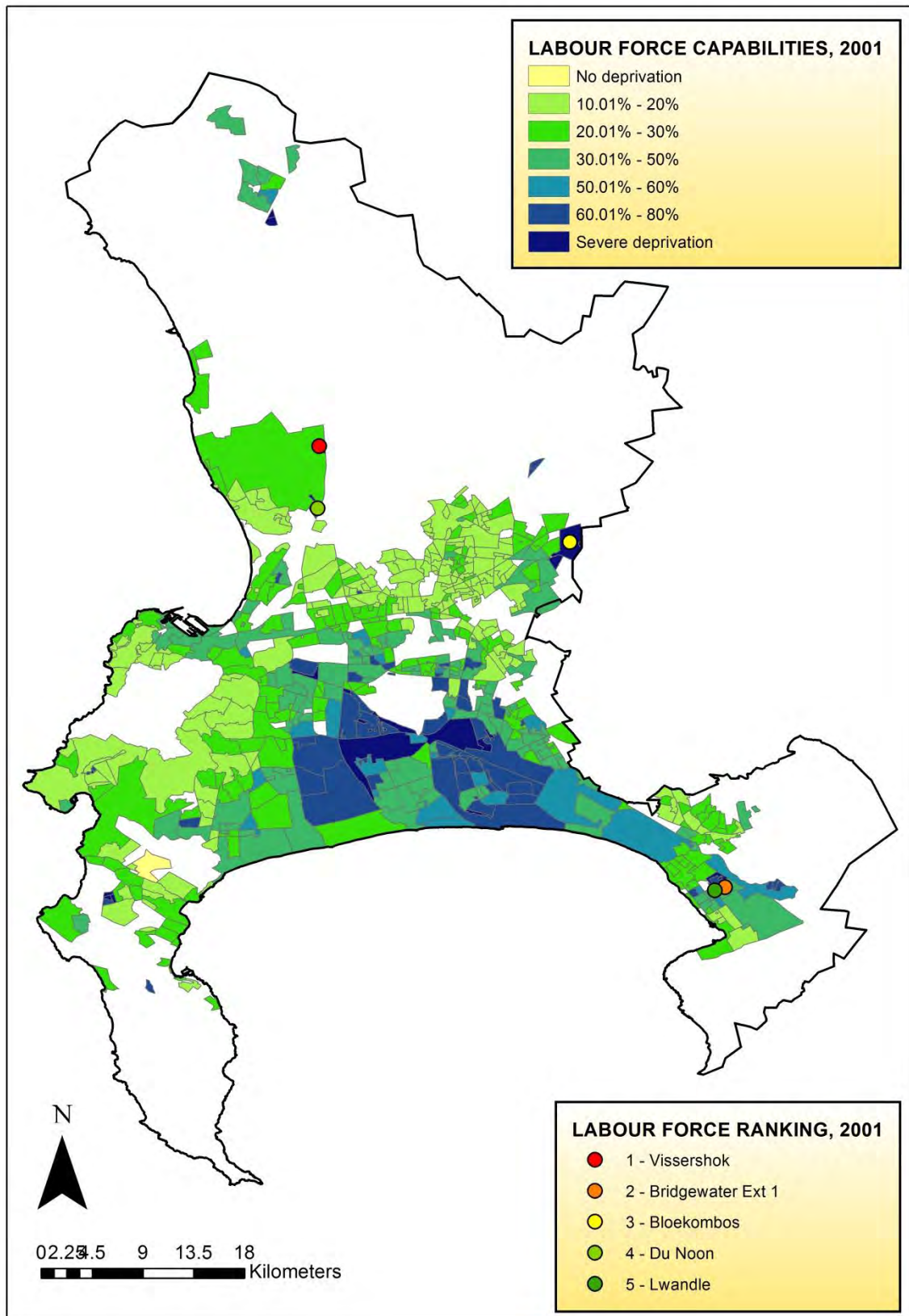
Map 29 illustrates how communities with similar homogenous labour force capability characteristics are habitually clustered together in specific regions across the City of Cape Town Metropolis. Common sense suggests that these spatial patterns are a result of communities that experience severe levels of labour force capability deprivation not being able to afford valued living conditions and are therefore habitually clustered in regions where they can afford to live and thus are segregated from the more affluent or wealthier communities. Map 30 shows the spatial distribution change in labour force capability deprivation and demonstrates the stubborn nature of labour force inequalities brought about as the result of constraining spatial legacies implemented during the then Apartheid regime and

continued job shedding brought about by the economic recession within the different sectors of the economy such as the Manufacturing and Construction industries. It also reveals the spatially unsustainable community pattern that abandons the majority of persons living in these highlighted communities who receive little access to decent employment opportunities; adequate education and health facilities, and other essential basic services. The NDP (2012:119-120) proposes the following in order for the government to develop a dynamic labour market environment, namely:

- Developing a labour market environment for sustainable employment and economic growth. To achieve this, a concerted move away from applying passive economic measures such as financial support through social grants to redress poor standards of living to more active economic measures such as improving educational; skills, and competency levels;
- Promoting employment in labour absorbing industries by expanding the small to medium sized companies through regulatory reform and support;
- Encouraging exporting and competitiveness within developing areas. The diversification of trade will have multiple impacts on standards of living, including a high proportion of Foreign Direct Investment; productivity and economic growth, and the creation of new employment opportunities;
- Enhancing the capabilities of government to implement its economic reform policies specifically in priority communities. This is critical as strained capacity can result in diverting necessary government attention from important social and economic policy issues, and;
- Showing strategic leadership in order for the country to works towards inculcating a national vision.

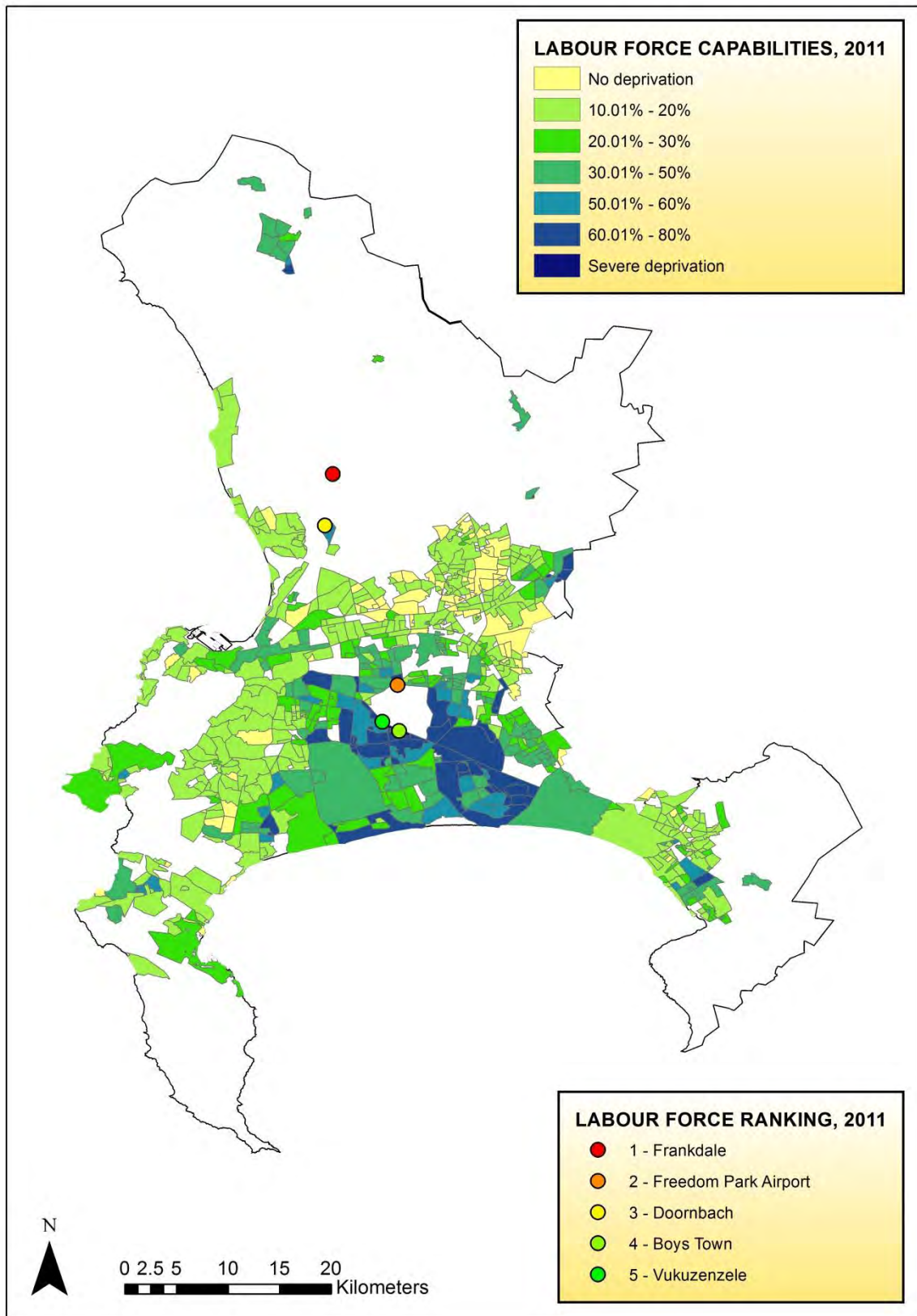
To ensure that these interventions are implemented in the intended communities, effective spatial decision making and implementation are required relating to spatial economic reform. For effective spatial decision making, the Global and Local Moran's I statistics; Getis-Ord G; and Kernel Density are used to extract inferences on inadequate levels of well-being that could be utilised to assist in redressing past influences with appropriate interventions.

Map 29: Spatial pattern of labour force capability deprivation in the City of Cape Town for 2001



Source: Own calculations

Map 30: Spatial pattern of labour force capability deprivation in the City of Cape Town for 2011



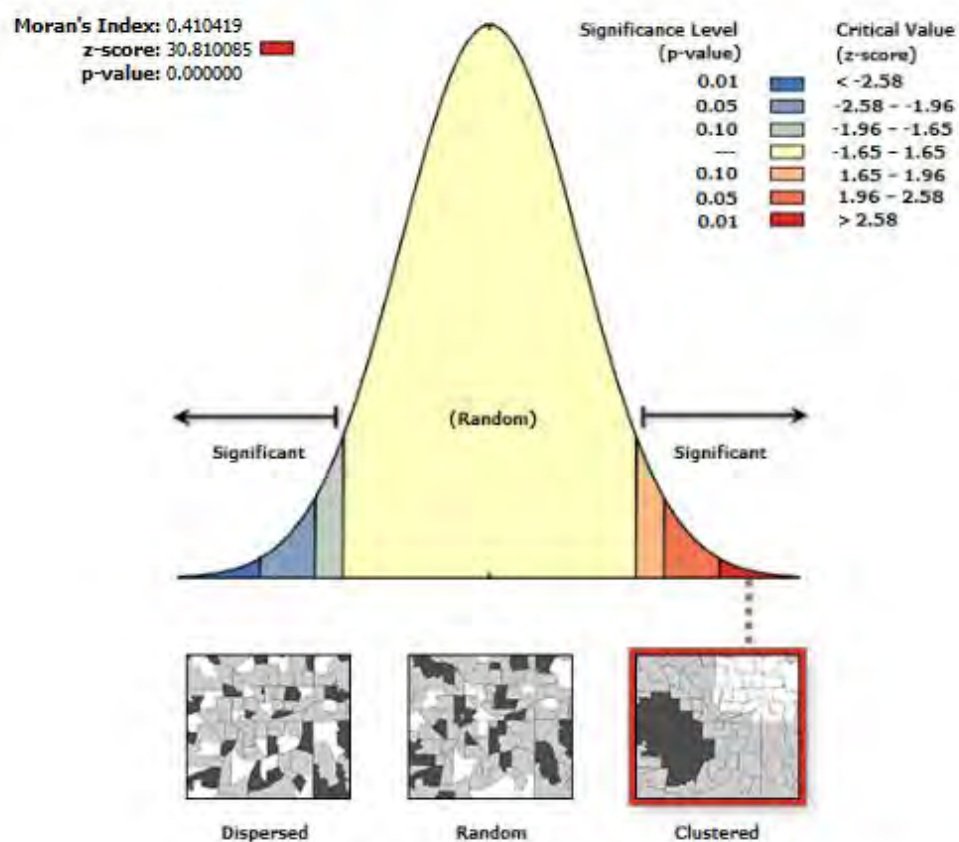
Source: Own calculations

## I. GLOBAL MORAN'S INDEX (I)

The analysis of spatial patterns of levels of labour force capability in the City of Cape Town focuses on communities that experience high levels of labour force capability deprivation that hinders the ability of citizens to take advantage of labour market opportunities across the City of Cape Town, also referred to as hotspots. The analysis of the spatial pattern was done using a spatial autocorrelation method called Global Moran's I index. To execute this analysis, two spatial autocorrelation coefficients were computed using Moran's I index and an associated Z-score using the basic services index values derived from the MCDM process as the input.

The results of the 2001 analysis as presented in Figure 19 below show a high positive Z score of 30.8 and a Moran's I index value of 0.41. These results generated from the spatial autocorrelation method indicate that the null hypothesis of 'no spatial clustering' can be rejected and that there is less than one percent likelihood that this clustered pattern could be the result of random chance. This statistically validates the stubborn nature of labour force inequalities existent predominately in the southern part of the City of Cape Town and brought about as the result of constraining spatial policies implemented during the time of the then Apartheid regime.

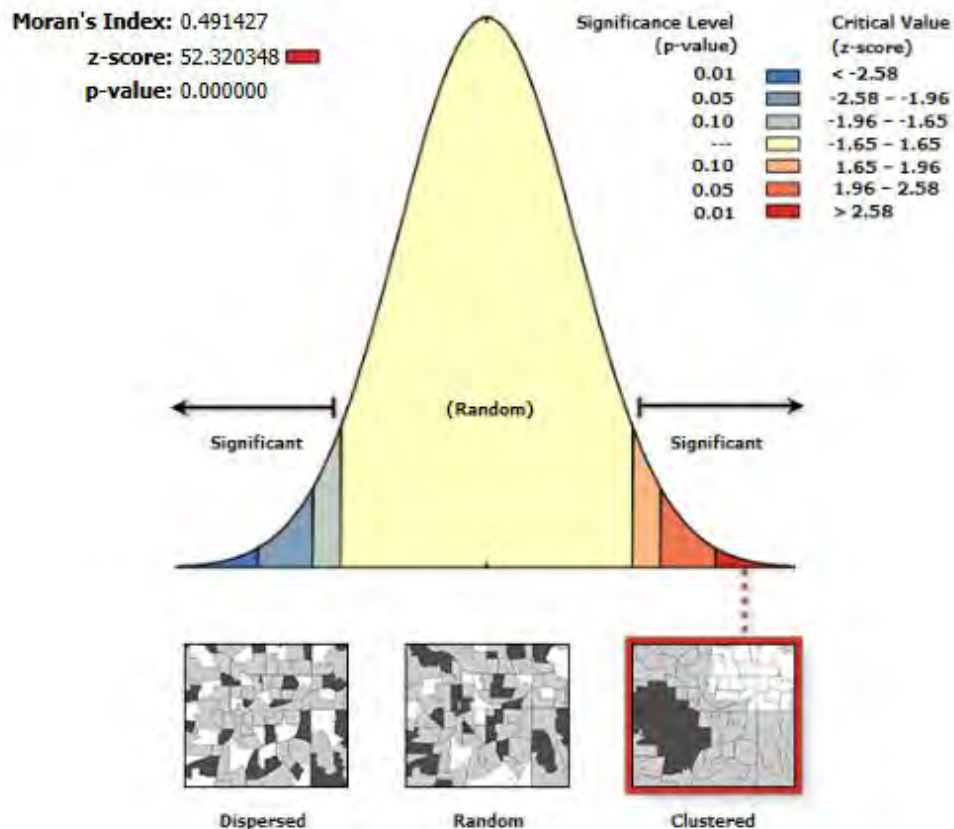
Figure 19: Moran's I classification for living standards in the City of Cape Town for 2001



Source: Own calculations

The results for 2011 as shown in the Figure 20 below display similar trends if compared with the results of 2001 as noted above. The outcome of the spatial autocorrelation analysis shows a high positive Z score of 52.3 and a Moran's Index score of 0.49. Like the 2001 results, the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance.

Figure 20: Moran's I classification for living standards in the City of Cape Town for 2011



Source: own calculation

The above highlights the significant spatial dependence of labour force capability deprivation as present for 2001 and 2011. The positive spatial autocorrelations for both years indicate that labour force capability deprivation is clustered. Thus, communities entrenched in high levels of deprivation are surrounded by neighbouring communities with similar high levels of labour force capability deprivation and communities with low levels of deprivation neighbored by communities with similar low levels of deprivation. The increase in the statistical significant Global Moran's I (from 0.41 to 0.49) indicate the increasing spatial association in labour force capability deprivation in the City of Cape Town. This might be the result of various economic policies implemented resulting in low economic growth and the economic focus shifting to the middle class, coupled with a lack of labour market competition; large numbers of discouraged work seekers because of the lack of work opportunities and skills shortages. These spatial autocorrelation measures may also have other social and economic effects, as more affluent households will unlikely have any contact with more deprived

communities, thus making it less likely that these individuals would invest in infrastructure related projects in these deprived communities (Reardon and Bischoff, 2011:1140). Moreover, the distance between deprived and non-deprived communities further results in deprived communities being unable to enjoy the same advantage of good schools and other public services located in more affluent communities.

## II. LOCAL INDICATOR OF SPATIAL ASSOCIATION (LISA)

Maps 31 and 32 below display the spatial clustering for the Labour Force (LF) capability deprivation residuals. The Local Moran's I is classified into four categories, namely communities characterised by:

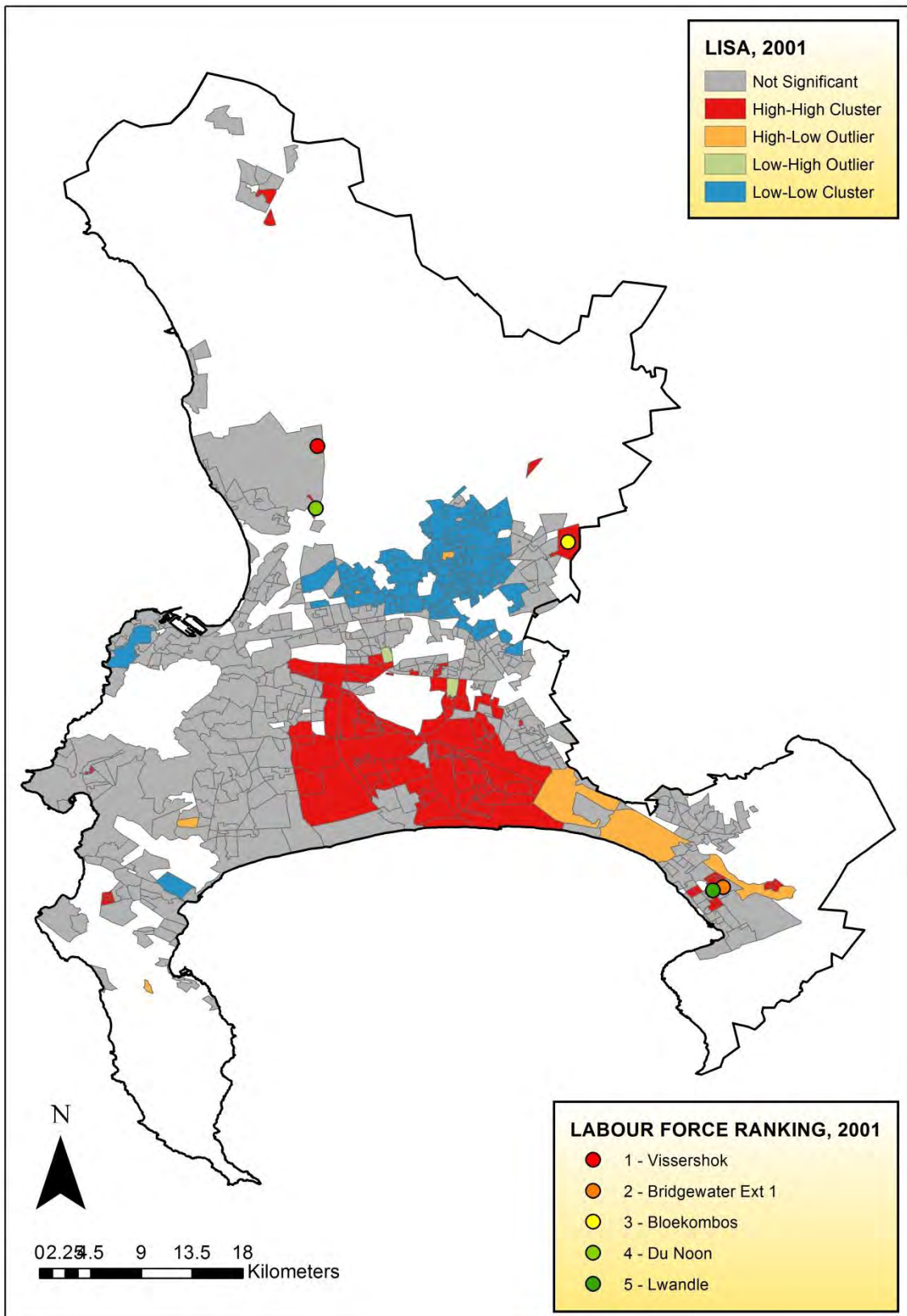
- High levels of capability deprivation surrounded by communities with high levels of LF capability deprivation (i.e. High–High or H–H);
- Low levels of LF capability deprivation surrounded by communities with low levels of LF capability deprivation i.e. (Low–Low or L–L)
- High levels of LF capability deprivation surrounded by communities with low levels of LF capability deprivation (i.e. High–Low or H–L), and;
- Low levels of LF capability deprivation surrounded by communities with high levels of LF capability deprivation (i.e. Low–High or L–H).

Map 31 shows that in 2001, there was one major spatial clusters of the H–H type in the surrounding Philippi, Khayelitsha, Mitchells Plain, Crossroads and Gugulethu areas. It also shows the existence of an H–L cluster, which indicates the presence of spatial uncertainties in the manner causing the spatial configuration of labour force capability deprivation in the City of Cape Town. This result reveals firstly, the presence of spatial heterogeneity, and secondly, a common spatial characteristic found in South Africa, which was predominantly brought about through Apartheid planning where communities characterised by high LF capability deprivation levels are surrounded by communities that are predominantly characterised by low LF capability deprivation levels.

Map 32 shows a similar spatial pattern when compared to Map 31 with a single major H–H cluster types in the Khayelitsha, Philippi, Crossroads, Mitchells Plain and Delft areas. When comparing these spatial patterns with Map 31, it is evident that between 2001 and 2011, government has made limited strides in terms of eroding the inherited spatial characteristics of LF capability deprivation. The partial findings of the spatial analysis presented in Maps 31 and 32 suggest that class and race still remains significant drivers of inequality in South Africa, or Cape Town for that matter. These findings are largely due to the concentric expansion of LF capability deprivation in the Khayelitsha, Philippi, Crossroads and Delft areas. This concentric expansion in LF capability deprivation is a result of both the passive and active types of exclusion policies as implemented in the City of Cape Town.

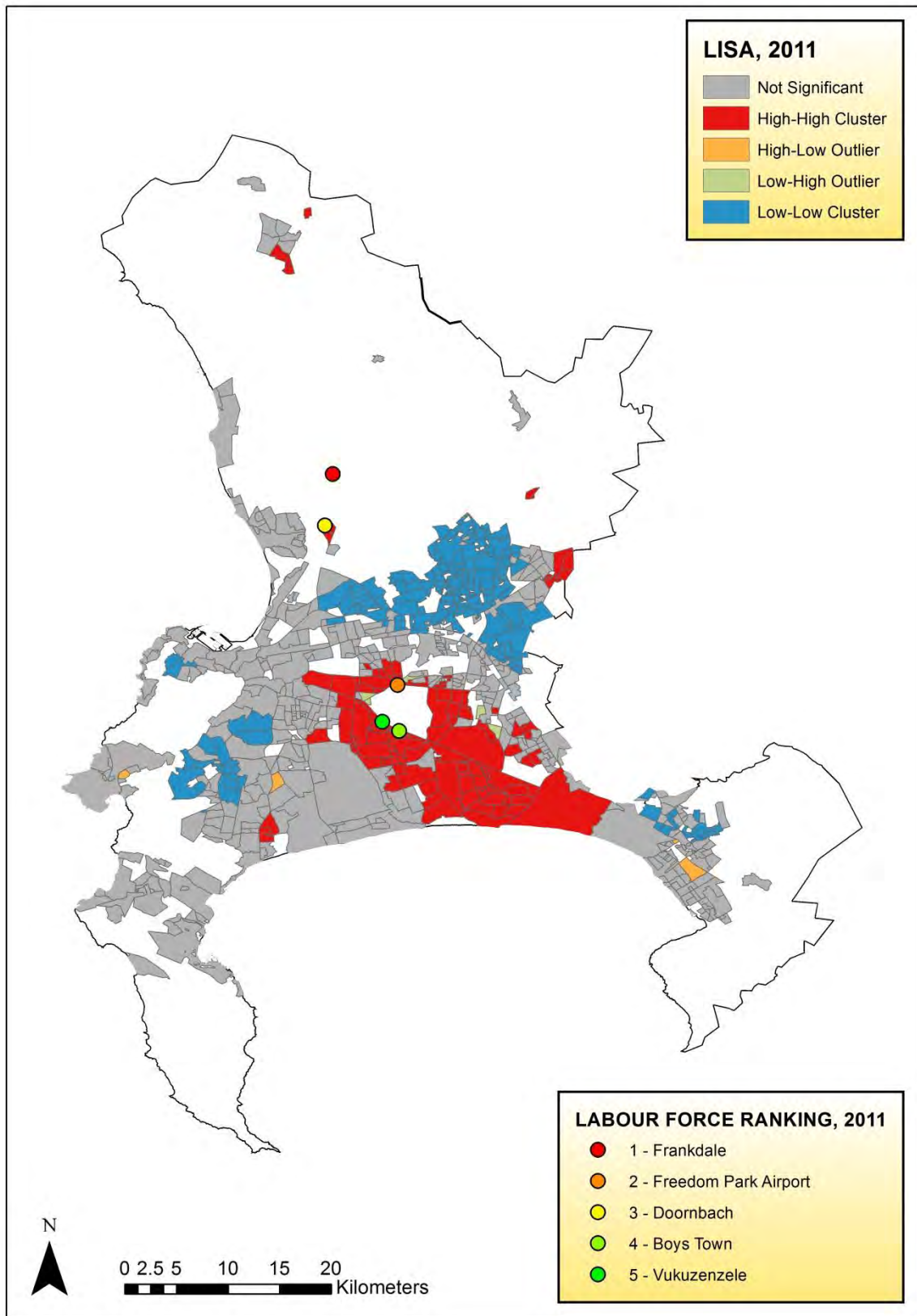


Map 31: LISA for 2001



Source: Own calculations

Map 32: LISA for 2011



Source: Own calculations

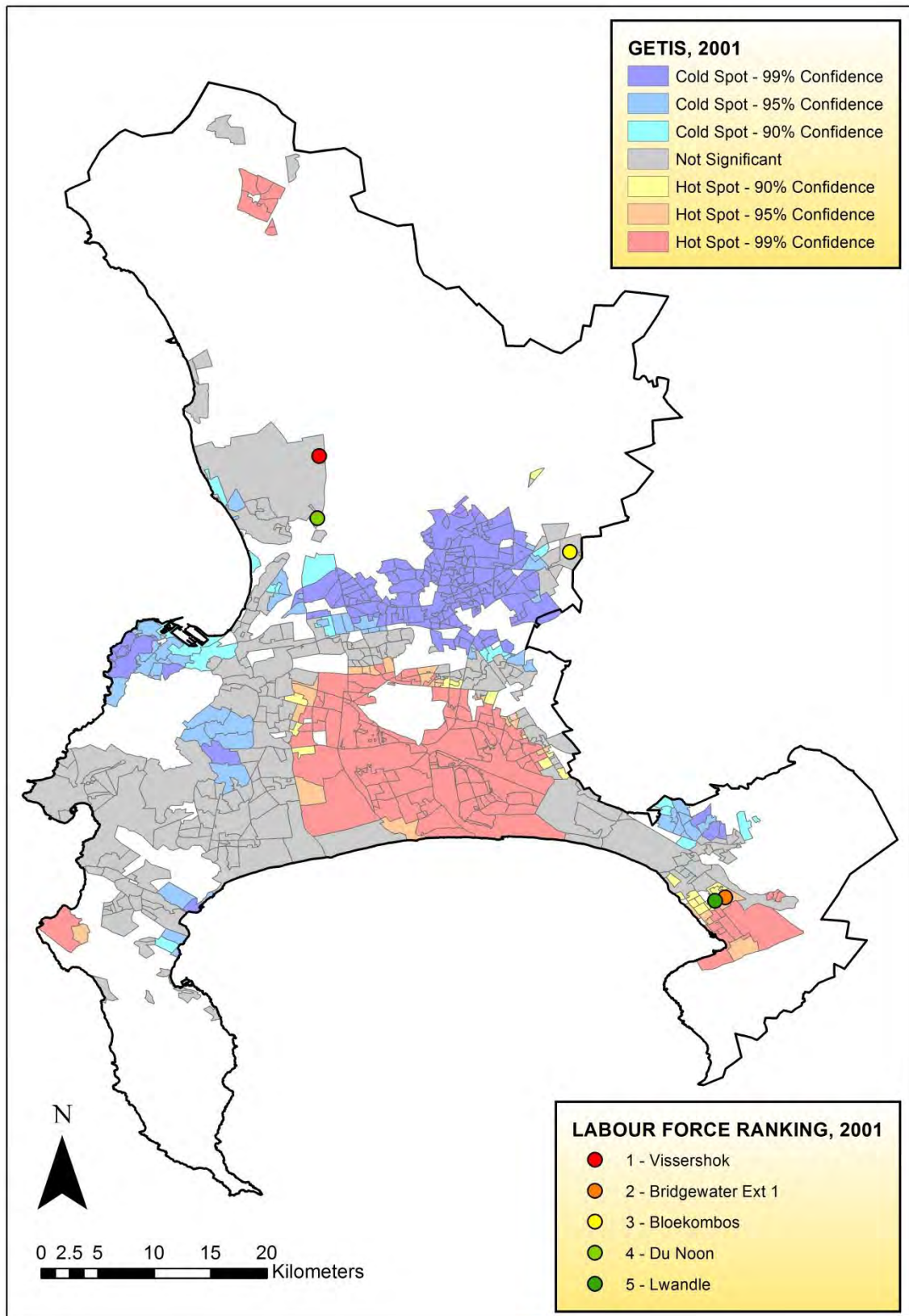
### III. GETIS – ORD $G_i^*$

A hotspot assessment for 2001 and 2011 using the LF capability deprivation levels in the City of Cape Town was used to perform spatial analysis using the spatial statistical tool called Getis-Ord  $G_i^*$  to investigate any indication for spatial patterning of LF deprivation. This statistical tool identifies spatial clusters of high values (i.e. hotspots) and low values (i.e. cold spots) using the  $G_iZ$  scores and  $G_iP$  scores for each community. Maps 33 and 34 below show the clustering of both positive and negative scores of  $Z[G_i^*(d)]$  that are significant at a 0.01, 0.05 and 0.1 level. The clustering of positive scores highlighted in red indicates the spatial association of high values ( $Z[G_i^*(d)] > 1.96$ ) and the negative clustering highlighted in blue shows the spatial association of low values ( $Z[G_i^*(d)] < -1.96$ ).

In 2001, the Getis-Ord  $G_i^*$  analysis of communities entrenched in high LF capability deprivation levels identifies multiple clustered communities with significantly raised incidences in the Khayelitsha/Philippi areas and Strand/Lwandle area (i.e. hotspots). These areas with high levels of labour force capability deprivation are completely enclosed by communities with no elevated or lowered deprivation levels (not significant). This region is then bordered by a fragmented band of communities with low levels of LF capability deprivation in the northern part of the City of Cape Town (i.e. cold spots).

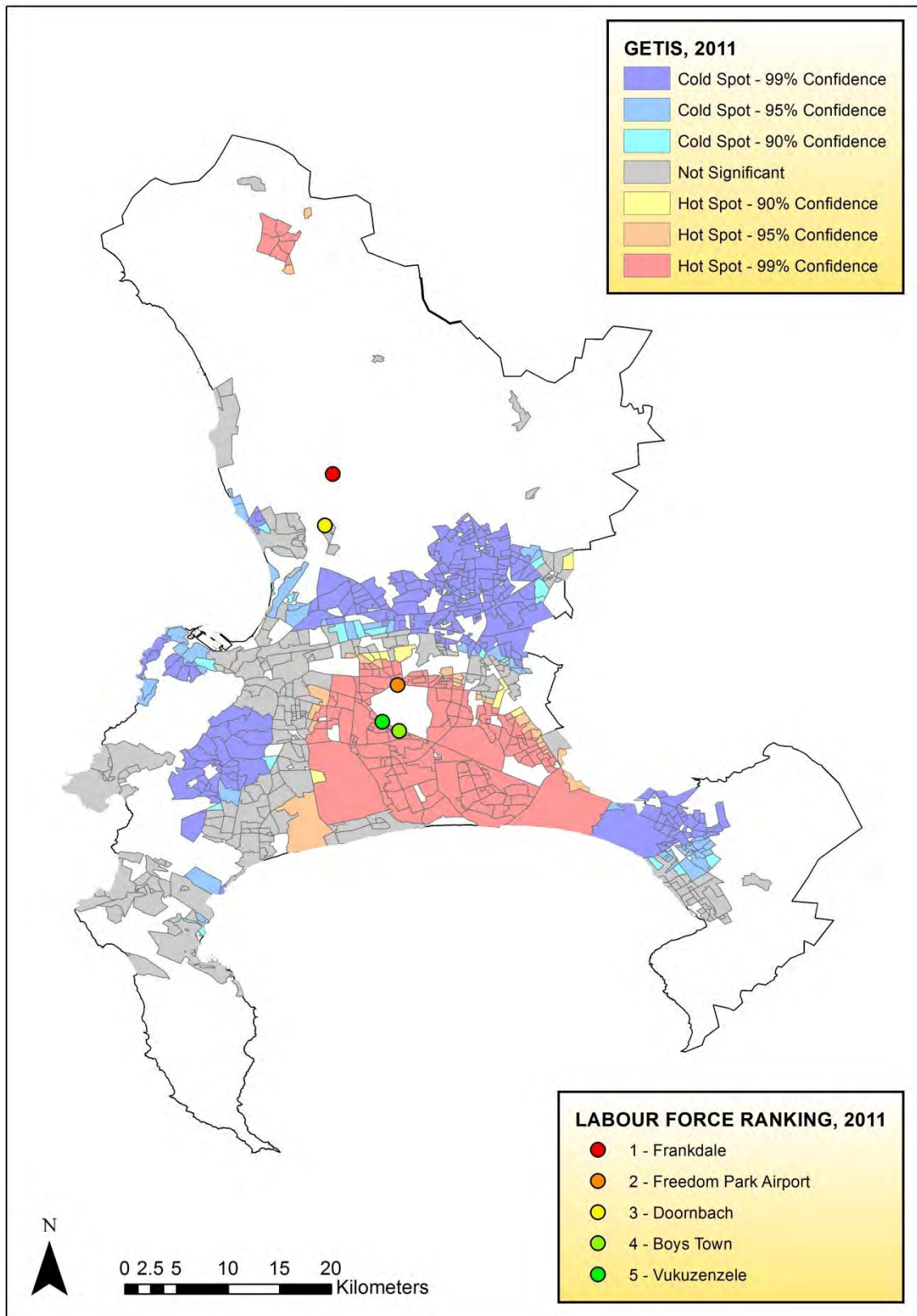
The  $G_i^*$  analysis for LF capability deprivation was also done for 2011 to assess the shift in spatial patterns between 2001 and 2011. The results of deprivation analysis for 2011 documents the changing spatial patterns of deprived communities across the City of Cape Town, using the latest Census data that reflects the consequences of the economic downturn, rising poverty and inequality. Map 34 similarly displays a single main cluster of raised incidences in the Philippi and Khayelitsha as well as surrounding areas and multiple clusters with lowered incidences, with distinctive pattern changes between 2001 and 2011. It also displays how by 2011 the number of clusters with raised incidences has decreased as compared with 2001, but the spatial cluster size for LF deprivation for the Philippi and Khayelitsha surrounding communities has increased. These segregation patterns amongst the labour force population suggest that governance and socio-economic interests characterised by different communities contend within larger demarcated regions (Lichter *et al.*, 2012:368). Thus, neighbouring communities ostensibly competes more directly for various formal and informal work opportunities and this implies the extent of labour force segregation present in the City of Cape Town labour markets. Thus, because spatial configurations and social suppleness are so closely related, the segregation of communities who experience severe levels of labour force capability deprivation, from non-deprived communities presages restricted work opportunities and exacerbates inter-generational poverty (Lichter *et al.*, 2012).

Map 33: Getis-Ord significance at the 1%, 5% and 10% significance level for 2011



Source: Own calculations

Map 34: Getis-Ord significance at the 1%, 5% and 10% significance level for 2011

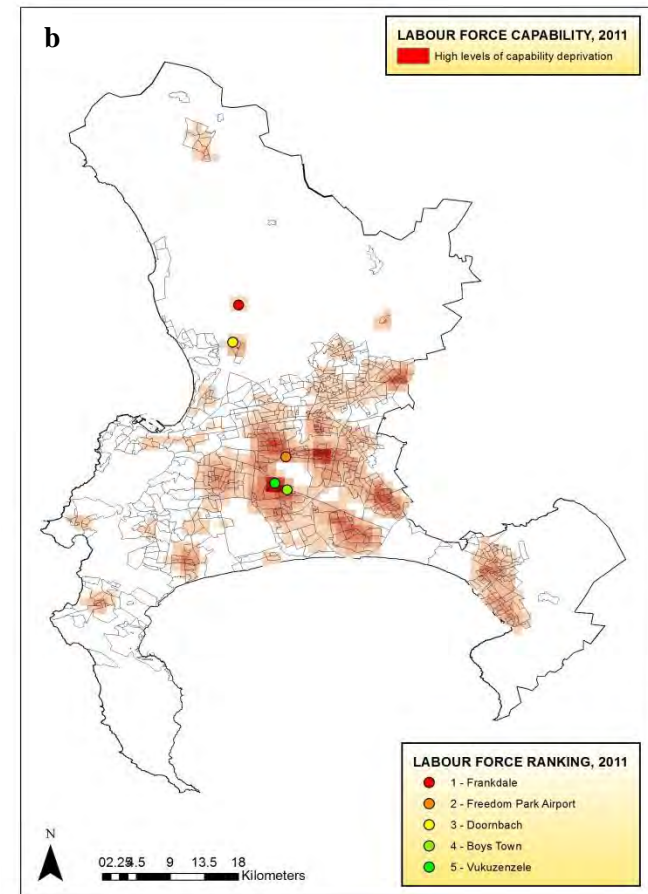
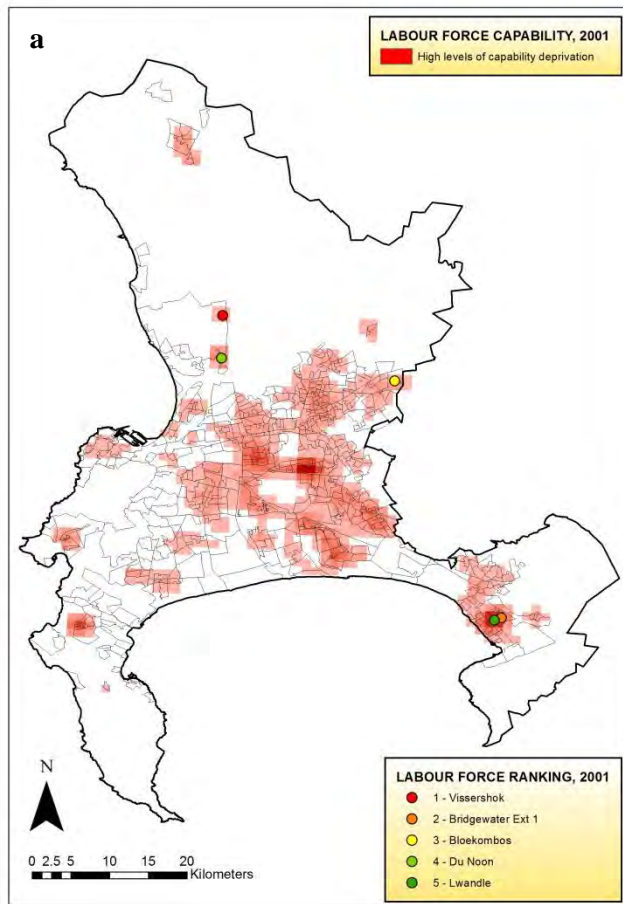


Source: Own calculations

#### IV. KERNEL DENSITY ESTIMATION (KDE)

To further strengthen the spatial analysis and segregation claims of this study, a KDE analysis was done to support the spatial outputs of the Moran's I and Getis Ord G analysis. The maps below show similar spatial segregation trends and show those communities with similarly high levels of capability deprivation to be mostly isolated in the southern parts of the City of Cape Town.

Map 35: Kernel Density Estimation for labour force capability deprivation in 2001(a) and 2011(b)



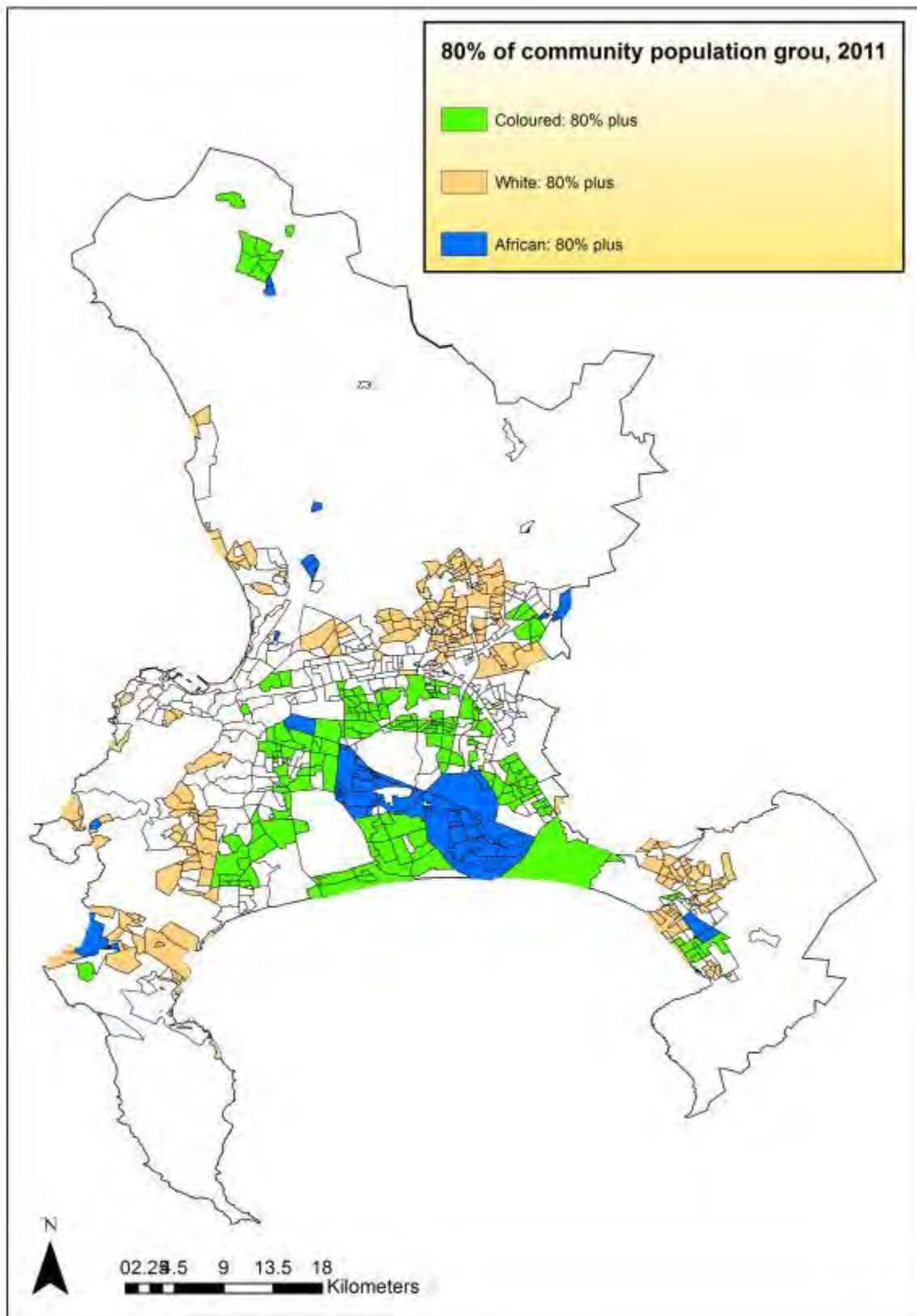
#### 4.2.4 HOUSING

Since the enactment of the Group Areas Act of 1950, the former Nationalist Government imposed constricting urban land use management policies with the objective of reserving exclusive rights for the white minority group to various prestige socio-economic resources and opportunities. These distorted land use patterns caused as a result of racial segregation had displaced the African, coloured and Indian communities to confined regions entrenched in high levels of poverty and inequality within the built environment, while the white minority were allowed to settle in regions characterised by low density urban development and quality education and health care services (Turok, 1994:243). Post 1994, the newly democratically elected government drafted and implemented wide ranging housing related legislation and policies such as, but not limited to the Housing Act, No. 107 of 1997; the Rental Housing Act, No. 50 of 1999; Social Housing Act, No. 16 of 2008, and Breaking New Ground (BNG) of 2004 to redress the issues of spatial exclusion and community marginalisation created by the Apartheid government.

Nonetheless, the issues of racial segregation and inadequate housing delivery still remain prominent policy issues for the City of Cape Town. Map 36 below shows the spatial distribution of communities in the City of Cape Town occupied by more than 80% of a certain race group. The map demonstrates that even though government has implemented various integrated housing delivery programmes and interventions across the City of Cape Town such as the BNG programme, the legacies of residential segregation inculcated by Apartheid spatial planning are still very much prominent in most communities across the Metropolis. These levels of residential segregation are largely as a result of the South African Government being unable to adequately address and keep pace with the growing housing needs of the poor living in the City of Cape Town. Government's inadequacy in this regard has largely been due to its inability to address the issue of unlocking suitable land in urban regions for housing development and connecting settlements to bulk infrastructure services (SERI, 2011:8).

To help government facilitate the unlocking of suitable land and connecting settlements to bulk infrastructure services a housing spatial MCDM model is developed for 2001 and 2011. This spatial MCDM model could assist decision makers to identify residentially segregated regions with clear boundaries within the City of Cape Town. This is done by using a housing index derived by amalgamating three housing related capabilities, i.e. annual income, child headed households, and dwelling type as sourced from Census 2001 and 2011. By identifying these regions government is able to firstly, reprioritise the allocation of bulk infrastructure resources to ensure that the identified impoverished communities actually benefit, and secondly, to help better inform political decision making regarding land use management within the built environment, which could ultimately promote enhanced social inclusion within the City of Cape Town.

Map 36: Population group distribution for 2011



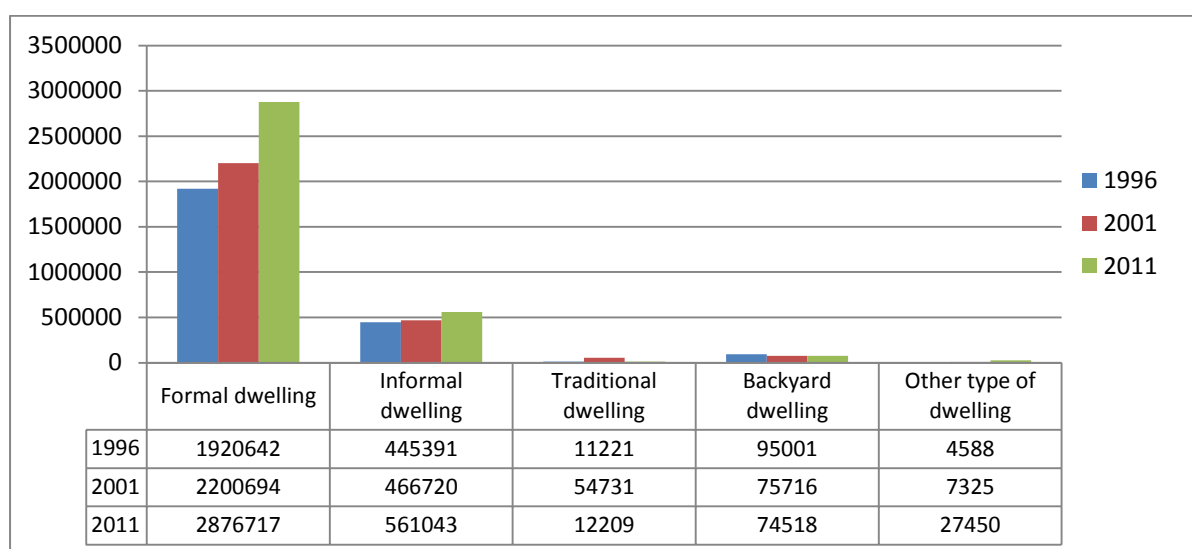
Source: Statistics South Africa, 2011, coupled with own calculations



#### 4.2.4.1 PROFILE OF HOUSING

The increasing urban growth in the City of Cape Town places significant strain on government’s ability to uphold section 26(1) of the South African Constitution, which aims to provide adequate housing opportunities to all South Africans. Using the results from Census 1996, 2001 and 2011, a housing profile for the City of Cape Town is compiled to evaluate the extent of housing delivery and residential segregation. The figure below shows that between 1996 and 2011, the number of persons living in formal dwelling structures had increased significantly from 1.9 million to 2.9 million dwellings. Equally, the number of people residing in informal dwelling structures has also increased, namely from 445 391 in 1996 to 561 043 in 2011. The increase in persons living in informal settlement structures are of concern to government given that it places additional pressure on basic services backlogs and housing delivery programmes.

Figure 21: Persons living in different dwelling types for 1996, 2001 and 2011



Source: Statistics South Africa, 1996, 2001 and 2011, coupled with own calculations

Table 33 below provides a percentage breakdown of dwelling type by population group for 2011. It highlights the stark inequalities that exist amongst the population groups in terms of formal and informal dwelling types.

Table 33: Dwelling type by population group, 2011

	Black African	Coloured	Indian or Asian	White	Total
Traditional dwelling	0.3%	0.4%	0.3%	0.4%	0.3%
Informal dwelling	34.1%	6.2%	1.9%	0.3%	15.9%
Formal dwellings	63.2%	89.8%	95.1%	97.9%	80.9%
Other type of dwelling	0.7%	1.0%	0.5%	0.2%	0.8%
Backyard dwelling	1.8%	2.6%	2.2%	1.1%	2.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Statistics South Africa, 2011, coupled with own calculations

#### 4.2.4.2 IDENTIFICATION OF DECISION CRITERIA

##### I. CONSTRUCTING THE DECISION MAKING MATRIX

Concerning adequate housing provision across the country, the NDP (2012:260) emphasises that the South African Government should (1) address the entrenched spatial patterns, which worsens poverty and inequality; (2) put into operation certain catalytic programmes and interventions with the objective of supporting better spatial governance; (3) establish a spatial equilibrium between spatial justice, economic effectiveness and preventing environmental degradation, and (4) providing citizens with sufficient capabilities to live where they feel valued.

To help inform the above-mentioned objectives, government requires credible data, information and measures on housing related issues at a micro level. Unfortunately, insufficient and unsuitable data has regularly been noted as major hindrances in the development of appropriate housing policies and interventions (SERI, 2011:30). For instance, the national Department of Human Settlements has admitted that the data and information it uses to approximate housing backlogs are notably fallacious and untrustworthy because of poor provincial and municipal housing delivery tracking and inadequate data on housing construction (SERI, 2011:30). Therefore, to address the issue of unreliable data and housing measures, the data and information from Census 2001 and 2011 are used to develop two spatial MCDM models to demonstrate how planners and decision makers could better inform the housing allocation strategy for the provisioning of appropriate housing opportunities.

It should be stressed that the already mentioned shortages with respect to housing data in South Africa makes it highly challenging for the purposes of this study to operationalise the capability approach within the housing context. Also, as indicated in Chapter three, there is no agreed framework for the assessment of any dimensions of the capability approach. In an attempt to overcome these data, information and methodological challenges, a robust spatial MCDM methodology is used as it takes into account the different interactions amongst the multiple capability related criteria. This methodology is used to derive housing deprivation (capability) measures to identify vulnerable communities within the City of Cape Town that lack the necessary housing resources, programmes and interventions required to achieve their valued functionings. As input into this spatial MCDM methodology, three evaluation criteria related to housing capabilities are sourced from the Census 2001 and 2011 community profiles and are used to develop the initial decision making matrices. The criteria used to develop these housing decision making matrices are the percentage of:

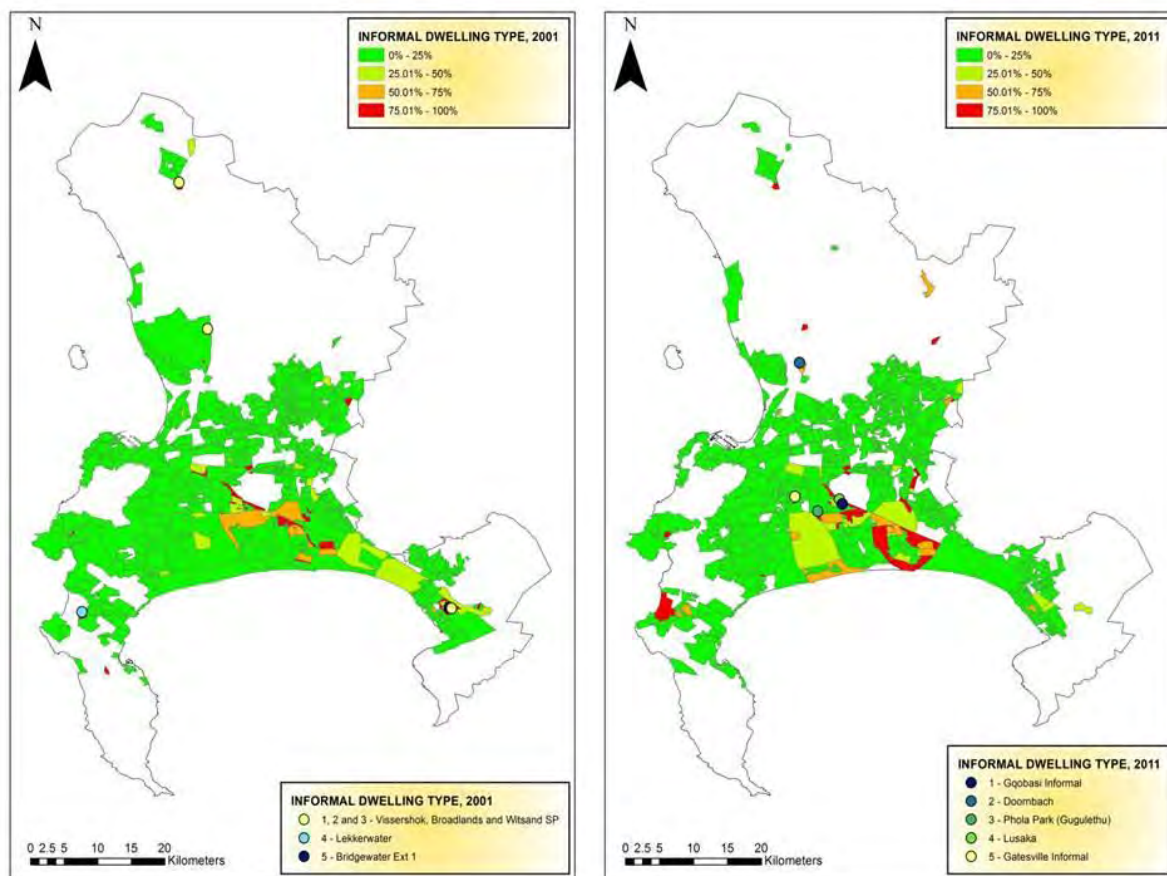
- Dwelling structures classed as informal;
- Households earning an annual income of less than R9 600, and;
- Households headed by children aged younger than 18 years.

## II. SPATIAL ANALYSIS OF EVALUATION CRITERIA

### a. INFORMAL DWELLING TYPE

According to the NDP (2012:273), informal settlements provide the urban poor and migrants with an inexpensive means to access various social and economic opportunities that exist in cities and big towns. These settlement types are typically characterised by the presence of high levels of multiple deprivation. The maps below show the spatial change in the distribution of informal settlements between 2001 and 2011. Map 37 provides a rapid assessment of informal settlement growth in the City of Cape Town and can be used as a mechanism to identify the rights of specific communities for the gradual upgrade of tenure rights. It highlights communities such as Khayelitsha and Crossroads where there has been a significant increase in informal dwellings.

Map 37: Informal settlement distribution for 2001 and 2011



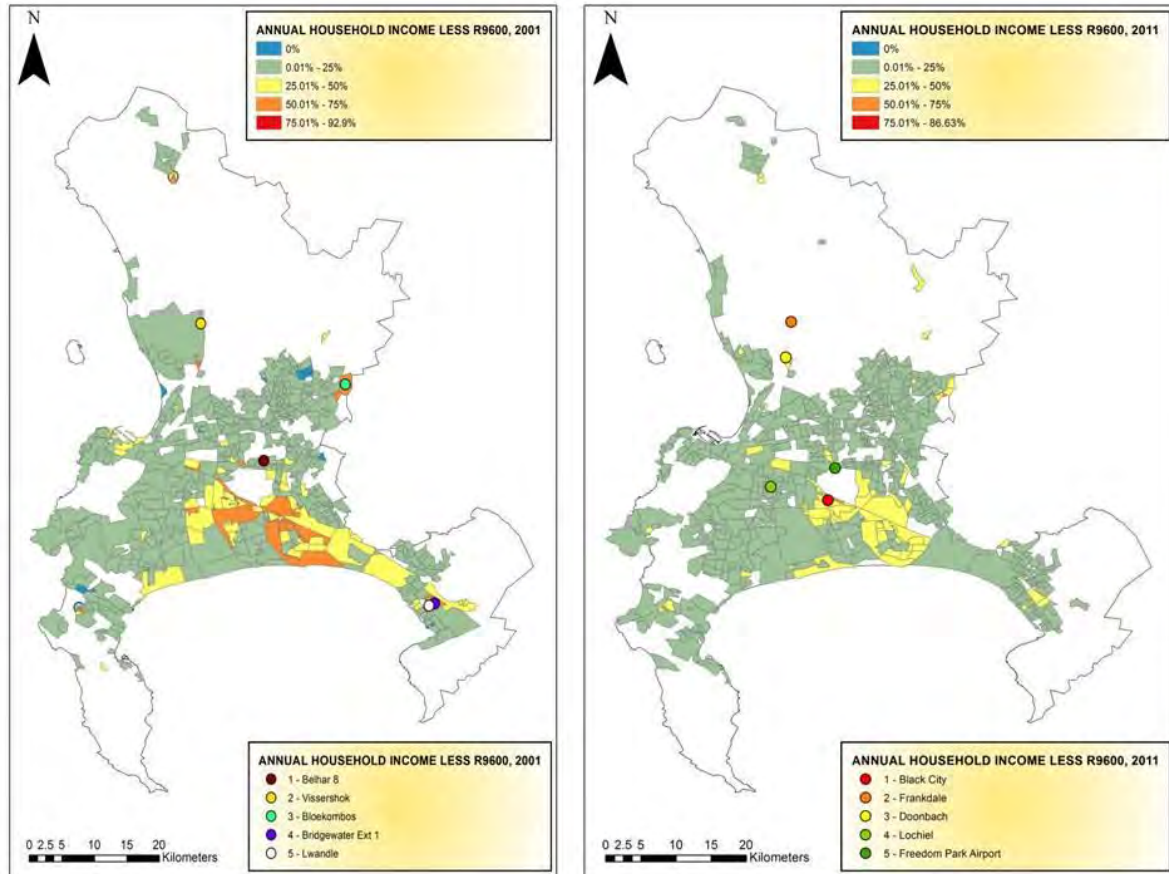
Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### b. ANNUAL INCOME OF LESS THAN R9 600 PER ANNUM

Through the promulgation of the NDP, the South African Government has been obligated to eradicate all forms of income poverty by 2030 through the implementation of various capability redress programmes and interventions. The maps below show the spatial distribution of communities and households earning less than R9 600 per annum across the City of Cape Town. It highlights communities such as Khayelitsha, Philippi, Delft and Mfuleni where necessary programmes and

interventions are needed so as to eradicate household poverty in these regions. Map 38 allows decision makers and planners to review the existing grant and support management for housing with the view of ensuring housing development promotes livelihood production and job creation; and safeguarding that government funding does not support the further proliferation of non-strategic human settlement development and investment in poorly located regions (NPC, 2012:287).

Map 38: Annual income less than R9600 per annum in 2001 and 2011



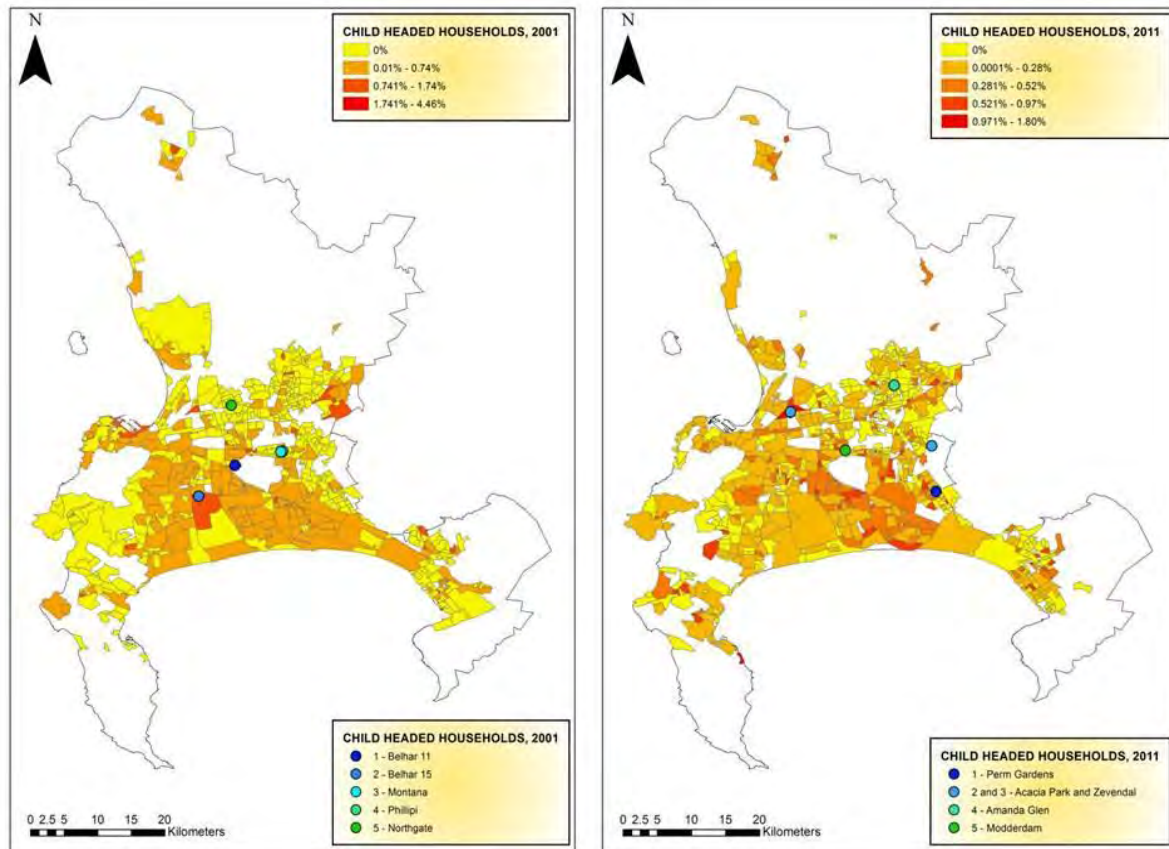
Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### c. CHILD HEADED HOUSEHOLDS

Child headed households remain a significant policy issue for government as this vulnerable group does not qualify for registered ownership of dwelling stands and cannot receive a housing subsidy. Coupled with the former, they only qualify for rental accommodation where and if legal guardianship is present (SERI, 2011:89). The maps below show the spatial change in households headed by children between 2001 and 2011.

The Constitution of South Africa protects the rights of all children to a safe and secure environment (NPC, 2012:396). Map 39 below shows the difficulty in realising these constitutional obligations as many smaller pockets of communities with child headed households exist across the City of Cape Town. The maps below could be utilised and applied by planners and decision makers to target appropriate programmes and interventions to alleviate the probable threat to child safety.

Map 39: Spatial distribution of child headed households in 2001 and 2011



Source: Statistics South Africa, 2001 and 2011, coupled with own calculations

### III. CONSTRUCTING THE WEIGHTED DECISION MAKING MATRIX

Before constructing the weighted decision matrix an investigation into the relationships between the initial housing capability indices and its related components are undertaken to establish the presence of multi-collinearity. The table below provides the related correlation coefficients for the housing capability index and the scores for its three components (i.e. informal dwelling type, annual income and child headed households). It shows that all criteria are highly correlated ( $\rho > 0.80$ ) with the initial housing index. In addition, it highlights that both informal dwellings and annual income less than R9 600 has a strong positive correlation with the initial housing index. These correlations raise the issue of repeatability in the MCDM model, which could significantly impair the MCDM model's results, and thus the need to test for multi-collinearity.

Table 34: Pearson correlation matrix for the three criteria used for the housing index for 2001

COMPONENT	HOUSING	INFORMAL	ANNUAL	CHILDHEAD
HOUSING	1.0000			
INFORMAL	0.9665*	1.0000		
ANNUAL	0.8756*	0.7924*	1.0000	
CHILDHEAD	0.1607*	0.1450*	0.1930*	1.0000

\* Statistically significant at  $p < 0.01$

The pairwise correlation matrix developed for 2011 between the initial housing index and its three related evaluation criteria used in the PCA analysis is shown in the table below. Statistically significant correlations were observed for all coefficients ( $\rho < 0.01$ ) and a high correlation coefficient ( $\rho > 0.80$ ) was observed for the criteria informal dwelling type and annual income. Also, when evaluating the relationships between the three evaluation criteria and the initial housing index, all criteria were found to have positive correlations with the initial housing index. These significantly high correlations are an indication of the presence of multi-collinearity, which will be addressed through the use of the Variance Inflation Factor technique to identify criteria that can be removed from the MCDM models.

Table 35: Pearson correlation matrix for the three criteria used for the housing index for 2011

<b>COMPONENT</b>	<b>HOUSING</b>	<b>INFORMAL</b>	<b>ANNUAL</b>	<b>CHILDHEAD</b>
<b>HOUSING</b>	1.0000			
<b>INFORMAL</b>	0.9916*	1.0000		
<b>ANNUAL</b>	0.8393*	0.7692*	1.0000	
<b>CHILDHEAD</b>	0.2870*	0.2690*	0.3138*	1.0000

\*\* Statistically significant at  $p < 0.01$

These Pearson correlation matrices for 2001 and 2011 present significant findings for policy planners and decision makers. For instance, it shows that persons living in informal dwelling types of housing are typically characterised by low annual household income levels. The above tables indicate that various housing delivery projects such as Breaking New Grounds could have a significantly positive influence on increased income levels but is dependent on the location of these housing projects. The matrices also show that informal settlement upgrades remain a significant policy conundrum for the South African Government. The reason for that is that all informal settlements are unique in nature in terms of their history, vulnerability and location (NPC, 2012:273). Accordingly, generic housing solutions will not adequately address the housing demands and needs of vulnerable communities. Government will thus require community specific solutions to meet the individual needs of each vulnerable community.

Tables 34 and 35 both corroborate the presence of multi-collinearity in the two MCDM models and that one or more criteria are interrelated with one another. The existence of multi-collinearity will not only result in repeatability errors, but will also add intricacies to the model development process. Therefore, VIFs are derived to ascertain which of the three evaluation criteria can be removed from the final spatial MCDM model without hindering the model's capabilities. Table 36 below presents the results of the VIF analysis for 2001 and shows all VIFs to be less than 10. These factors indicate that although the criteria, i.e. informal dwelling types and annual household income less R9 600 are

highly correlated with each other, the presence of multi-collinearity can be negated and all three criteria can remain in the final spatial MCDM model.

Table 36: VIF scores for each criterion in 2001

<b>CRITERIA</b>	<b><i>VIF<sub>all</sub></i></b>	<b><i>1/VIF</i></b>
<b>ANNUAL</b>	2.73	0.3659
<b>INFORMAL</b>	2.69	0.3721
<b>CHILDHEAD</b>	1.04	0.9626
<b>MEAN VIF</b>	2.15	

The results of the multi-collinearity testing have shown that all housing related criteria for both 2001 and 2011 can be retained in the MCDM models. The following tables and results will show the PCA results for these three criteria and how these results were applied to derive the average weighting schema for the final housing capability indices. Table 37 shows the results of the PCA for 2001 and 2011. It is observed that Principal Component 1 accounts for more than 91% and 94% of the total variation in both the 2001 and 2011 models, respectively. Based on these variations, the eigenvectors relating to the first PC are used to derive the average weighting schema for both 2001 and 2011.

Table 37: Results of the PCA for 2001 and 2011 applied to the housing domain

<b>COMP</b>	<b>YEAR</b>	<b>EIGENVALUE</b>	<b>DIFFERENCE</b>	<b>PROPORTION</b>	<b>CUMULATIVE</b>
<b>COMP1</b>	2001	0.0672	0.0606	0.9098	0.9098
	2011	0.0572	0.0533	0.9364	0.9364
<b>COMP2</b>	2001	0.0066	0.0066	0.0901	0.9998
	2011	0.0039	0.0039	0.0635	0.9999
<b>COMP3</b>	2001	0.0000	0.0000	0.0002	1.0000
	2011	5.13371e-06	0.0000	0.0001	1.0000

The eigenvectors of the two criteria used to develop the education indices for 2001 and 2011 are shown in Table 38. It is observed that the coefficients for Principal Component 1 relating to the informal dwelling type criterion are positive. This result implies, considering that all factors remain constant, that communities with higher proportions of informal dwelling structures will be ranked higher in terms of government prioritization.

Table 38: Eigenvector values for 2001 and 2011 for each of the criteria

<b>CRITERIA</b>	<b>YEAR</b>	<b>COMP1</b>	<b>COMP2</b>	<b>COMP3</b>
<b>INFORMAL</b>	2001	0.8429	-0.5381	0.0004
	2011	0.9327	-0.3607	n/a
<b>ANNUAL</b>	2001	0.5381	0.8429	-0.0049
	2011	0.3607	0.9327	n/a

<b>CHILDHEAD</b>	2001	0.0024	0.0043	1.0000
	2011	0.0028	0.0054	n/a

Bearing in mind that Principal Component 1 for 2001 and 2011 accounts for more than 95% and 96%, respectively of the total variation in the education model, its related normalised eigenvectors ( $\sum_{i=1}^n |\varphi| = 1$ ) are used as the preferred weighting schema for the development of the education capability indices. The mathematical sequences below show the weighting schemas for 2001 and 2011 used to derive the average weighting schema to be applied to the decision making matrices. The three weighting schemas show that the criterion concerning informal dwelling type has been assigned priority in the MCDM models followed by annual household income and child headed households.

$$HOUSING\ INDEX_{2001} = \{INFORMAL(0.61), ANNUAL(0.39), CHILDHEAD(0.002)\}$$

$$HOUSING\ INDEX_{2011} = \{INFORMAL(0.72), ANNUAL(0.28), CHILDHEAD(0.002)\}$$

$$HOUSING\ INDEX_{average} = \{INFORMAL(0.66), ANNUAL(0.33), CHILDHEAD(0.002)\}$$

Now that the average weighting schema has been developed, it is applied to the two multi-criteria decision making matrices to derive the housing capability deprivation indices used to rank each of the 580 communities within the City of Cape Town from no capability deprivation ( $I_{housing} < 10\%$ )–households with the necessary housing related capabilities needed to easily remove themselves from any oppressive environment–to severe housing capability deprivation ( $I_{housing} > 80\%$ ). The following section of this study shows the results generated from the two housing spatial MCDM models.

#### 4.2.4.3 IDENTIFICATION OF IDEAL SOLUTION

The objective of the following section is to derive the appropriate housing deprivation indices for 2001 and 2011 used to rank each of the community alternatives based on housing capability and assess change in deprivation levels. These rankings will be based on the inverse calculation that subtracts the closeness index value from one. Table 39 displays the  $S_i^+$  and  $S_i^-$  values for 2001 that are used in deriving the housing capability deprivation index, which ranks the 580 communities within the City of Cape Town using the three evaluation criteria (i.e. informal dwellings; annual income, and child headed households). According to the 2001 ranking index, Vissershok was ranked as being the most capability deprived community in the City of Cape Town in terms of housing capability, followed by Bridgewater Ext 1, Wallacedene, Lwandle and Witsand SP.

Table 39: The distance values and the final rankings for housing capability deprivation in 2001

<b>ALTERNATIVE</b>	<b><math>S_i^+</math></b>	<b><math>S_i^-</math></b>	<b><math>C_i</math></b>	<b><math>1 - C_i</math></b>	<b>RANK</b>	<b>PLACE</b>
$A_1$	0.01	0.73	0.98	0.02	552	Acacia Park
....						
$A_{87}$	0.70	0.06	0.08	0.92	2	Bridgewater Ext1



$A_{306}$	0.66	0.09	0.12	0.88	4	Lwandle
$A_{534}$	0.72	0.04	0.05	0.95	1	Vissershok
$A_{543}$	0.68	0.09	0.12	0.88	3	Wallacedene
$A_{570}$	0.70	0.10	0.12	0.88	5	Witsand SP
.....						
$A_{580}$	0.13	0.67	0.84	0.16	95	Zonnebloem

The table below presents the  $S_i^+$  and  $S_i^-$  scores used in deriving the housing capability deprivation index for 2011, which similarly ranks the identified communities within the City of Cape Town using the three evaluation criteria (i.e. informal dwellings, annual income and child headed households). According to the 2011 housing index, Doornbach was identified as the most deprived community in terms of housing capabilities followed by Freedom Park Airport Informal, Boys Town, Vukuzenzele, and Frankdale.

Table 40: The distance values and the final rankings for housing capability deprivation in 2011

ALTERNATIVE	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.07	0.70	0.90	0.10	175	Acacia Park
.....						
$A_{94}$	0.67	0.12	0.15	0.85	3	Boys Town
$A_{168}$	0.69	0.08	0.11	0.89	1	Doornbach
$A_{220}$	0.61	0.12	0.16	0.84	5	Frankdale
$A_{221}$	0.67	0.11	0.14	0.86	2	Freedom Park
$A_{657}$	0.67	0.12	0.15	0.85	4	Vukuzenzele
.....						
$A_{705}$	0.05	0.70	0.93	0.07	249	Zwartdam

Table 41 below presents the summary statistics of the housing capability deprivation scores in the City of Cape Town for 2001 and 2011. It shows a slight decrease between 2001 and 2011 for both the mean (from 12.2% to 11.7%) and standard deviation (from 19.6% to 18.5%). These summary statistics show that despite government implementing numerous human settlement redress programmes that the progress to date has been significantly slow. These results underline the inability of the government to address the supply and demand of appropriate housing opportunities in the City of Cape Town.

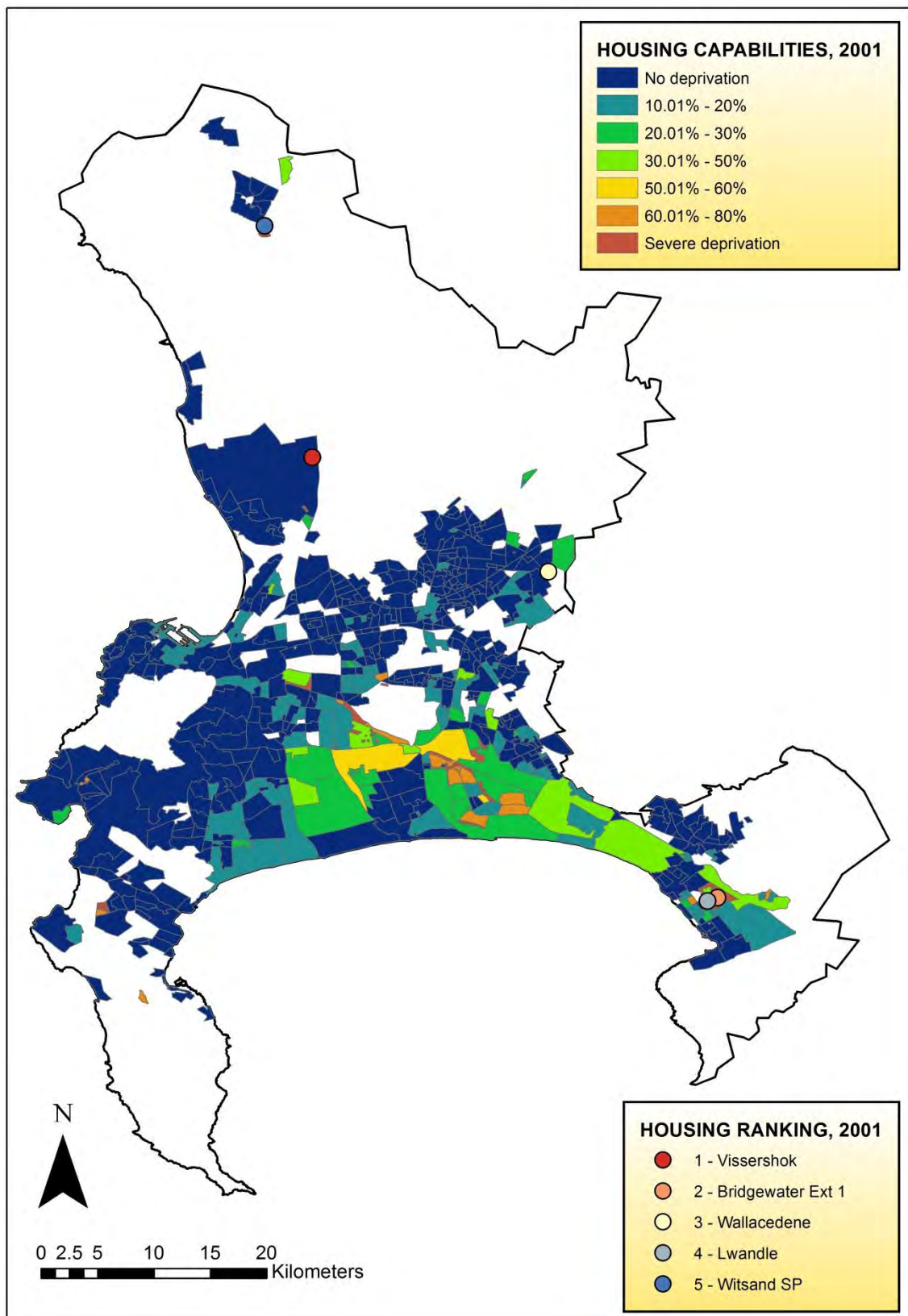
Table 41: Summary statistics for Housing capability deprivation scores for 2001 and 2011

CAPABILITIES	OBS	MEAN	STD. DEV	MIN	MAX
Housing index 2001	580	0.1224	0.1960	0	0.9518
Housing index 2011	705	0.1171	0.1855	0	0.8933

The maps below demonstrate the spatial distribution and change in housing capability deprivation in the City of Cape Town for 2001 and 2011. The use of GIS in addressing housing deprivation with the spatial illustration and analysis of criteria relating to housing capabilities and poverty would assist planners and decision makers to reform current housing policies and programmes. This will assist provincial government and local municipalities to meet their forever increasing demands for housing, needed to ensure and protect both social and economic stability and future potential growth in South Africa.

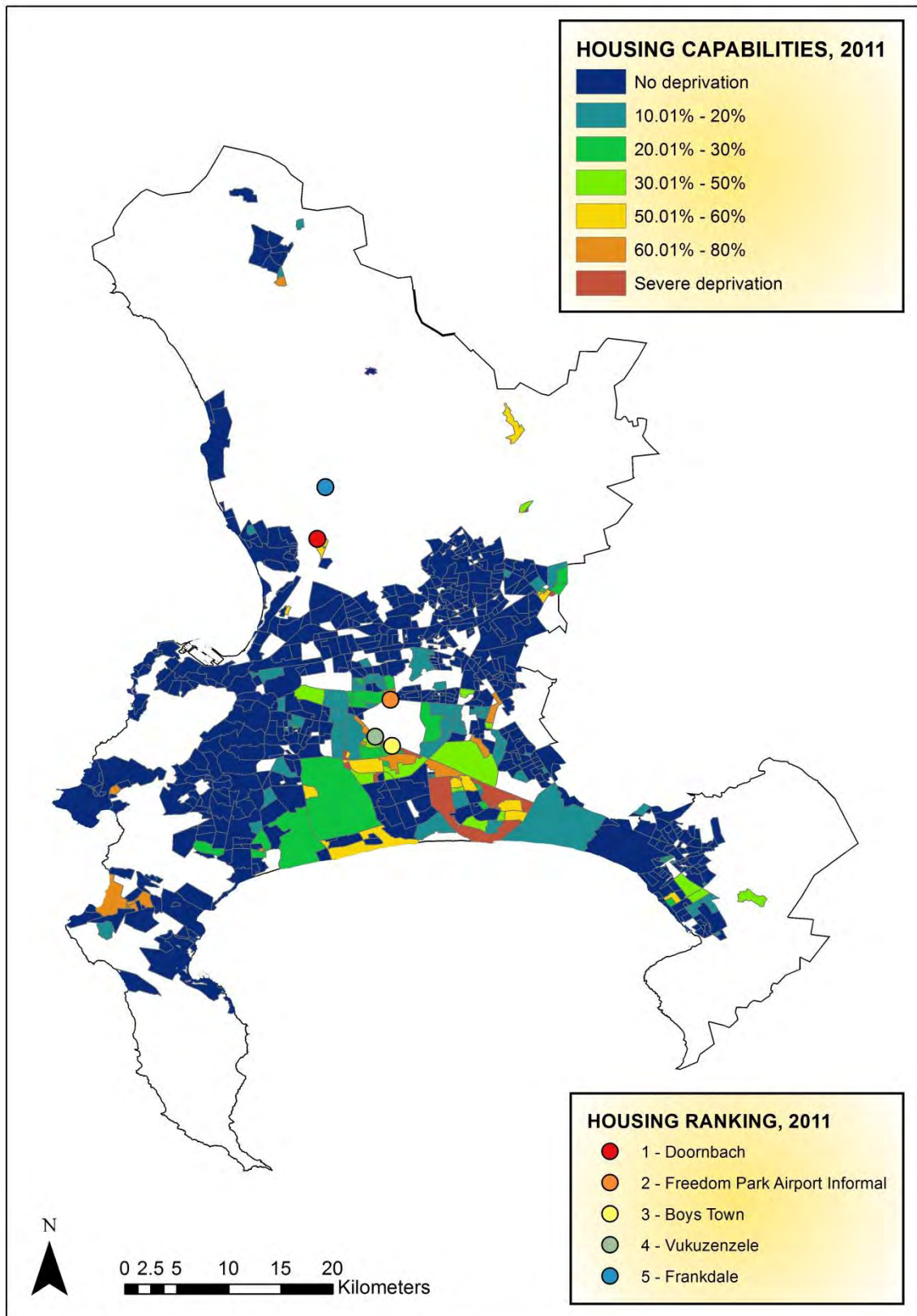
This growing demand has resulted from increased migration trends of the poor towards certain informal regions within the City of Cape Town. The former caused an increase in the number of informal settlements, and this, coupled with both overcrowding and slow service delivery, gave rise to increased levels of service delivery protests. Recent government efforts in South Africa through the implementation of a number of housing reform programmes such as the Upgrading of Informal Settlements Programme and Breaking New Grounds have been focused on creating an enabling environment to create sustainable human settlements of adequate quality. However, the results of the spatial MCDM models as shown in Maps 40 and 41 suggest that the delivery of adequate housing opportunities in the City of Cape Town is still quite variable and much can still be done by government to improve the housing conditions in certain regions of the City. Two critical factors that continue to hinder government's ability to effectively deliver appropriate housing are the lack of detailed records of municipal spending on housing delivery and robust decision making models (National Treasury, 2009:100). These factors continue to discredit any sort of government oversight, accountability and governance processes related to housing delivery in South Africa.

Map 40: Spatial pattern of housing capability deprivation in the City of Cape Town in 2001



Source: Own calculations

Map 41: Spatial pattern of housing capability deprivation in the City of Cape Town in 2011



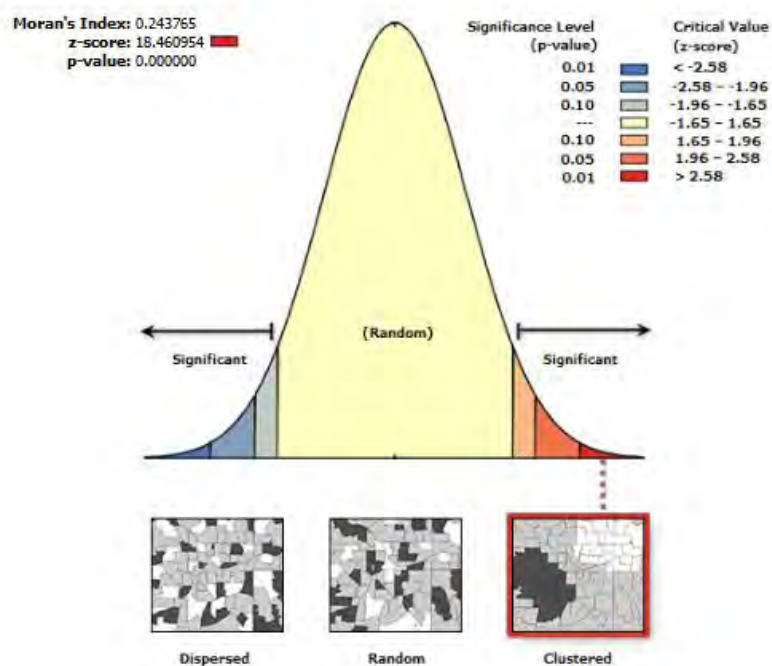
Source: Own calculations

## I. GLOBAL MORAN'S INDEX (I)

To develop more robust housing related decision making models, housing capability must be assessed concurrently with other techniques and elements that are interrelated with housing capability and spatial information. Accordingly, spatial autocorrelation methods are used to explore spatial dependencies and assist decision makers and planners in detecting and understanding the spatial patterns of housing capability deprivation. The analysis of spatial patterns of housing capability deprivation in the City of Cape Town focuses on the extent to which communities that experience severe levels of housing capability deprivation are confined to certain regions within the City of Cape Town. Therefore, the first spatial autocorrelation method used to assess residential segregation patterns in the City of Cape Town is the Global Moran's I. To initiate this analysis, the housing index scores derived from the MCDM process are used as the input.

The results of the 2001 analysis are presented in the figure below. The results show a positive Z score of 18.46 and a statistically significant Moran's I score of 0.24. These results generated from the spatial autocorrelation method indicate that the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance. This statistically validates the notion of an entrenched segregated pattern along a housing capability line as presented in Map 38, which emanated from the implementation of Apartheid type of spatial planning policies and further entrenched by the implementation of current housing regulations.

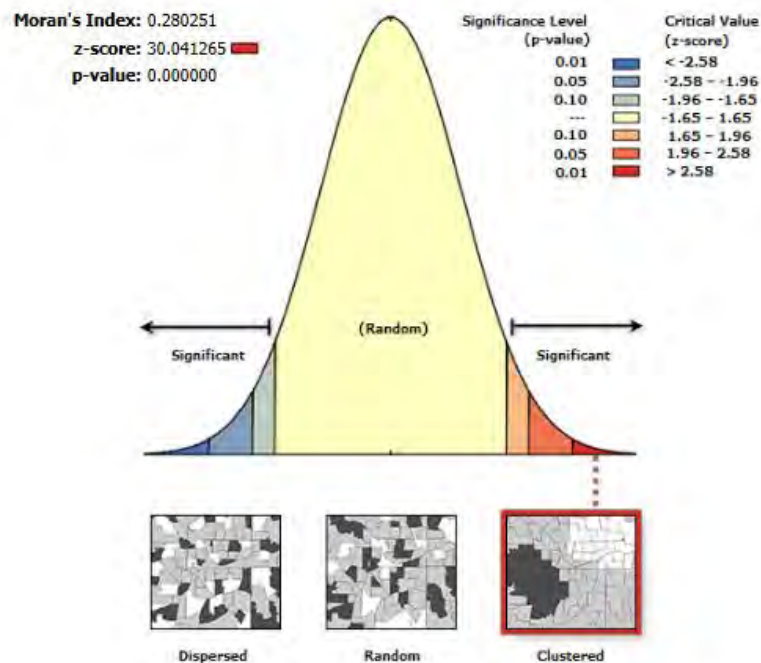
Figure 22: Moran's I classification for housing capability in the City of Cape Town in 2001



Source: Own calculations

The results for 2011 as shown in the figure below display slightly elevated trends as compared with the results of 2001. The outcome of the spatial autocorrelation analysis shows a higher positive Z score of 30.0 and a Global Moran's Index score of 0.28. Similar to the 2001 results, the 2011 results indicate that the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance. These positive spatial autocorrelations scores for both years indicate that housing deprivation in the City of Cape Town is clustered in such a way that communities with high levels of housing deprivation are surrounded by neighbouring communities with similar high levels of housing capability deprivation and communities with low levels of deprivation neighboured by communities with similar low levels of deprivation.

Figure 23: Moran's I classification for housing capability in the City of Cape Town in 2011



Source: Own calculations

The presence of residential segregation patterns as shown in the two figures above are of significant concern given that section 26(1) of the South African Constitution enshrines the right of all South Africans to have access to adequate housing opportunities. These autocorrelation measures also support the NPC's (2012:260) claim that there are no quick fixes in terms of restructuring the Apartheid topography of South Africa. It is thus important for policy planners and decision makers to adequately monitor and evaluate the outcomes of their current housing policies that are intended to change the trajectory of spatial development in both the built environment and national economy of South Africa. The following section presents the spatial results of the Local Moran's I analysis, which demonstrates through the use of hotspots and cold spots the outputs of the trajectory change brought about by post-1994 housing policies.

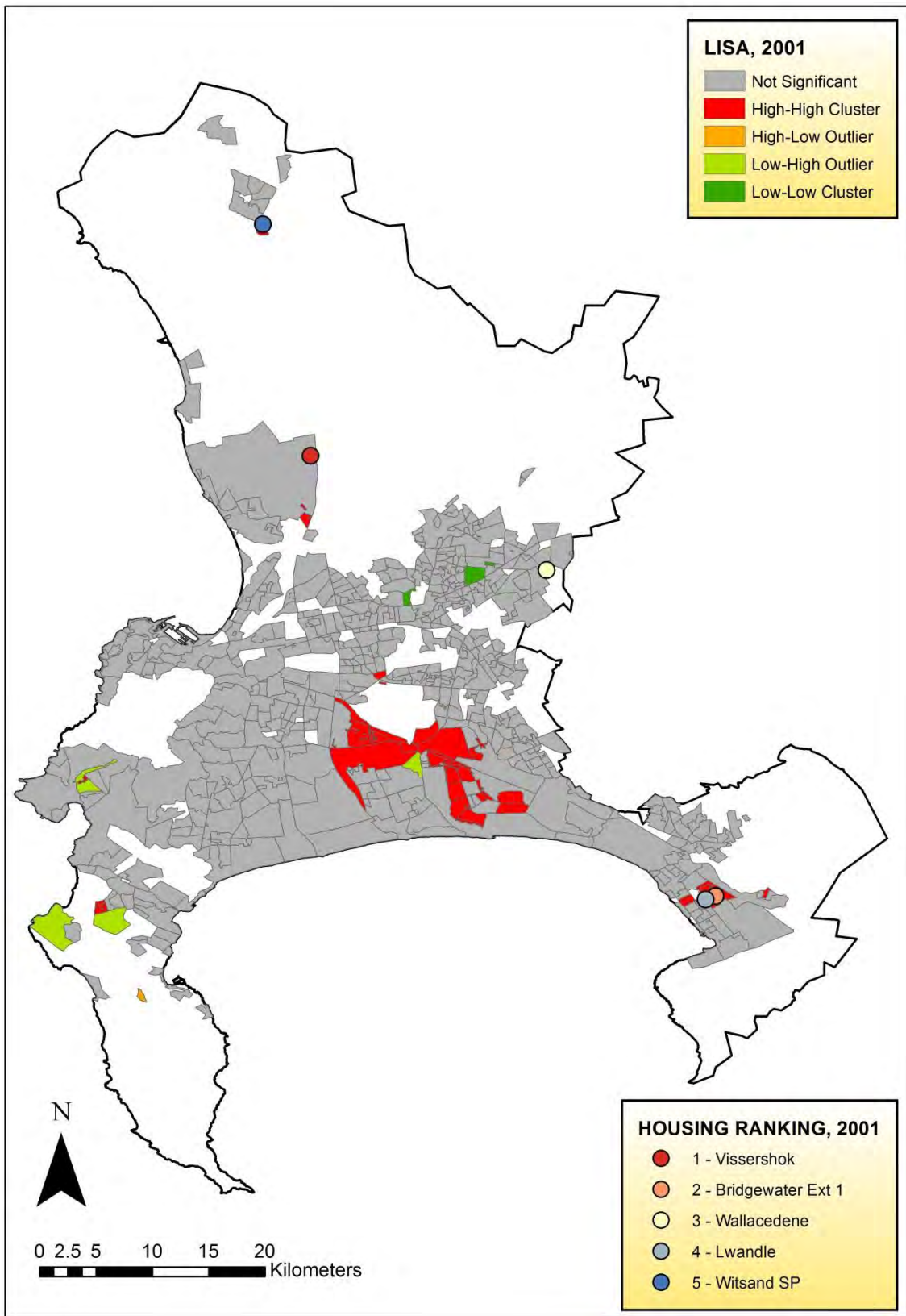
## II. LOCAL INDICATOR OF SPATIAL ASSOCIATION (LISA)

The maps below display the spatial clustering for the Housing capability deprivation residuals. The Local Moran's I classify housing deprivation into four categories, namely communities characterised by:

- 1) High levels of housing deprivation surrounded by communities with high levels of housing capability deprivation (i.e. High–High or H–H);
- 2) Low levels of housing capability deprivation surrounded by communities with low levels of housing capability deprivation (i.e. Low–Low or L–L);
- 3) High levels of housing capability deprivation surrounded by communities with low levels of housing capability deprivation (i.e. High–Low or H–L), and;
- 4) Low levels of housing capability deprivation surrounded by communities with high levels of housing capability deprivation (i.e. Low–High or L–H).

Map 42 shows that in 2001, there was one major spatial cluster of the H–H type in the surrounding Philippi, Khayelitsha, Crossroads, Nyanga and Delft areas. It also shows the existence of H–L and L–L type clusters that indicates the presence of spatial uncertainties in the manner causing the spatial configuration of housing capability deprivation in the City of Cape Town. These results reveal the presence of spatial heterogeneity and a common spatial characteristic found in South Africa, which was predominantly brought about through Apartheid type of spatial planning policies where communities characterised by high housing deprivation levels are surrounded by communities that are predominantly characterised by low housing deprivation levels. Map 43 demonstrates the topography change between 2001 and 2011 brought about by the implementation of various post-Apartheid housing reform policies. The map shows the further expansion of the 2001 H–H cluster type, which now includes the greater Khayelitsha and Delft areas, as well as Gugulethu. According to Seekings (2010:5), these persisting segregation patterns are created by the implementation of what he describes as “neo–liberal” post-Apartheid housing policies such as the Upgrading of Informal Settlements Programme. These policies have managed to, albeit slowly, erode racial inequalities, but at the same time it has given rise to new a form of market inequality, which provides suitable land for global capitalism, used to address any possible limitations brought about by national policies. Another critical factor that Seekings considers to have significantly contributed to these persistent segregation patterns has been the ever increasing migration from rural to urban areas. These in-migration trends have resulted in a large percentage of segregated regions within the City of Cape Town now including communities who did not previously exist when the Group Areas Act of 1950 was abolished (Seekings, 2010). Map 43 shows the pattern of residential segregation in 2011 for the City of Cape Town and how, since 2001 at least, the ever increasing trends regarding in-migration especially into the informal regions have resulted in the propagation of larger clusters of segregated regions within Cape Town.

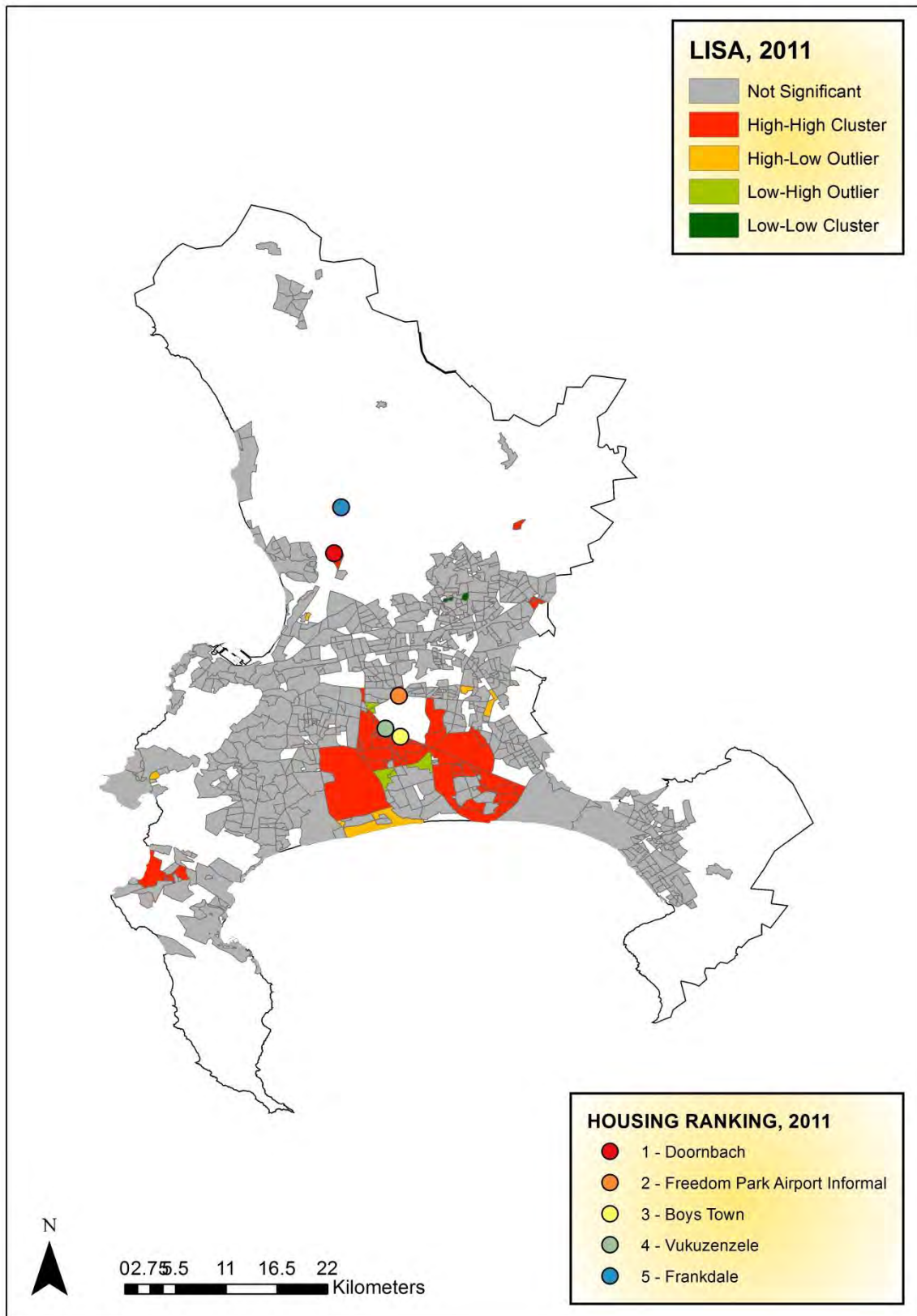
Map 42: LISA in 2001



Source: Own calculations



Map 43: LISA in 2011



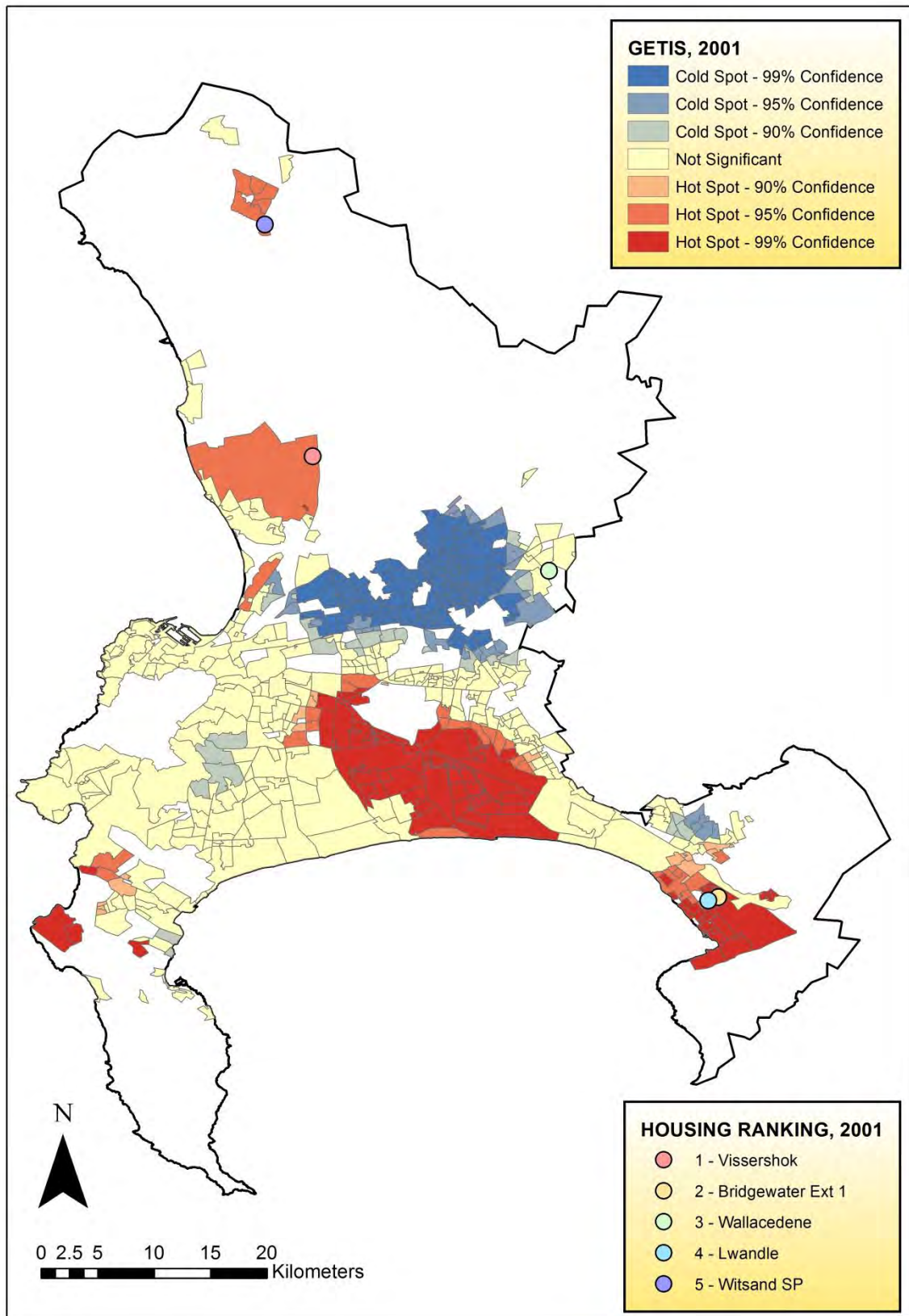
Source: Own calculations

### III. GETIS – ORD $G_i^*$

The desegregation of urban cities is a complex conundrum which needs intrepid measures to change the trajectory of spatial development in urban cities. While the housing spatial MCDM models do not intrinsically evaluate the effects of multiple cross cutting housing capabilities on residential desegregation, it does however have the ability to monitor and validate the spatial change within the City of Cape Town and evaluate the effects of various housing programmes on residential desegregation. To monitor and statistically validate the spatial change in residential segregation, a hotspot assessment using the housing capability deprivation scores for 2001 and 2011 is done using the spatial autocorrelation measure called Getis-Ord  $G_i^*$ . The  $G_i^*$  statistics identify spatial clusters of high values (i.e. hotspots) and low values (i.e. cold spots) using the  $G_iZ$  scores and  $G_iP$  scores for each community. The maps below illustrate the clustering of both positive and negative scores of  $Z[G_i^* (d)]$  that are significant at a 0.01, 0.05 and 0.1 level. The clustering of positive scores highlighted in red indicates the spatial association of high values ( $Z[G_i^* (d)] > 1.96$ ) and the negative clustering highlighted in blue shows the spatial association of low values ( $Z[G_i^* (d)] < 1.96$ ).

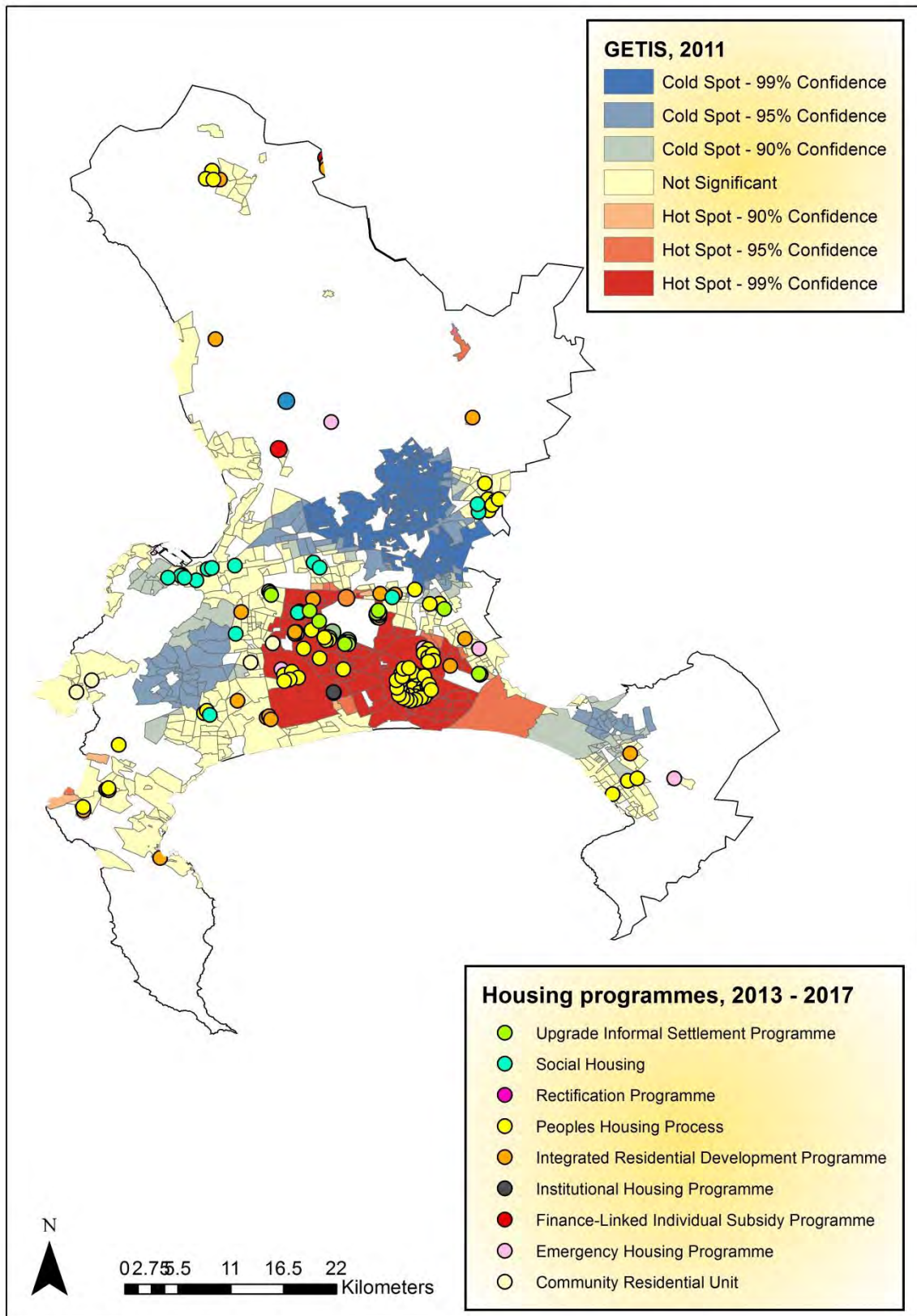
In 2001, the Getis-Ord  $G_i^*$  analysis of residential segregation identifies two major clusters of communities with significantly raised incidences (i.e. hotspots). The first major cluster includes communities such as Khayelitsha, Philippi, Crossroads, Mfuleni and Delft. The second cluster includes areas such as Lwandle and Nomzamo. These residentially segregated regions with their high levels of housing deprivation are completely enclosed by communities with no elevated or lowered deprivation levels (not significant). This region is then bordered by a fragmented band of communities with low levels of housing capability deprivation in the northern part of the City of Cape Town (i.e. cold spots). The  $G_i^*$  analysis for housing capability deprivation is also completed for 2011, which shows the trajectory change in residential segregation patterns between 2001 and 2011 shaped by the implementation of various housing programmes. Both Maps 44 and 45 concur with findings by Seekings (2010) that shows how the implementation of housing programmes and the growth in population size has caused for the proliferation of residential segregation in newly developed (mostly white) communities located on the Northern and North–Eastern fringes (i.e. cold spots) of the City of Cape Town. It also shows how the segregation patterns have rapidly expanded predominately in African communities and the slower growth in coloured communities (i.e. hotspots). While Besteman (2008) and Lemanski (2010) as well as Seekings (2010) all argue that economic influences play a critical role in both African and coloured citizens' capabilities to ascend past the various affordability levels within the housing market, the role of government's housing programmes in further entrenching residential segregation patterns should also be noted. Map 45 shows that while government has sufficiently targeted the communities most in need of housing opportunities, little change has taken place in terms of community desegregation.

Map 44: Getis-Ord significance at the 1%, 5% and 10% significance level in 2001



Source: Own calculations

Map 45: Getis-Ord significance at the 1%, 5% and 10% significance level in 2011

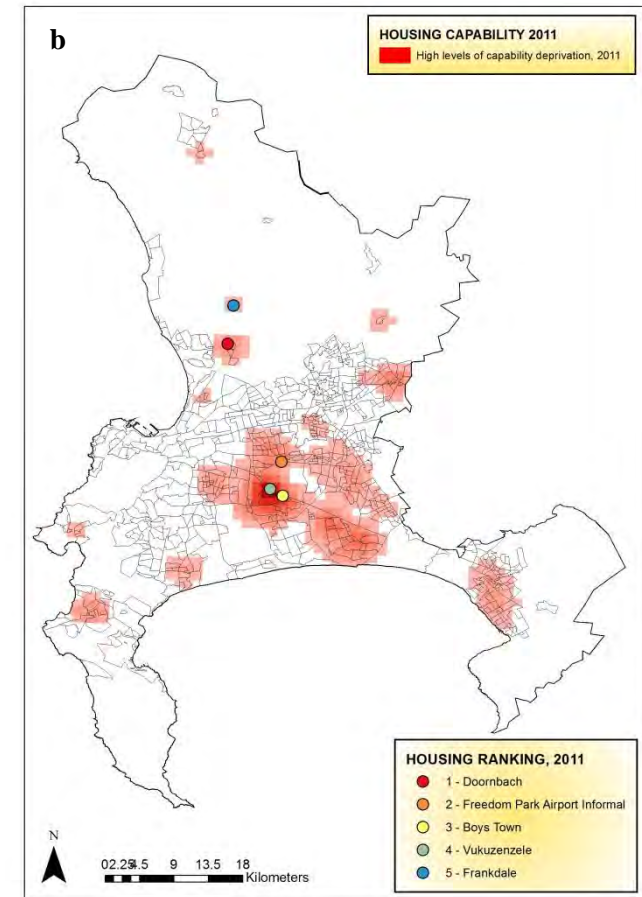
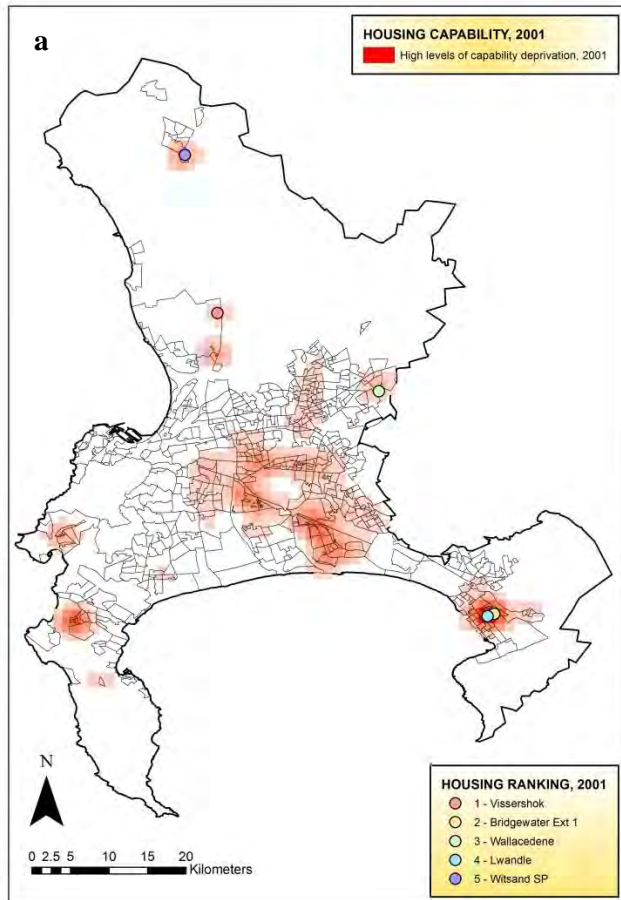


Source: Own calculations

#### IV. KERNEL DENSITY ESTIMATION (KDE)

The Kernel Density Estimation (KDE) for 2001 and 2011 as demonstrated in the maps below and derived from the housing capability deprivation scores, alludes to variability in the spatial distribution of levels of housing opportunities in the City of Cape Town. KDE was used as a secondary spatial statistical measure to quality assures the results produced using the  $G_i^*$  'family' spatial statistics.

Map 46: Kernel Density Estimation for housing capability deprivation in 2001(a) and 2011(b)



#### 4.2.5 COMPOSITE POVERTY MEASURE

Since the advent of democracy in 1994, government initiatives such as the RDP in 1994 and NDP in 2011 gave rise to an increase in multiple citizen capabilities. Coupled with the former, the attainment of various functionings as fundamental means has received significant policy debate and attention regarding the improvement of citizen well-being and the eradication of poverty as opposed to the conventional monetary deprivation utility being considered as the primary criterion of poverty eradication. This has largely been due to the NPC recognising that citizens have multiple social and economic preferences and needs. This paradigm shift in terms of understanding poverty as being the lack of necessary capabilities as opposed to lower income levels is critical, mainly because:

- The capabilities approach is focused on the deprivation of fundamentally important criteria as opposed to lower income levels that are only instrumentally meaningful;
- There are multiple criteria other than income that has significant influences on variations of capability deprivation, and;
- The correlations between income deprivation and capability deprivation fluctuate between communities, and therefore, the effects of income on capabilities are provisional and uncertain.

The South African Government's intent to significantly enlarge citizen capabilities signifies the need for a standardised evaluation method, which can be used to assess the developmental progress made in terms of eradicating poverty in the City of Cape Town. This approach could widely be conceived as a paradigm framework that could be utilised by policy planners and decision makers to improve on spatial policies through the evaluation of numerous socio-economic related issues entrenched in different communities across the City of Cape Town. These enhanced spatial policies will assist to "...coordinate and connect the principal decisions that create and shape places to improve how they function" (NPC, 2012:278). In doing so, government will enable marginalised communities to be empowered through the provision of sufficient citizen capabilities necessary to achieve valued functionings; build more resilient communities; promote social inclusion, and ultimately eradicate poverty.

The capability approach framework is primarily centered on the social and economic data and information needed to attain spatial perceptiveness about citizen's capabilities required to achieve valued functionings and freedoms, and subsequently disregards any other approaches that are, according to Sen (1992), conceptually ineffectual. Functionings and freedom are both considered by Wagle (2009:511) to be theoretical concepts that are fundamentally difficult to quantitatively explain and spatially analyse due to them being qualitative and uncompromising in nature. Capabilities, on the other hand, are more operational in nature and are thus mathematically more acceptable in terms of evaluating the levels of community capabilities because of its emphasis being placed on 'available resources' rather than 'desire resources' (Wagle, 2009:511). The work done by Sen (1992) further

reaffirms that poverty should be assessed in a capabilities space rather than a functionings space, and that the emphasis of capability assessments should be placed on opportunities rather than accomplishments (Frediani, 2010:176). Accordingly, the next section will focus on the operationalisation of the capability approach using the multiple Census criteria, thus enabling the spatial evaluation of capabilities space in the City of Cape Town.

The evaluation of capability space in the City of Cape Town is done in this study through the amalgamation of the twelve capability related criteria as sourced from Stats SA's Census datasets for 2001 and 2011, into two composite measuring units used to exemplify, categorise, and assess the evolving distribution of poverty (capability deprivation) and its explicit spatial patterns within the various communities across the City of Cape Town. This capability measure can be used by policy planners and decision makers to assess and develop a comprehensive spatial vision for the City of Cape Town. Such a spatial vision should ideally include community members having the necessary capabilities needed to overcome the different social and economic impediments in order for them to achieve valued functionings. Related to such a vision, the NPC (2012:277) emphasises the following pertinent spatial objectives, namely:

1. Address the current spatial divisions brought about as a result of Apartheid planning legacies. The existing spatial configurations only exacerbate social exclusion, which in turn aggravates economic progression resulting in the expansion of poverty and inequality.
2. Unblock the multiple bottlenecks that exist in terms of hindering communities' development potential. Different communities in the City of Cape Town are not economically progressing because of them experiencing inadequate access to proper infrastructure services; insufficient skillsets, and bad governance.
3. Assist in the development of an evidence-based approach used to inform infrastructure development and investment.
4. Monitor on-going socio-economic shifts in communities.

In an attempt to realise the above-mentioned objectives, this study develops two composite poverty measures for both 2001 and 2011. This, coupled with GIS, are done by firstly, rank each of the identified communities with the capability space in the City of Cape Town based on capability deprivation indices developed using the MCDM models to spatially analyse the existing spatial configuration brought about during the Apartheid regime, and secondly, to assess the spatial vicissitudes in poverty (capability deprivation) between 2001 and 2011 in order to monitor the socio-economic and ecological shifts in communities and identify institutional red tape impeding potential community development; and lastly, to help better inform government's spatial planning and decision making processes relating to infrastructure development and investment. To achieve these objectives, composite measures are required to populate the CA framework.

#### 4.2.5.1 IDENTIFICATION OF DECISION CRITERIA FOR POVERTY INDEX

##### I. CONSTRUCTING THE DECISION MAKING MATRIX

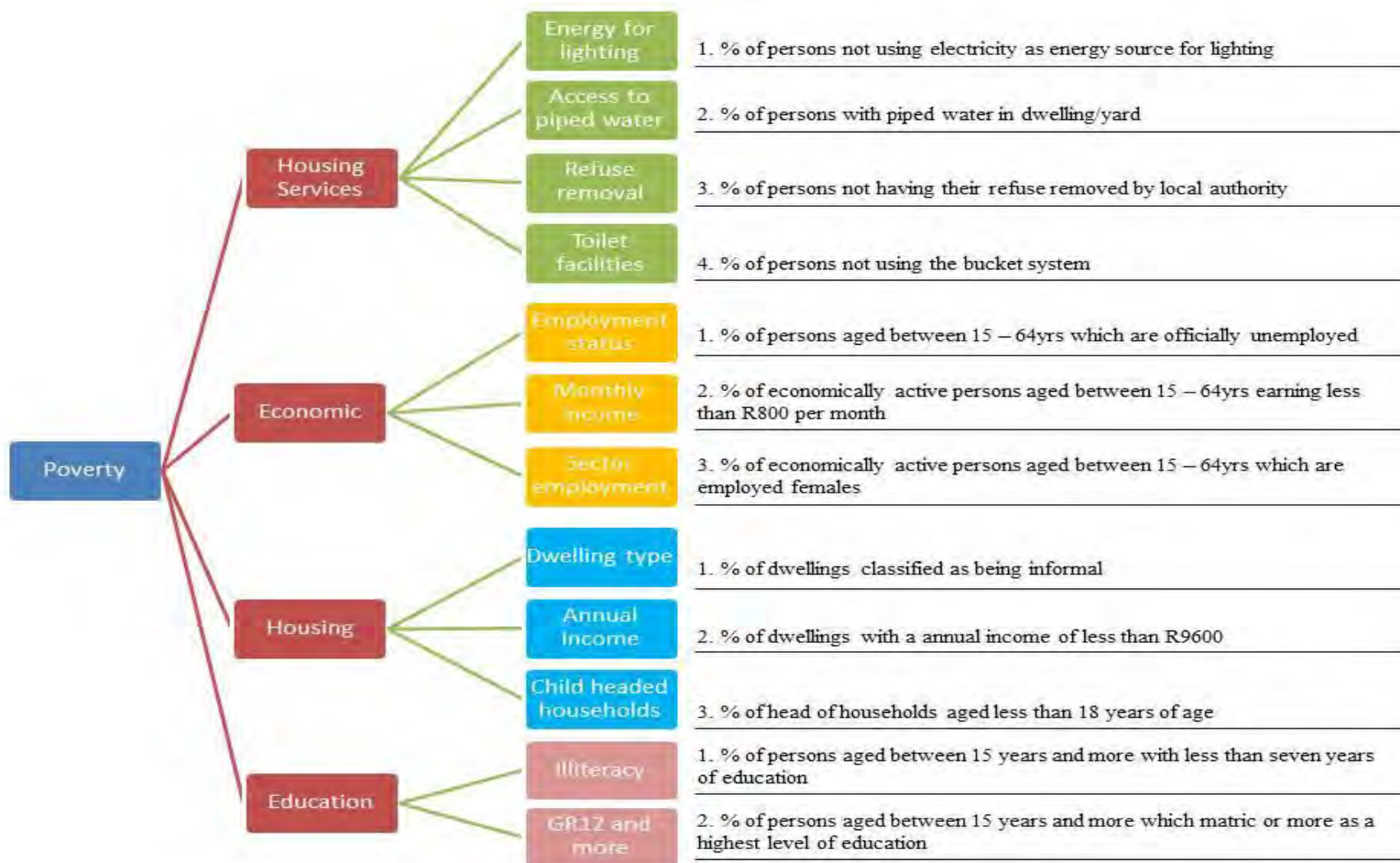
In the absence of any recent, credible, comparable and comprehensive socio-economic surveys conducted to ascertain the various capabilities needed by communities across various parts of the City of Cape Town, the capability domains and related criteria used to develop the composite measures are principally selected based on accords from associated policy documents, i.e. NDP and literature reviews related to international and domestic research on capability measurements. The NDP identifies the minimum capability which includes nutrition, housing, transport, water, sanitation, electricity, education and skills, safety and security, health care, employment, recreation and leisure, and clean environment. However, due to the spatial disjunction between administrative and official data sources, as noted in section 3.4.4.4, the only capability sets that had a comparative spatial logic and were able to be amalgamated into a single composite capability deprivation score for 2001 and 2011, were education and skills (i.e. Education); employment and income (i.e. both Labour Force); housing (i.e. Housing); and services (i.e. Basic Services). The selection of criteria used to populate each domain, according to Alkire (2007:7), is primarily done using five approaches, namely data availability, assumptions, public agreements, consultation, and survey data. The research done by both Klasen (2000) and Qizilbash and Clark (2005) concur to some extent, highlighting specifically data availability as imperative for criteria selection, which is then also the case for all criteria selected for the purposes of this study.

When spatially analysing capability deprivation for the City of Cape Town, the data source used in deriving capability scores must incorporate both individual and household level information at a micro level. Accordingly, the related criteria sourced from Stats SA are selected to ultimately populate each of the capability sets as listed below and also presented in the figure below. These criteria include the percentage of:

- Persons using electricity as a source for lighting;
- Persons with piped water in dwelling/yard;
- Persons not having their refuse removed by local authority;
- Persons not using the bucket system;
- Economically active persons aged between 15 and 64 years who are officially unemployed;
- Economically active persons aged between 15 and 64 years earning less than R800 per month;
- Economically active population who are employed females;
- Dwelling structures classed as informal;
- Households earning an annual income of less than R9 600;
- Households headed by children aged younger than 18 years;
- Persons aged 15 years and older who are functionally illiterate, and;
- Persons aged 15 years and older who has a highest education level of Grade 12 and higher.



Figure 24: Criteria tree for poverty (capability deprivation)



Source: Own calculations

## II. CONSTRUCTING THE WEIGHTED DECISION MAKING MATRIX

In the development of the decision making matrices used to derive the poverty measures for 2001 and 2011 using the selected evaluation criteria, an average weighting schema is derived using the mean of the two weighting schemas for 2001 and 2011. The average weighting schema is applied across the various communities in the City of Cape Town. This entails using the same average weighting schema for each of the related criteria in this study to ensure spatial comparability between 2001 and 2011. This indirectly suggests a common locus point used in this study in relation to measuring capability deprivation. This weighting schema methodology is very much applicable given that there is a particular policy interest in the entrenched spatial pattern changes across communities in the City of Cape Town, which is often worsened by poverty, inequality and social exclusion.

Tables 42 and 43 below both illustrate the Pearson correlation coefficient matrices for 2001 and 2011. These tables provide planners and decision makers with significant policy insights into the relationships between the initial composite poverty measures and their related criteria, and the relationships between the various evaluation criteria. For starters, Table 40 demonstrates that all coefficients are statistically significant at a 99% confidence level for 2001. Secondly, it highlights the very high positive and negative relationships between unemployment and monthly income (i.e. 0.945), and female employment (i.e. -0.908). The female employment coefficient presents meaningful economic policy awareness, which could inspire economic empowerment debates about gender equality in the labour market. The coefficient indicates that females still remain the most marginalised labour group in the City of Cape Town and that through the provision of equal employment opportunities for females, the South African government would be able to achieve its unemployment targets as set out in the NDP.

Table 43 shows similar results for 2011 as compared to the above table highlighting the results for 2001. When compared, it is evident that between 2001 and 2011 the nature of the relationships between electricity for lighting and piped water, and electricity for lighting and informal dwelling structures remain the same, but the degree of the relationships has substantially reduced. This is a positive indication of national government's progress made between 2001 and 2011 in terms of improving access, especially in the informal settlement areas, to the electricity grid and its intentions of meeting the NDP target of 95% household access to the electricity grid target by 2030.

With regards to the relationship between the initial poverty measure and its related criteria, both tables show which of the criteria are highly correlated with the initial poverty measures. The presence of highly correlated criteria does not always necessarily indicate the presence of multi-collinearity, but would suggest testing. Thus, according to Pearson's coefficients presented in Tables 42 and 43 there are indications of the presence of multi-collinearity and for that reason, multi-collinearity testing is required to negate model repeatability.

Table 42: Pearson correlation matrix of the criteria related to the initial poverty measure for 2001

CRITERIA	POV2001	TOILET	REFUSE	LIGHT	WATER	ILLITERATE	MATMORE	UNEMPLOY	INFORMAL	FEMPLOY	NORMAL	ANNUAL	CHILDHEAD
POV2001	1.0000												
TOILET	-0.6752*	1.0000											
REFUSE	0.4197*	-0.4930*	1.0000										
LIGHT	0.7055*	-0.798*	0.5786*	1.0000									
WATER	-0.7108*	<b>0.8673*</b>	-0.5811*	<b>-0.8895*</b>	1.0000								
ILLITERATE	<b>0.8704*</b>	-0.5169*	0.4546*	0.6319*	-0.6149*	1.0000							
MATRICMORE	<b>-0.8912*</b>	0.3850*	-0.2554*	-0.4155*	0.4140*	<b>-0.8113*</b>	1.0000						
UNEMPLOY	<b>0.9202*</b>	-0.5270*	0.2673*	0.5613*	-0.5344*	0.7555*	-0.7935*	1.0000					
INCOME	<b>0.9525*</b>	-0.5757*	0.3746*	0.6186*	-0.5988*	0.8556*	<b>-0.8301*</b>	<b>0.9453*</b>	1.0000				
FEMPLOY	<b>-0.8962*</b>	0.5546*	-0.3686*	-0.6075*	0.5882*	-0.7441*	0.7442*	<b>-0.9079*</b>	<b>-0.8992*</b>	1.0000			
INFORMAL	<b>0.8023*</b>	-0.7842*	0.4361*	<b>0.8182*</b>	<b>-0.8442*</b>	0.6730*	-0.5104*	0.6912*	0.7282*	-0.6910*	1.0000		
ANNUAL	<b>0.8498*</b>	-0.6389*	0.4174*	0.7067*	-0.6872*	0.7766*	-0.6188*	0.8517*	<b>0.8772*</b>	<b>-0.8259*</b>	0.7924*	1.0000	
CHILDHEAD	0.2295*	-0.1483*	0.1688*	0.1283*	-0.1304*	0.2181*	-0.2129*	0.1939*	0.2633*	0.2131*	0.1450*	0.1930*	1.0000

\* Statistically significant at  $p < 0.01$

Highly ( $p > 0.80$ ) correlated criteria with initial poverty measure for 2001

1. Monthly income less than R800
2. Unemployment
3. Female employment
4. Grade 12 and higher as the highest educational level
5. Illiteracy
6. Annual income less than R9 600
7. Informal dwellings

Table 43: Pearson correlation matrix of the criteria related to the initial poverty measure for 2011

CRITERIA	POV2011	TOILETS	REFUSE	LIGHT	WATER	ILLIT	MATMORE	UNEMPLOY	INCOME	FEMPLOY	INFORMAL	ANNUAL	CHILDHEAD
POV2011	1.0000												
TOILETS	-0.6700*	1.0000											
REFUSE	0.5458*	-0.5892*	1.0000										
LIGHT	0.5375*	-0.4570*	0.5337*	1.0000									
WATER	-0.7426*	<b>0.8343*</b>	-0.7118*	-0.6756*	1.0000								
ILLITERATE	<b>0.8088*</b>	-0.4248*	0.3758*	0.4398*	-0.4922*	1.0000							
MATRICMORE	<b>-0.8584*</b>	0.3284*	-0.2517*	-0.2409*	0.3382*	-0.7519*	1.0000						
UNEMPLOY	<b>0.8854*</b>	-0.5269*	0.3744*	0.3955*	-0.5560*	<b>0.8115*</b>	-0.7560*	1.0000					
INCOME	<b>0.8879*</b>	-0.5310*	0.3967*	0.4179*	-0.5781*	<b>0.8380*</b>	-0.7411*	<b>0.9640*</b>	1.0000				
FEMPLOY	<b>-0.8791*</b>	0.5550*	-0.4165*	-0.4414*	0.6100*	-0.7871*	0.7169*	<b>-0.9337*</b>	<b>-0.9170*</b>	1.0000			
INFORMAL	<b>0.8254*</b>	-0.7573*	0.6712*	0.6143*	<b>-0.9127*</b>	0.6020*	-0.4524*	0.6929*	0.7228*	-0.7425*	1.0000		
ANNUAL	0.7641*	-0.5691*	0.4582*	0.4939*	-0.6647*	0.6535*	-0.5086*	0.7527*	0.7972*	-0.7635*	0.7692*	1.0000	
CHILDHEAD	0.3001*	-0.1807*	0.2022*	0.1339*	-0.2239*	0.2659*	-0.2392*	0.2950*	0.3121*	-0.2882*	0.2690*	0.3138*	1.0000

\* Statistically significant at  $p < 0.01$

Highly ( $p > 0.80$ ) correlated criteria with initial poverty measure for 2011

1. Monthly income less than R800
2. Unemployment
3. Female employment
4. Grade 12 and higher as the highest educational level
5. Illiteracy
6. Informal dwellings

According to Parker and Smith (1984:804), multi-collinearity is at its worst when multiple combined criteria have abnormally high correlation coefficients with one another and the criteria share high covariance with the dependent criteria (capability deprivation index). Using this theory, the presence of multi-collinearity between the initial poverty measures and its related criteria are substantiated for the purposes of this study. Multi-collinearity testing is conducted through the use of regression analysis and subsequently deriving the VIF for 2001 by using the twelve evaluation criteria as the independent variables and the initial composite poverty measure as the dependent variable. This analysis will determine which of the twelve criteria are to be removed from the Principal Component Analysis process and ultimately from the final composite poverty measures for 2001 and 2011.

Following the above, the results of the multi-collinearity testing are shown in the table below. It shows that the criteria, i.e. percentage of persons earning a monthly income of less than R800 and the percentage of unemployed persons have high VIF scores ( $VIF > 10$ ) of 21.03 and 15.27, respectively. Thus, through the process of elimination, both the criteria were incrementally removed from the regression models and VIF analysis. The final outputs shown in column  $VIF_{INCOME+UNEMPLOY}$  indicate that once both criteria (i.e. income and unemployment) are removed from the regression analysis, all other VIF scores for the ten remaining criteria are less 10, and thus, the presence of multi-collinearity is negated. These results are carried through the analysis and applied when developing the final composite poverty measure for 2001 and 2011.

Table 44: VIF scores for each criterion for 2001

CRITERIA	VIF	$VIF_{INCOME}$	$VIF_{INCOME+UNEMPLOY}$
INCOME	21.03		
UNEMPLOY	15.27	10.57	
WATER	8.86	8.78	8.54
ANNUAL	7.38	6.91	5.32
FEMPLOY	6.77	6.62	4.51
ILLITERATE	6.51	5.65	5.54
LIGHT	5.68	5.67	5.67
INFORMAL	5.59	5.56	5.45
MATRICMORE	5.46	5.20	4.16
TOILET	4.50	4.43	4.41
REFUSE	1.80	1.78	1.71
CHILDHEAD	1.13	1.08	1.08
MEAN VIF	7.50	5.66	4.64

The results of the multi-collinearity testing have shown that two of the twelve capability deprivation related criteria for both 2001 and 2011 can be removed from the PCA process and the final index derivation process. To test the effects of removing these two criteria from the MCDM process,  $R^2$

coefficients are calculated for 2001 and 2011. The  $R^2$  analysis for 2001 and 2011 shows coefficient values of 0.998 and 0.998, respectively when all twelve criteria are present in the regression models and coefficient scores of 0.993 and 0.995 for 2001 and 2011, respectively after the two criteria are removed from the regression models. This shows that the removal of income and unemployment from both PCA processes and MCDM model development has little to no effect on the predictive properties of the final MCDM models for poverty. To address the issue of multi-collinearity in the model datasets the two criteria (i.e. unemployment and monthly income) are removed from the final composite poverty measure. Although these criteria, shown to have high correlation coefficient values and high VIF scores, are removed from the two final composite poverty models, certain remaining criteria are still highly correlated with the initial poverty measure. Therefore, PCA is used to transform the remaining criteria into composite sets of uncorrelated criteria that retain the underlying data pattern. The table below shows the results of the PCA for 2001 and 2011. It is observed that Principal Component 1 accounts for 66% and 61% of the total variation in the 2001 and 2011 models, respectively. Keeping the former in mind, the eigenvectors related to the first PC are used to derive the average weighting schema used to develop the weighted decision matrices for 2001 and 2011.

Table 45: Results of the PCA for 2001 and 2011 applied to the poverty domain

COMP	YEAR	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
COMP1	2001	0.2003	0.1475	0.6610	0.6610
	2011	0.1779	0.1207	0.6142	0.6142
COMP2	2001	0.0528	0.0388	0.1744	0.8354
	2011	0.0572	0.0410	0.1974	0.8116
COMP3	2001	0.0140	0.0038	0.0463	0.8817
	2011	0.0161	0.0057	0.0557	0.8673
COMP4	2001	0.0102	0.0037	0.0338	0.9155
	2011	0.0104	0.0016	0.0360	0.9033
COMP5	2001	0.0065	0.0007	0.0216	0.9371
	2011	0.0088	0.0032	0.0306	0.9339
COMP6	2001	0.0059	0.0008	0.0194	0.9564
	2011	0.0057	0.0012	0.0196	0.9535
COMP7	2001	0.0051	0.0018	0.0168	0.9733
	2011	0.0044	0.0008	0.0153	0.9688
COMP8	2001	0.0033	0.0004	0.0109	0.9842
	2011	0.0036	0.0002	0.0126	0.9814
COMP9	2001	0.0029	0.0010	0.0096	0.9938
	2011	0.0034	0.0015	0.0119	0.9933
COMP10	2001	0.0019	0.0000	0.0062	1.0000
	2011	0.0019	0.0000	0.0067	1.0000

Table 46: Eigenvector values for 2001 and 2011 for each of the criteria

<b>CRITERIA</b>	<b>YEAR</b>	<b>COMP1</b>	<b>COMP2</b>	<b>COMP3</b>	<b>COMP4</b>	<b>COMP5</b>	<b>COMP6</b>	<b>COMP7</b>	<b>COMP8</b>	<b>COMP9</b>	<b>COMP10</b>
<b>TOILETS</b>	2001	-0.2967	-0.2726	-0.0343	0.4232	0.4584	0.3442	0.4017	0.0721	-0.3751	0.1468
	2011	0.2460	-0.2455	0.1049	0.4704	0.2715	0.6233	0.1961	-0.0614	-0.0504	-0.3741
<b>REFUSE</b>	2001	0.1621	0.1515	0.7835	0.3807	0.0745	0.1955	-0.3670	-0.0864	0.0105	0.0769
	2011	-0.1336	0.1493	-0.0076	-0.1325	0.2244	0.0590	0.4718	0.0857	0.8109	0.0307
<b>LIGHTS</b>	2001	0.3230	0.2661	0.1279	-0.0107	0.2484	-0.1232	0.6321	-0.4691	0.3287	0.0613
	2011	-0.1675	0.1762	-0.0714	0.2887	0.7720	-0.1342	-0.4046	-0.0966	0.0186	0.2551
<b>WATER</b>	2001	-0.3933	-0.3516	-0.1526	0.2918	-0.0538	0.1016	-0.1999	-0.4349	0.6009	-0.0987
	2011	0.3928	-0.4266	0.0941	0.2520	-0.1466	-0.0110	0.0027	0.0188	0.1956	0.7288
<b>ILLITERATE</b>	2001	0.2291	-0.1604	0.0829	0.1768	0.1226	0.0217	0.1757	0.5089	0.3113	-0.6939
	2011	-0.2749	-0.1762	0.0194	0.4105	0.0808	-0.5138	0.5879	0.1571	-0.2885	-0.0197
<b>MATRICMORE</b>	2001	-0.4637	0.7809	-0.1410	0.3004	-0.0527	-0.0482	0.0273	0.0636	-0.0082	-0.2348
	2011	0.5102	0.7341	0.1402	0.3372	-0.1482	-0.1727	0.1068	-0.0646	0.0040	-0.0121
<b>FEMPLOY</b>	2001	-0.2193	0.1270	0.1115	-0.2653	0.1311	0.2432	0.0759	0.4986	0.5260	0.4956
	2011	0.3329	0.0952	-0.0456	-0.4042	0.3602	0.1314	0.2101	0.6200	-0.3326	0.1689
<b>INFORMAL</b>	2001	0.4509	0.2338	-0.4657	0.0357	0.1681	0.6442	-0.2646	-0.0907	0.0464	-0.0146
	2011	-0.4773	0.3492	-0.0040	0.0906	-0.1752	0.5222	0.2137	-0.0832	-0.2511	0.4723
<b>ANNUAL</b>	2001	0.3259	-0.0214	-0.2829	0.6196	-0.1414	-0.4012	-0.0341	0.2413	0.1155	0.4192
	2011	-0.2320	0.0551	0.1174	0.3607	-0.2403	0.0667	-0.3577	0.7455	0.2065	-0.1033
<b>CHILDHEAD</b>	2001	0.0389	-0.0382	0.0960	0.1171	-0.7978	0.4242	0.3948	0.0106	-0.0286	0.0302
	2011	-0.1047	-0.0212	0.9691	-0.1745	0.1086	-0.0403	-0.0207	-0.0570	-0.0423	0.0133

In the PCA analysis of the 10 evaluation criteria selected for the development of the composite poverty measure used to assess the capability space in the City of Cape Town, the normalised eigenvector ( $\sum_{i=1}^n |\varphi| = 1$ ) values for component 1 was selected because it explained more than 60% of the variations in both models. These eigenvectors were selected as the preferred weight schemas applied to derive the single average weighting schema to be used for both composite poverty models to ensure spatial output comparability. The results of both models are presented in the following section.

*POVERTY*<sub>2001</sub>

= {*TOILET*(0.1022), *REFUSE*(0.0558), *LIGHT*(0.11130), *WATER*(0.1355), *ILLITERATE*(0.0789), *MATRICMORE*(0.1597), *FEMPLOY*(0.0755), *INFORMAL*(0.1553), *ANNUAL*(0.1123), *CHIELDHEAD*(0.0134)}

*POVERTY*<sub>2011</sub>

= {*TOILET*(0.0857), *REFUSE*(0.0465), *LIGHT*(0.0583), *WATER*(0.1368), *ILLITERATE*(0.0957), *MATRICMORE*(0.1777),

*FEMPLOY*(0.1159), *INFORMAL*(0.1662), *ANNUAL*(0.0808), *CHIELDHEAD*(0.0365)}

***POVERTY***<sub>AVERAGE</sub>

= {***TOILET***(0.0939), ***REFUSE***(0.0512), ***LIGHT***(0.0848), ***WATER***(0.1361), ***ILLITERATE***(0.0873), ***MATRICMORE***(0.1687),

***FEMPLOY***(0.0957), ***INFORMAL***(0.1608), ***ANNUAL***(0.0965), ***CHIELDHEAD***(0.0249)}

#### 4.2.5.2 IDENTIFICATION OF IDEAL SOLUTION

The following section of this study aims to evaluate the capability space in the City of Cape Town between 2001 and 2011 using multi-indicator construct models that are developed using the weighted decision matrices derived in the previous section. These matrices are used to derive and identify the positive and negative ideal capability solution that assists in exemplifying; categorising, and assessing the evolving distribution of poverty (capability deprivation) and its explicit spatial patterns within the various communities across the City of Cape Town. This analysis assumes that any community that is capability deprived, experiences high levels of poverty, and vice versa. To comprehensively evaluate these capability spaces within the context of the NDP, the spatial MCDM measures for 2001 and 2011 are developed with the intent to conform to the various normative principles that seek to address spatial justice, spatial sustainability, spatial resilience, spatial quality and spatial efficiency (NPC, 2012:277).

These composite spatial MCDM measures for 2001 and 2011 derived from the 10 selected evaluation criteria are jointly used to rank and categorise; thus, ensuring adherence to the normative principles as set out in the NDP, each of the communities identified for the study's focus area according to their levels of capabilities achieved to lead valued lives. Note though that due to Sen's (1993:32) inability to provide proper direction with respect to defining a robust framework that researchers can use to operationalise the capabilities approach, the ability to define definitive capability deprivation cut-offs becomes an instinctively less conspicuous process. Therefore, it becomes increasingly challenging for



researchers to actually define who is so-called capability deprived (or not) in the City of Cape Town and to actually make comparisons in terms of government’s progress made.

To define definitive cut-offs for capability deprivation, this study draws on the interpretations of the research done by Klasen (2000:43) and Qizilbash and Clark (2005:111) that both use ‘worst off 20%’ (i.e. capability scores of more than 80% are considered to be worst off) as the cut–off threshold for capability deprived communities. Moreover, this study also incorporates the research done by Higgs (2007:343), which uses seven partitions to define poverty thresholds, namely Affluent; I’m Ok; The basics; Difficult conditions; Living in poverty; Poverty stricken, and Severe hardship.

Based on the above-mentioned research, seven thresholds have been developed to categorise the communities within the scope of this study in terms of ‘who is capability deprived’ and ‘who is not’. Keeping in mind that the above-mentioned researchers failed to adequately define what being capability deprived actually means, this study, based on the research done by Sen (1992), attempts to provide some definition direction in this regard. That said, the cut–off thresholds for capability deprivation for the purposes of this study are conceptualised and defined as:

- Full capability: A community who has a full spectrum of capabilities needed to access any desired opportunities that exist across the City of Cape Town quite easily;
- High capability: A community who has a large spectrum of capabilities needed to access any desired opportunities that exist across the City of Cape Town easily;
- Moderate capability: A community who has a limited yet sufficient spectrum of capabilities needed to access certain opportunities that exist across the City of Cape Town. Accessing these opportunities becomes moderately challenging;
- Low capability: A community who has a very small spectrum of capabilities and finds accessing certain opportunities across the City of Cape Town to be very challenging;
- Deprived: An impoverished community who lacks the basic capabilities and experiences community segregation and thus is only able to access limited opportunities;
- High deprivation: An impoverished community who is deprived of any basic capabilities and experiences high levels of segregation, thus finding it extremely difficult to access any opportunities, and;
- Severely deprived: An impoverished community who is entrenched in deep rooted deprivation and is severely deprived of any basic capability, and for these reasons, is unable to access any opportunities that exist across the City of Cape Town.

Table 47: Cut–offs for capability deprivation

	<b>Full capability</b>	<b>High capability</b>	<b>Moderate capability</b>	<b>Low capability</b>	<b>Deprived</b>	<b>High deprivation</b>	<b>Severe deprivation</b>
Cut – off	0% - 10%	10.1% – 20%	20.1% - 30%	30.1% - 50%	50.1% - 60%	60.1% - 80%	80%+

## I. COMPOSITE POVERTY INDEX RESULTS

Once the weighted decision matrices are obtained, the positive and negative ideal solutions (i.e. the  $S_i^+$  and  $S_i^-$  for 2001 and 2011 are derived. The positive and negative ideal solutions were used to derive the 2001 capability deprivation measure for each of the 580 communities in the City of Cape Town. The results of the analysis are shown in the table below. According to the 2001 ranking index, Welgelegen was ranked as being the most severely deprived community in the City of Cape Town, followed by Lwandle, Lekkerwater, Wallacedene and Red Hill.

Table 48: The distance values and the final rankings for capability deprivation for 2001

ALTERNATIVE	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.06	0.30	0.83	0.17	390	Acacia Park
....						
$A_{298}$	0.30	0.06	0.18	0.82	3	Lekkerwater
$A_{306}$	0.29	0.06	0.16	0.84	2	Lwandle
$A_{410}$	0.29	0.08	0.22	0.88	5	Red Hill
$A_{543}$	0.30	0.07	0.18	0.82	4	Wallacedene
$A_{548}$	0.30	0.06	0.16	0.84	1	Welgelegen
.....						
$A_{580}$	0.08	0.28	0.78	0.22	313	Zonnebloem

The table below presents the  $S_i^+$  and  $S_i^-$  values used in deriving the poverty measure for 2011. It also categorises and ranks the identified communities within the City of Cape Town using the standardised decision matrix. According to the 2011 poverty rank model, Frankdale is identified as being the most severely deprived community in the City of Cape Town, followed by Modderdam, Boys Town, Freedom Park Airport Informal and Doornbach.

Table 49: The distance values and the final rankings for capability deprivation for 2011

ALTERNATIVE	$S_i^+$	$S_i^-$	$C_i$	$1 - C_i$	RANK	PLACE
$A_1$	0.08	0.29	0.79	0.21	509	Acacia Park
....						
$A_{94}$	0.30	0.07	0.19	0.81	3	Boys Town
$A_{168}$	0.30	0.09	0.23	0.77	5	Doornbach
$A_{220}$	0.30	0.06	0.17	0.83	1	Frankdale
$A_{221}$	0.30	0.07	0.20	0.80	4	Freedom Park
$A_{398}$	0.29	0.07	0.19	0.81	2	Modderdam
.....						
$A_{705}$	0.13	0.27	0.68	0.32	313	Zwartdam

Whereas the static representation of ‘who is’ capability deprived and ‘who is not’ in the City of Cape Town is an interesting undertaking, especially in terms of understanding the current state of deprivation, the more dynamic feature relates to how deprivation has changed over time. This evolution of deprivation is critical to policy planners and decision makers in order for them to better understand the social and economic factors that actually play a critical role in citizens’ or communities’ capabilities to successfully negate deprivation or repress deprivation levels even further. When comparing the capability scores for 2001 and 2011, the results begin to show the changing distribution of poverty (capability deprivation) and its related criteria across the City of Cape Town. These distribution changes between 2001 and 2011 underline government’s progress made in terms of redressing past spatial injustices through the implementation of various related policies, as mentioned throughout this study.

The table below presents the summary statistics of the composite poverty models for the City of Cape Town for 2001 and 2011. Concerning basic capabilities, it shows a slight increase in the mean deprivation between 2001 and 2011 (i.e. from 27.6% to 30.6%) and a minor decrease in the standard deviation (i.e. 14.88% to 14.33%). These results support highly documented theory (e.g. Strait (2001) and Joassart-Marcelli *et al.* (2005)) that concentrated poverty within urban regions is on the increase.

Table 50: Summary statistics for labour force capability deprivation scores for 2001 and 2011

<b>CAPABILITIES</b>	<b>OBS</b>	<b>MEAN</b>	<b>STD. DEV</b>	<b>MIN</b>	<b>MAX</b>
Capability deprivation 2001	580	0.2762	0.1488	0.074	0.843
Capability deprivation 2011	705	0.3062	0.1433	0.054	0.829

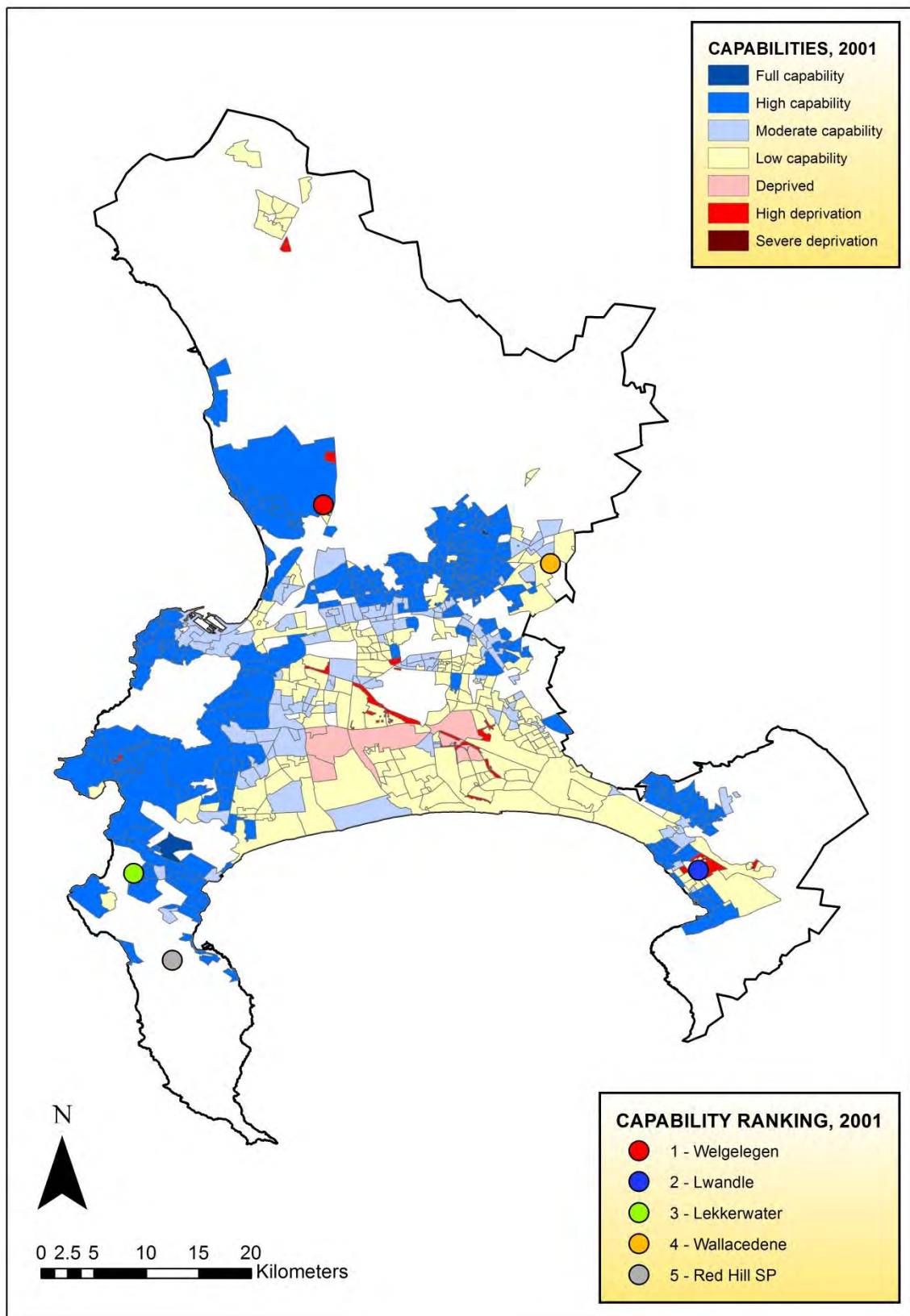
In order for government to eradicate poverty by 2030 by redressing the inherited spatial divisions; enhancing the City of Cape Town’s development potential; better informing infrastructure development and investment; and monitoring social and economic shifts, it is crucial that decision makers and planners begin to spatially understand the geographical distribution and changes of capability deprivation (poverty) in the City of Cape Town, so as to better inform the targeting of appropriate government interventions. By spatially enabling the MCDM model outputs, spatial analysis is able to be performed on the relevant capability spaces in the City of Cape Town. The maps below illustrate the changing topology of poverty (capability deprivation) between 2001 and 2011 in the City of Cape Town. These maps show that over the course of the decade in question, few communities have been able to transcend their capability levels by directly benefiting from multiple government interventions. They also demonstrate that a large proportion of communities have an identical capability level to that of previous years. Likewise, these maps stress that clusters of communities who have been capability deprived since 2001, and whose basic capabilities have been depleted between 2001 and 2011, have regressed into severe levels of poverty. The latter is especially troublesome for government since it points to the fact that the current host of government policies

specifically related to education and housing has failed to redress past spatial inequalities. Similarly, it points out that the generic social and economic policies implemented by government between 2001 and 2011 resulted in communities with high levels of capabilities benefiting disproportionately.

Furthermore, these maps below highlight that the implementation of inadequate redress programmes and interventions between 2001 and 2011 resulted in the further spatial proliferation of polarised societies, in which communities who experience high levels of capability deprivation are increasingly being clustered and segregated from the necessary opportunities that they desperately need to achieve valued functionings. Massey and Fischer (2000:671) argue that under such high levels segregation, the added poverty created between 2001 and 2011 is usually absorbed by smaller and more densely populated communities that are spatially clustered together, thereby further eroding these communities' capability levels. This is evident in Map 48, which shows that between 2001 and 2011 poverty levels increased significantly in smaller areas of communities such as Khayelitsha, Gugulethu, Crossroads, Nyanga, Philippi and Mitchells Plain who are all typically characterised by densely populated communities. Another important factor specifically relevant to the City of Cape Town, and which further influences the polarisation of societies, is in-migration. According to Census 2011, more than 18% of the total City of Cape Town population was not actually born in the Western Cape Province. When further investigating the origin of these migrants, Census 2011 reveals that approximately 53% were born in the Eastern Cape Province. Also, most of these migrants wishing to enter into the City of Cape Town labour market do so at the bottom of the so-called 'pecking order' because of their capabilities being skewed significantly to the right (i.e. they are inadequately skilled). Being cognisant of the research of Massey and Fischer (2000:672), it is rational to argue that in-migration is an interrelated variable, which fuels capability segregation and creates converged communities with high levels of poverty.

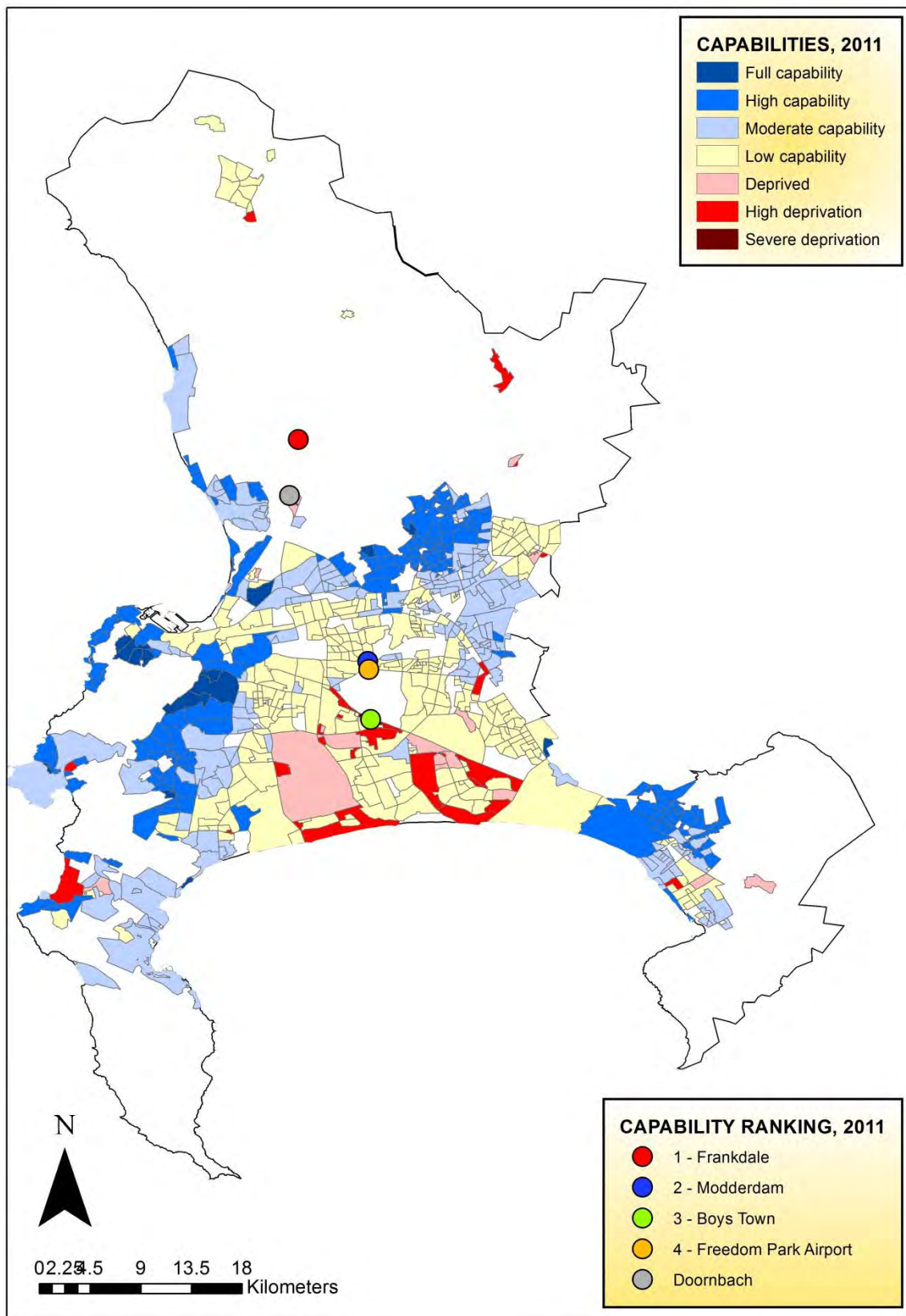
According to Massey (1990:342), high levels of poverty is not an impartial phenomenon and that with these levels of poverty come an array of other social and economic problems such as elevated crime rates, increased dropout rates, political exclusion, urban sprawling, and so forth. Therefore, the segregation of the poor or capability deprived place a high fiscal burden on government and on society (i.e. tax payers) as a whole because of the provision of multiple mitigation services that inadequately target the severely capability deprived communities (Brinegar & Leonard, 2008:583). To reduce this fiscal burden, government should consider utilising statistically robust methods to better comprehend the spatial distribution of capability deprivation, and in doing so, equip itself to better address the challenges associated with spatial development planning.

Map 47: Spatial pattern of Capability deprivation in the City of Cape Town for, 2001



Source: Own calculations

Map 48: Spatial pattern of Capability deprivation in the City of Cape Town for 2011



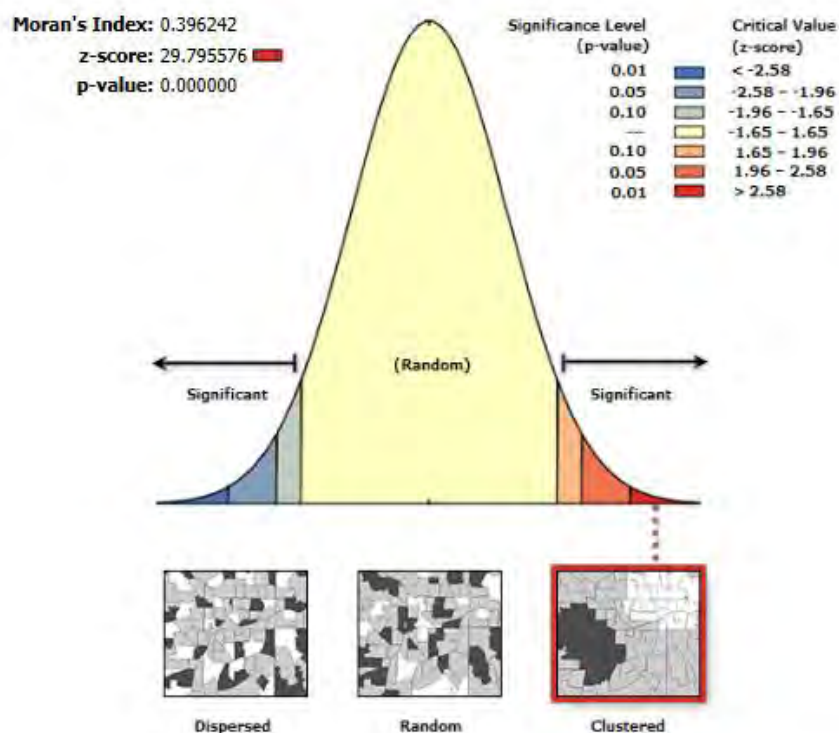
Source: Own calculations

## II. GLOBAL MORAN'S INDEX (I)

The conventional hypothesis of urban poverty suggests that communities with high capability deprivation levels are often confined to certain smaller regions within urban cities. This implies that multiple communities in urban cities with severe levels of capability deprivation are often segregated from many social and economic opportunities that exist across the City of Cape Town. Therefore, the objective of this section is to firstly, test the hypothesis, using the spatial autocorrelation functionalities in ArcGIS, that the spatial configurations of communities suffering from high levels of capability deprivation in the City of Cape Town are confined to certain regions of the city, and secondly, to assess changes (if any) between 2001 and 2011.

The results of the 2001 Global analysis are presented in Figure 25 below. The results show a highly positive Z score of 29.8, which is statistically significant at 0.01 with a Global Moran's I index value of 0.396. These results generated from the spatial autocorrelation method indicate that the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance. This result statistically validates the research hypothesis that in 2001, communities suffering from high levels of capability deprivation were segregated from communities with higher levels of capabilities.

Figure 25: Global Moran's I classification for the poverty in the City of Cape Town in 2001

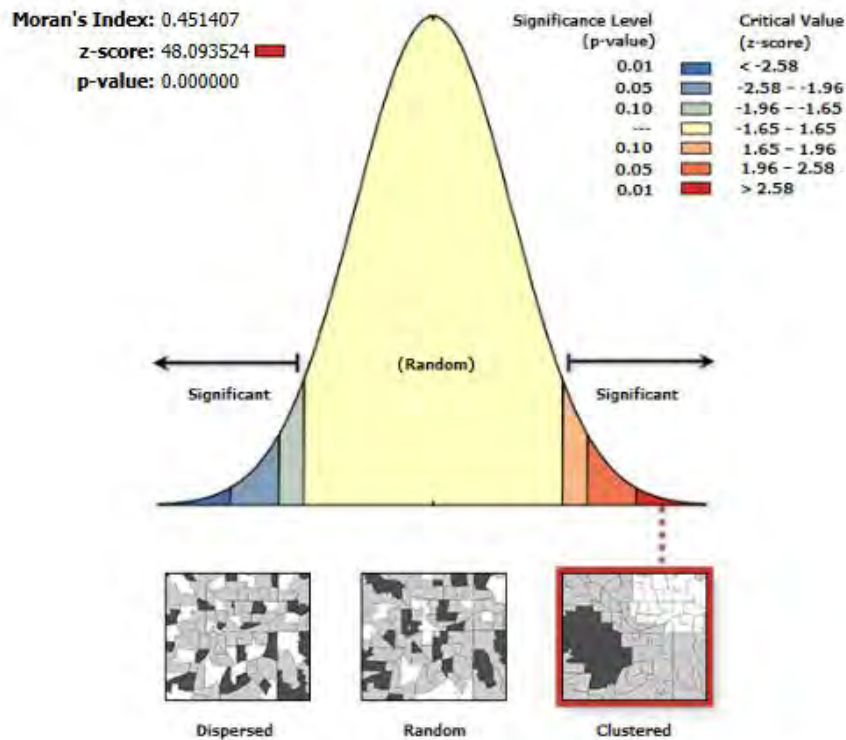


Source: Own calculations

The results for 2011 as shown in the figure below display similar trends when compared with the results of 2001. The outcome of the spatial autocorrelation analysis shows a high positive Z score of

48.1 and a Moran's Index score of 0.45. Similarly to the results for 2001, the null hypothesis of 'no spatial clustering' can be rejected and there is less than one percent likelihood that this clustered pattern could be the result of random chance.

Figure 26: Global Moran's I classification for the poverty in the City of Cape Town in 2011



Source: Own calculations

When comparing the Global Moran's I coefficients values for 2001 and 2011, the principal finding emerging from the Global Moran's I analysis is that capability deprivation has become more persistent and geographically isolated in the City of Cape Town. These simple coefficient findings point to the failure of local governments to successfully implement their Spatial Development Frameworks and Integrated Development Plans. This has systematically resulted in the further entrenchment of spatial patterns that exacerbates capability deprivation and social exclusion. Thus, these results support the recommendation of Chapter 8 of the NDP, which focuses on developing a national spatial framework to "create spaces that are livable, equitable, sustainable, resilient and efficient, and supports economic opportunities and social cohesion" (NPC, 2012: 259).

### III. LOCAL INDICATOR OF SPATIAL ASSOCIATION (LISA)

It is now widely accepted in both national and international planning communities that the effects of urban planning in South Africa under the Apartheid regime underpinned both class and racial inequalities. This was definitively achieved through the promulgation and implementation of the Group Areas Act of 1950, with the objective of racially segregating all social and economic resources and opportunities so as to protect the well-being of the white minority group. This gave rise to



racially homogeneous white minority communities that were typically located on the periphery of the urban cities and characterised as being fiscally independent; having separate essential services; housing, and job opportunities. Through these segregation measures, so-called non-white townships were segregated and deprived of the necessary capabilities needed to achieve valued functionings, and thus, were unable to remove themselves from entrenched poverty and inequality.

To address the issues of high concentrated poverty and inequality, especially in African and Coloured townships, the newly democratic elected government in 1994, through the enactment of three key pieces of socio-economic legislation, namely the RDP, GEAR and ASGISA, implemented economic, social and fiscal reform interventions with the objective of redressing the past spatial patterns of unequal resource distribution that suppressed the valued functionings of non-whites both African, Coloured and Indian communities. Despite the progress made by these interventions, the NPC (2012:434) notes that the Apartheid spatial legacies still configure the majority of the South African landscape. Likewise, research conducted by Turok (1994:251) and Schensul and Heller (2011:80), focus on the spatial dimensions of transformation in post-Apartheid cities, highlighting three critical points, namely:

- 1) Post-Apartheid cities are being subjected to increased levels of spatial division, and social and economic polarisation;
- 2) Spatial fragmentation in city regions are at present still primarily being determined by underlying market influences like housing prices and education institution costs, and;
- 3) Local governments' inability to further advance both economic and racial desegregation in urban cities.

The following section spatially analyses capability segregation patterns using the Local Moran's I statistic to determine both hotspots and cold spots of community capability statuses. The analysis includes the measurement and visualisation of capability segregation understood through the changing social and economic contexts of the City of Cape Town. The spatial segregation patterns are assessed for 2001 and 2011 using the MCDM model output and its related Census data. One of the major challenges with assessing local spatial autocorrelation is the determination of the appropriate spatial weight. To date, there has been very little research done on the derivation and selection of weighted matrices to help inform the spatial autocorrelation process. Due to this paucity, this study opted to utilise the Euclidian distance matrix as the preferred weighting factor in the local spatial autocorrelation analysis as this is the most commonly used approach. Another major challenge as indicated in section 3.4.4.4 is the gradual amendments of Census demarcation boundaries needed because of changing population structures. While this remains a significant challenge, this spatial analysis produced will provide an estimated topology of capability derivation change between 2001 and 2011 for the City of Cape Town.

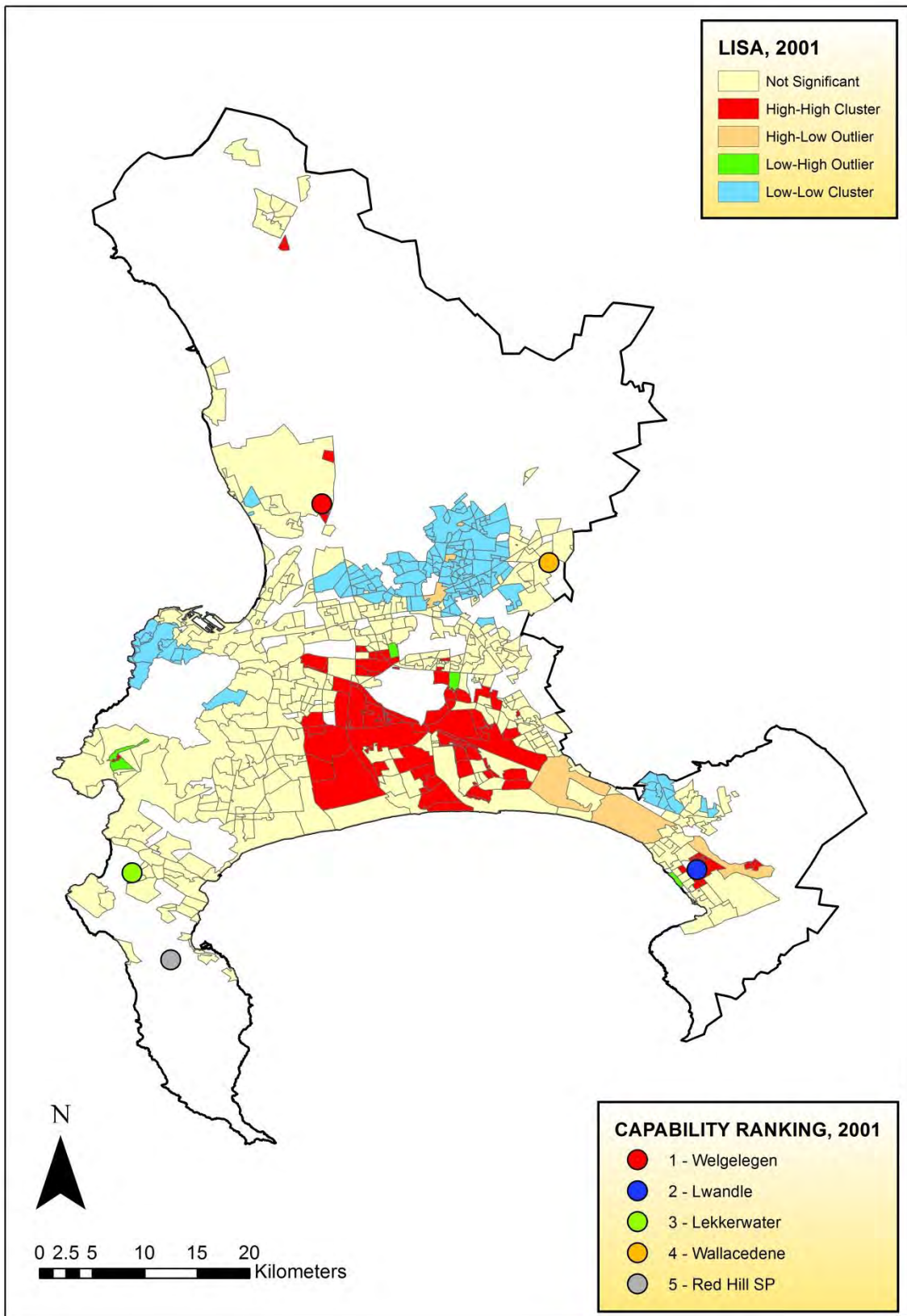
For the spatial analysis of community segregation based on capability levels, the Local Indicators for Spatial Association (LISA) coefficients were estimated for 2001 and 2011 using the centroid inverse distance method. The LISA statistic classifies the spatial analysis results into four broad cluster types, namely communities characterised by:

- High levels of capability deprivation surrounded by communities with similarly high levels of capability deprivation (High–High Cluster or H–H type);
- Low levels of capability deprivation surrounded by communities with low levels of capability deprivation (Low–Low Cluster or L–L type);
- High levels of capability deprivation surrounded by communities with low levels of capability deprivation (High–Low Cluster or H–L type), and;
- Low levels of capability deprivation surrounded by communities with high levels of capability deprivation (Low–High Cluster or L–H type). These results are used to identify regions in the City of Cape Town that experience high levels of segregation based on capability levels, i.e. poverty hotspot areas.

Map 49 of the City of Cape Town shows that in 2001, there were major spatial clusters of the H–H type in the surrounding Philippi; Khayelitsha; Crossroads; Nyanga; Delft; Mfuleni; Guguelthu; Modderdam, and Freedom Park areas and three spatially isolated clusters of the L–L type in the Durbanville, Sea Point and Camps Bay as well as Somerset West areas. The LISA analysis spatially demonstrates the fragmentation of urban communities along capability lines to be widespread throughout the City of Cape Town. Seemingly homogeneous regions across the City of Cape Town are found to have hotspots of segregation that overlap with the spatial locations that are classed as being severely deprived or full capability scores (as shown in the map below).

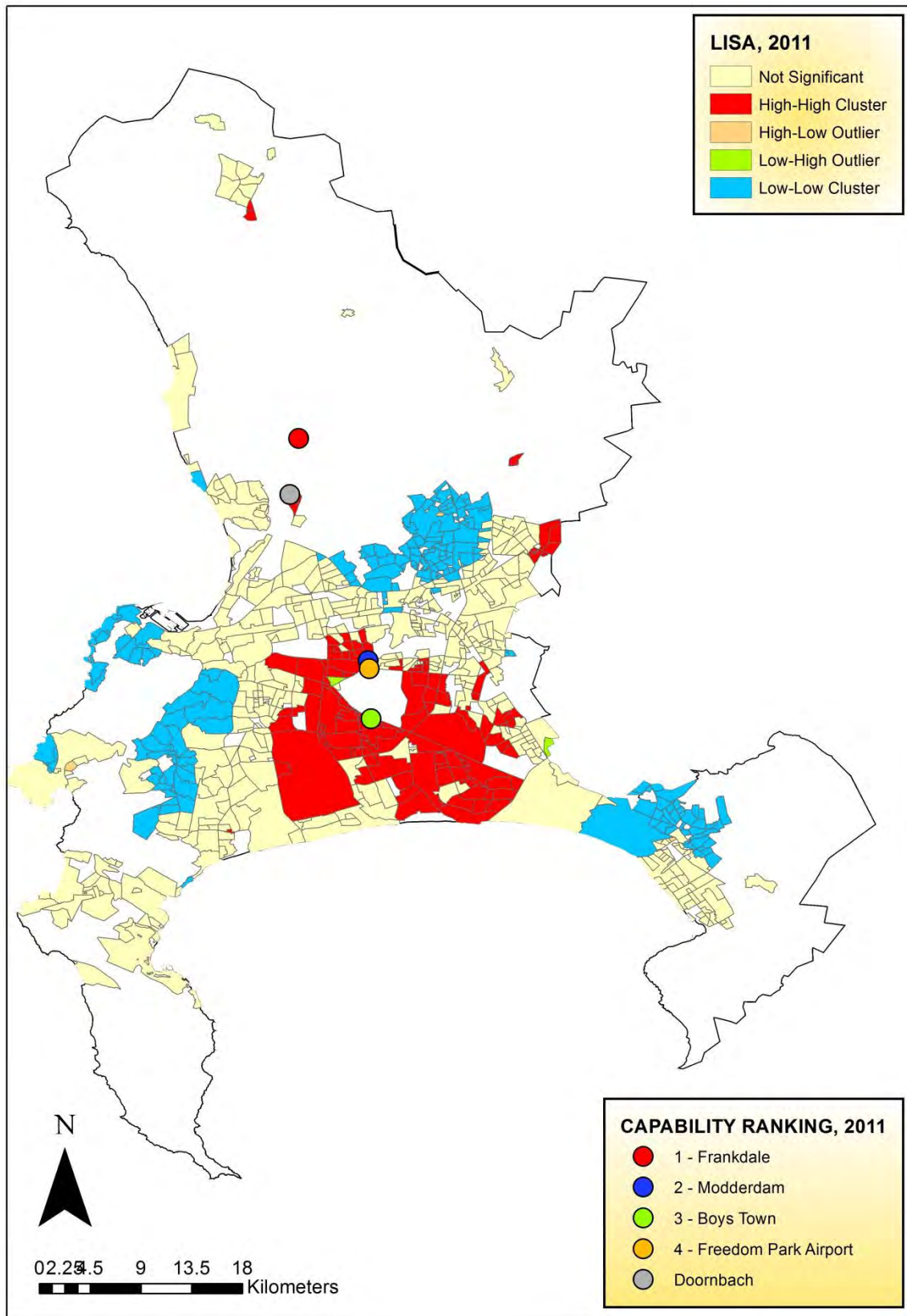
Map 50 illustrates the LISA coefficient results for 2011. It shows similar hotspot trends as compared to above map for 2001 since it indicates major spatial clusters of the H–H type in the surrounding Philippi, Khayelitsha, Crossroads, Nyanga, Delft, Mfuleni, Guguelthu, Modderdam and Freedom Park areas. However, the 2011 map also demonstrates that between 2001 and 2011, the spatial spread of H–H type clusters increased to include the surrounding Uitsig, Elsie's River and Bonteheuwel areas. As for the L–L type clusters, there has been a significant increase in this cluster type in the surrounding Rondebosch, Claremont, Tokai and Newlands areas.

Map 49: LISA for 2001



Source: Own calculations

Map 50: LISA for 2011



Source: Own calculations

## V. GETIS – ORD $G_i^*$

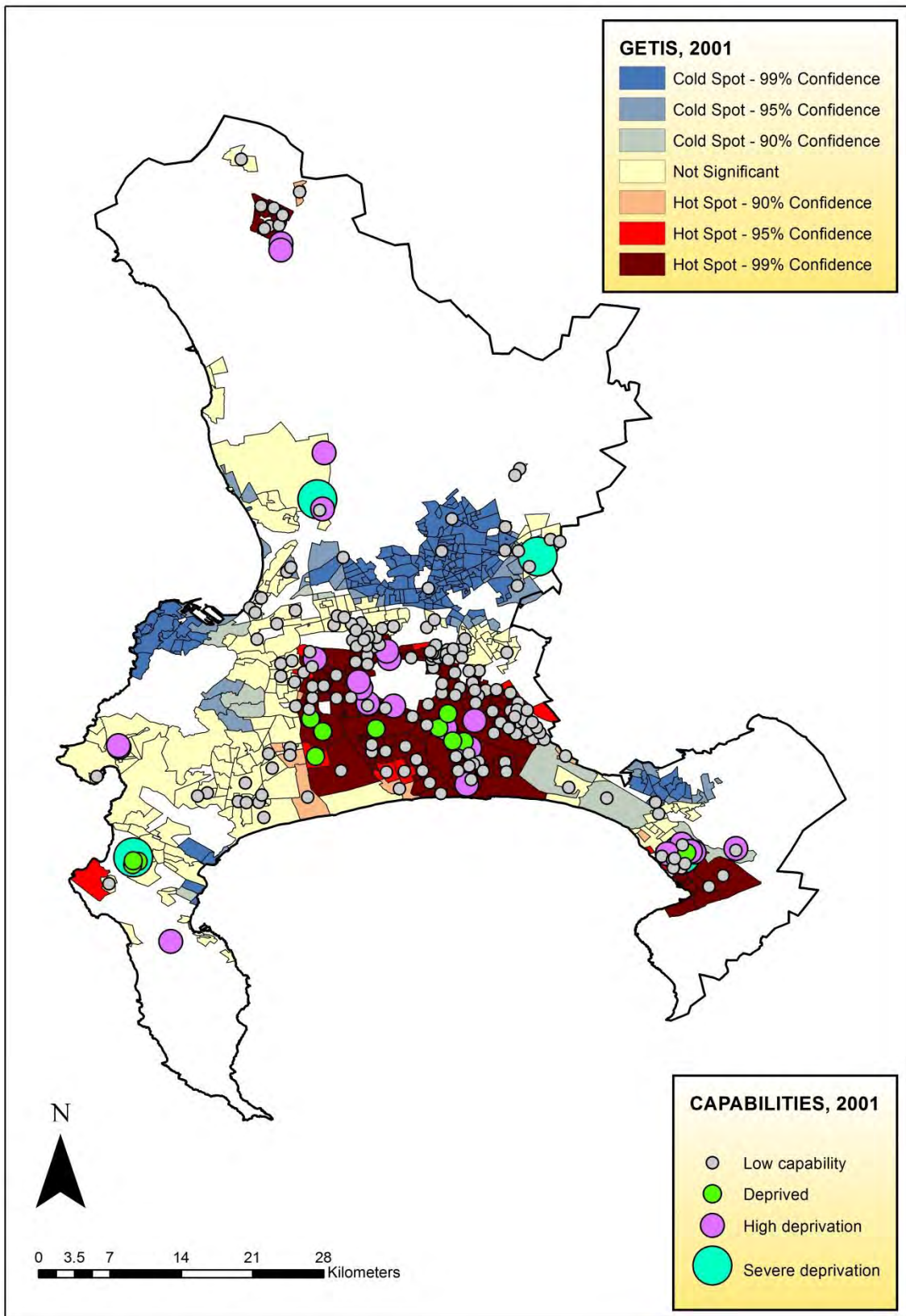
To validate the local spatial associations produced by the LISA analysis, which relates to the effects of community segregation on capability deprivation levels in the City of Cape Town, the distance – based static  $G_i^*(d)$  is used. This spatial statistic is functional as it allows planners and decision makers to identify spatially homogenous communities experiencing high levels of poverty due to the severe lack of basic capabilities. Because the  $G_i^*(d)$  is based on distance, it provides planners and decision makers with an acquiescent method of analysing local associations using positive variables (Prasannakumar *et. al*, 2011:320).

In the maps below, the results of the  $G_i^*(d)$  analyses are superimposed over the composite poverty indices for 2001 and 2011, respectively. The outputs of the  $G_i^*(d)$  analysis demonstrate similar spatial trends as compared with the LISA results. It similarly shows large statistical significant hotspots in the surrounding Philippi, Khayelitsha, Crossroads, Nyanga, Delft, Mfuleni, Gugulethu, Modderdam and Freedom Park areas and fragmented statistically significant cold spots in the surrounding Rondebosch, Claremont, Tokai and Newlands areas. These results therefore validate the local spatial association results produced through the LISA spatial analysis, and also validate the claim that spatial fragmentation and social polarisation in the City of Cape Town increased between 2001 and 2011.

When superimposing the  $G_i^*(d)$  analysis over the composite poverty indices, government can begin to better understand which communities are most vulnerable to poverty augmentation due to the low levels of basic capabilities. In the segregated communities experiencing high levels of poverty, any social or economic distress caused by the increase in the number of informal settlements; unemployment; poor education or lack of health care services, and so forth may not only result in an increase in poverty but also in the increased spatial concentration of poverty as seen in the maps below . The increase in the spatial concentration of poverty is as a result of the additional poverty created by any social or economic ‘shock’, being unevenly distributed to certain segregated parts of a region. Thus, when capabilities shift within segregated communities, it has the ability to disintegrate both social and economic environments of poorer communities, resulting in the proliferation of poverty and other socio–economic disorders such as high crime rates, social exclusion, and others.

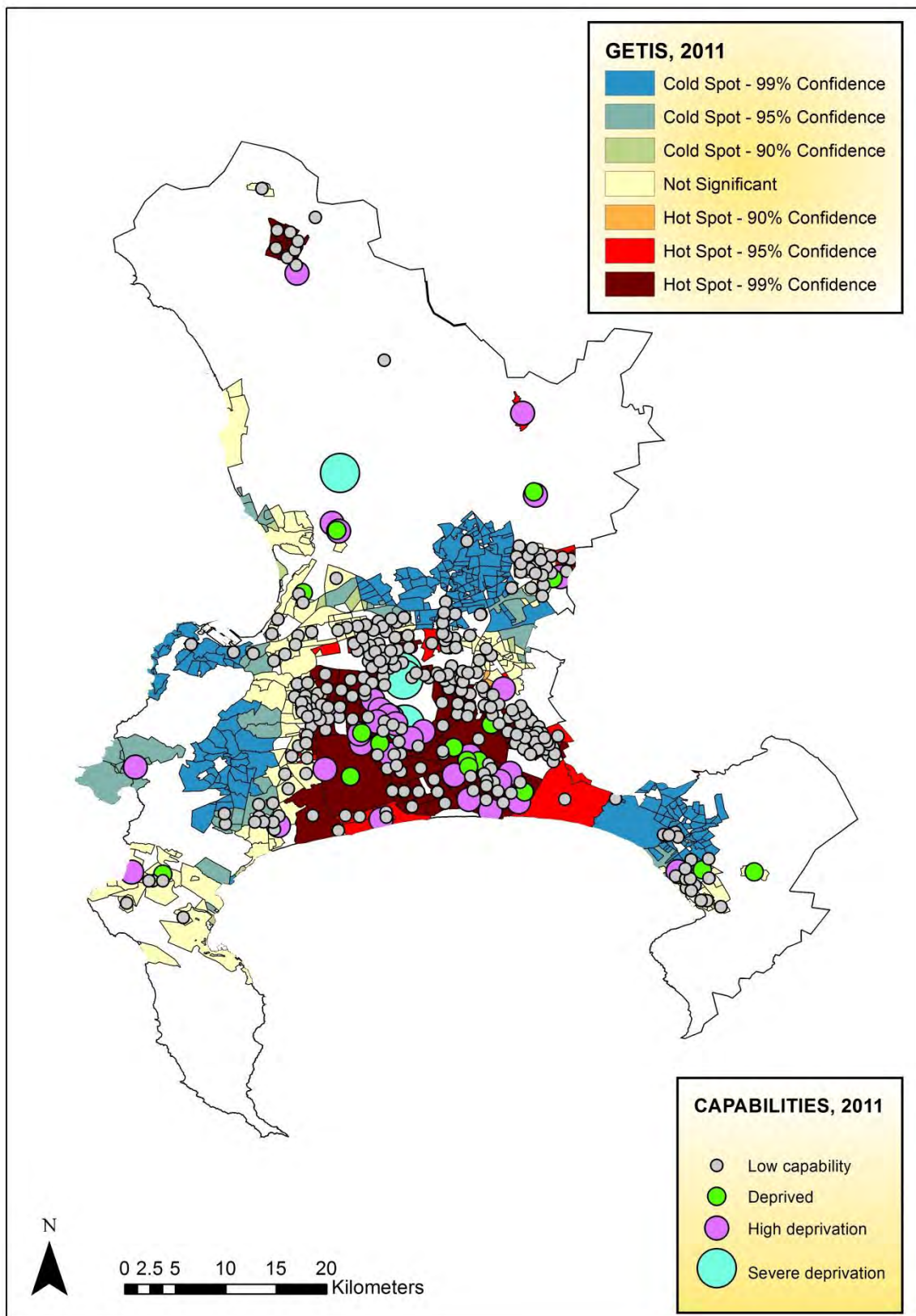
The Local Moran’s I analysis has demonstrated that segregation at the beginning of the 21<sup>st</sup> century is structured by multiple domains of both social and economic functionings. Both sets of spatial analysis show that on average, communities with different levels of basic capabilities live in different homogeneous regions of the City of Cape Town. Therefore, segregation is proliferated along a capabilities line thereby increasing concentrated poverty and social exclusion. These results also show that the spatial and democratic transformation since the advent of democratic South Africa has been slow and more perplexing than initially thought and planned for.

Map 51: Getis-Ord significance at the 1%, 5% and 10% significance level in 2001



Source: Own calculations

Map 52: Getis-Ord significance at the 1%, 5% and 10% significance level in 2011

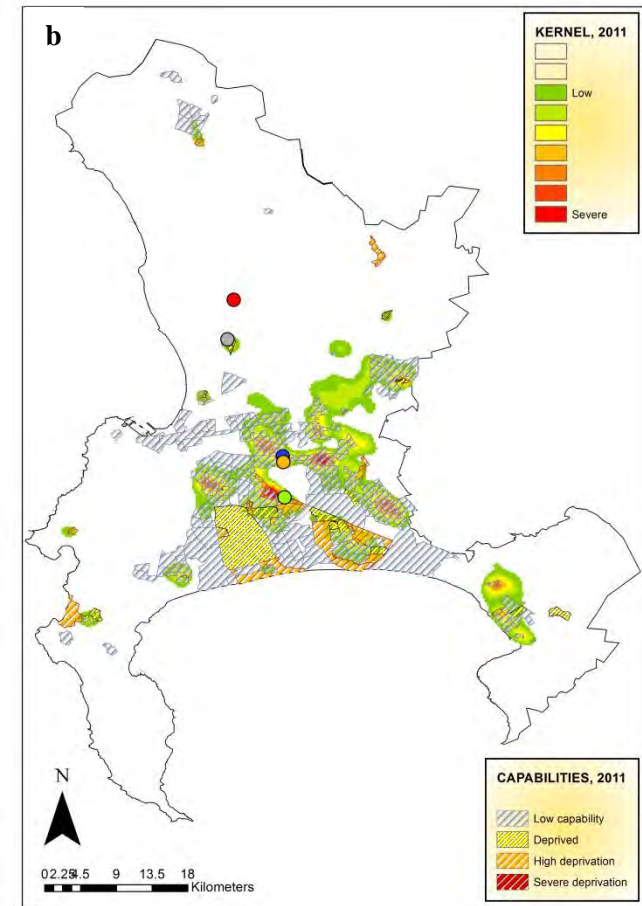
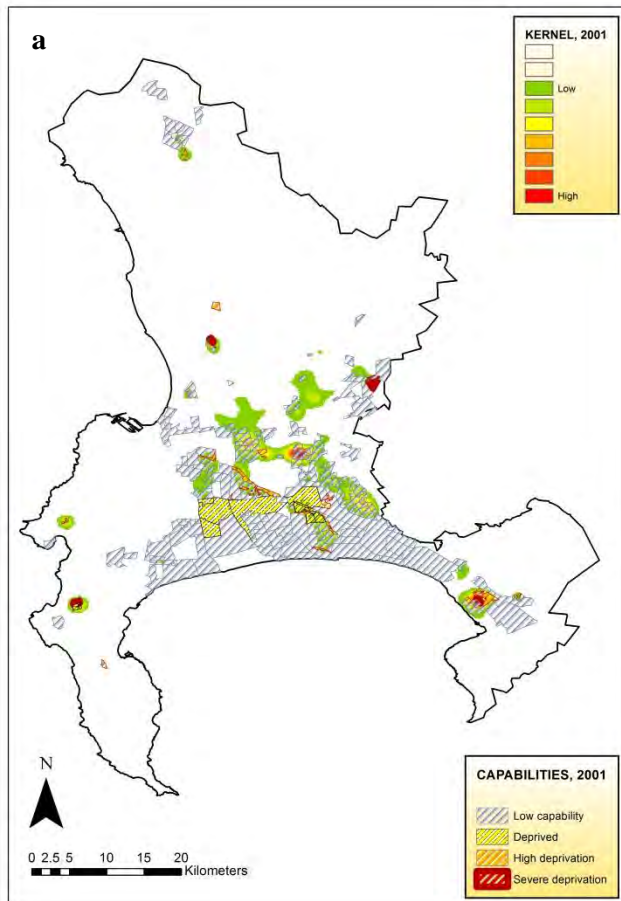


Source: Own calculations

## VI. KERNEL DENSITY ESTIMATION (KDE)

To further strengthen the spatial analysis and segregation claims of this study, a KDE analysis was done to support the spatial outputs of the Moran's I and Getis Ord G analysis. The maps below show similar spatial segregation trends of those communities with similarly high levels of capability deprivation to be mostly isolated in the Southern parts of the City of Cape Town.

Map 53: Kernel Density Estimation for the composite capability deprivation measure in 2001(a) and 2011(b)





### 4.3 SENSITIVITY TESTING

Spatial models are designed to simulate various spatial scenarios describing real world events. These spatial models undoubtedly encompass multiple improbabilities due to the incorporation of multiple stakeholder perspectives. The outputs of these spatial models are largely driven by the weighting schemas that are typically subject to many uncertainties and biased notions. The spatial model uncertainties impress a certain level of constraint on the credibility of the decision making model output. Also, this study utilises Moran's I and Getis – Ord GI\* methods extensively to simulate and identify communities in need. These autocorrelation methods are largely dependent on prior knowledge of weighted matrices selection but often this knowledge is not available and typically analysts utilise the Euclidian distance as the default spatial weighted matrix. For these reasons, sensitivity analysis is conducted on the spatial MCDM model output to improve model credibility.

In this study, global sensitivity analysis is used to increase confidence in the spatial MCDM output by simultaneously varying the weighting schema in the MCDM model and assessing the spatial distribution change in poverty (capability deprivation). Two individual weighting schemas were randomly generated using the Monte Carlo simulation technique and applied to the two autocorrelation techniques. The results of the Monte Carlo simulations are used to develop two independently generated weighting schemas that are applied to two spatial MCDM models called *POVERTY<sub>A</sub>* and *POVERTY<sub>B</sub>*. These two weighting schemas are presented below:

#### *POVERTY<sub>A</sub>*

= {*TOILET*(0.137), *REFUSE*(0.684), *LIGHT*(0.555), *WATER*(0.424), *ILLITERATE*(0.211), *MATRICMORE*(0.277), *FEMPLOY*(0.871), *INFORMAL*(0.058), *ANNUAL*(0.232), *CHIELDHEAD*(0.807)]

#### *POVERTY<sub>B</sub>*

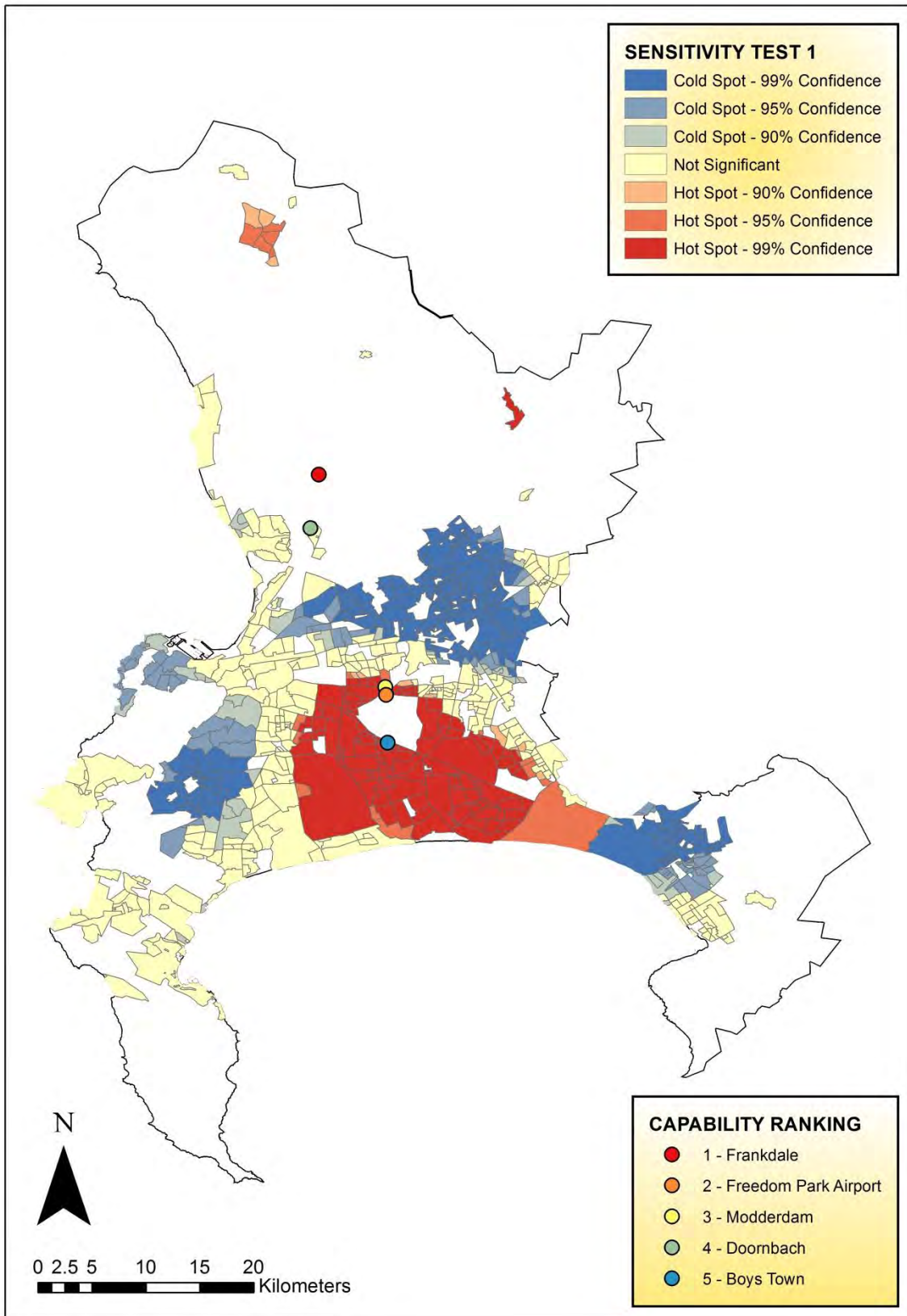
= {*TOILET*(0.643), *REFUSE*(0.109), *LIGHT*(0.871), *WATER*(0.898), *ILLITERATE*(0.564), *MATRICMORE*(0.118), *FEMPLOY*(0.461), *INFORMAL*(0.676), *ANNUAL*(0.098), *CHIELDHEAD*(0.102)]

#### 4.3.1 RESULTS OF SENSITIVITY ANALYSIS

The results of the spatial sensitivity analysis, through the application of the two different spatial MCDM models described in the above models, are shown in Maps 52 and 53. Both models output different community rankings. Nonetheless, when comparing the hotspot analysis it is clear that certain common regions in the City of Cape (i.e. Khayelitsha, Delft, Gugulethu, Mitchells Plain, Mfuleni, Cross Roads, and Nyanga) were classified by both spatial MCDM models as having high levels of capability deprivation.

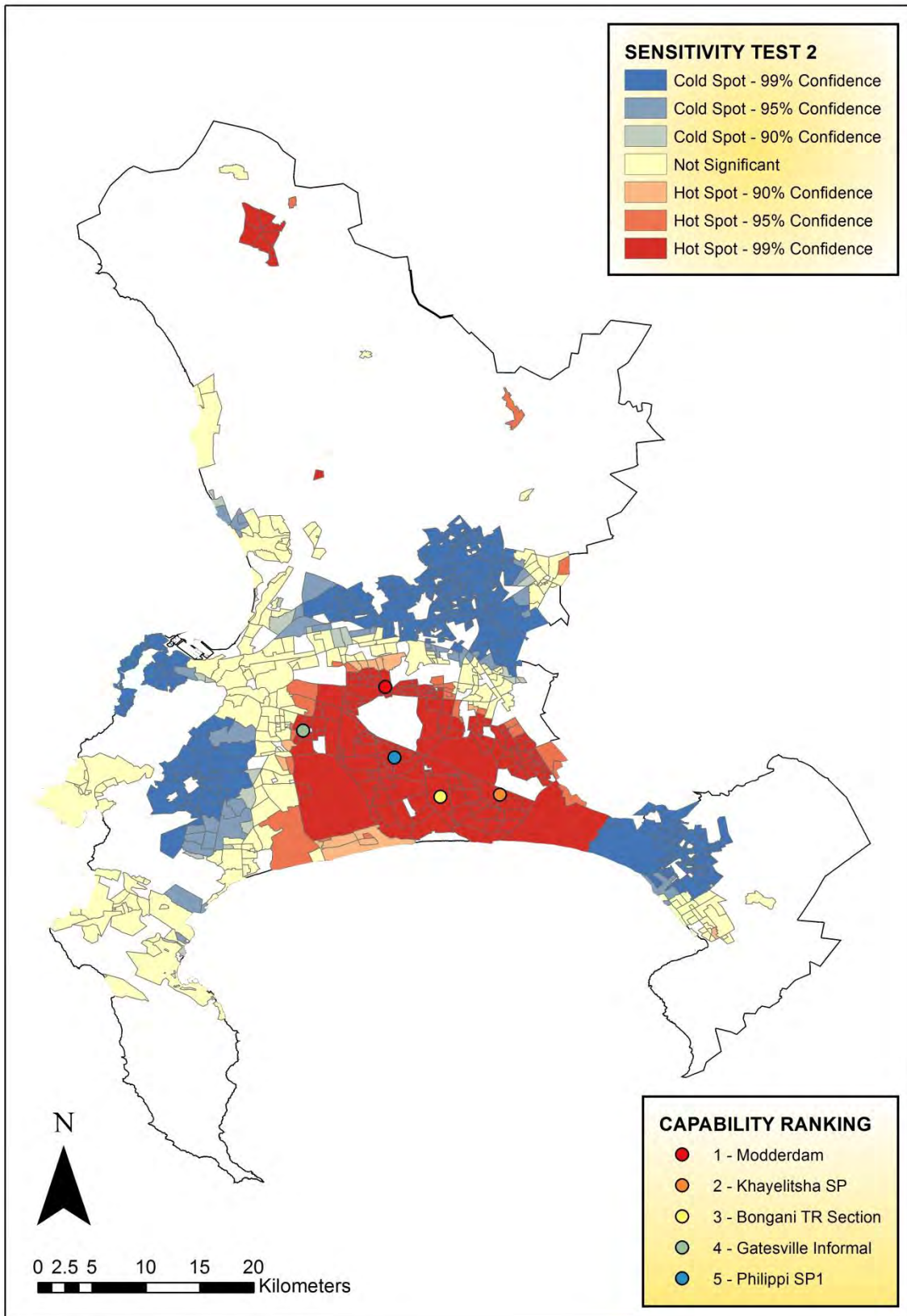
Conversely, the hotspot analysis shows regions including communities such as Bishops Court, Rondebosch, Newlands and others, which were classified by both models as having low levels of capability deprivation. The sensitivity analysis shows the output variations of both models when weighting parameters are systematically changed to assess the robustness against changes in the criteria weighting schemas.

Map 54: Spatial sensitivity testing using **POVERTY<sub>A</sub>**



Source: Own calculations

Map 55: Spatial sensitivity testing using *POVERTY<sub>B</sub>*



Source: Own calculations

#### 4.4 SPATIAL COPRAS

In this study, the capability index evaluation for ranking and identifying the most severely impoverished community in the City of Cape Town is realised through the use of four conceptual capability models derived by applying the TOPSIS decision rule. To assess the spatial outputs derived from the implementation of the TOPSIS method, a comparative spatial analysis regarding the alternative rankings and spatial distribution change is conducted using COPRAS. The normalisation process and weighting schema remains the same for the decision model, ensuring the integrity of the analysis results. The alternative rankings and spatial patterns for both MCDM models are compared to evaluate the robustness of the TOPSIS results. Similarly to the TOPSIS decision rule, the COPRAS method is categorised into main two processes. These steps and processes are:

- Construct normalised decision matrix
  - Construct the weighted normalised decision matrix
  - Sum weighted normalised criteria ( $S_i^+$  and  $S_i^-$ )
  - Determine the significance of each decision alternative  $Q_i$
  - Calculate the performance index of each alternative  $P_i$
- } Identification the decision criteria

} Identification of ideal solution

##### 4.4.1 COMPOSITE POVERTY MEASURE

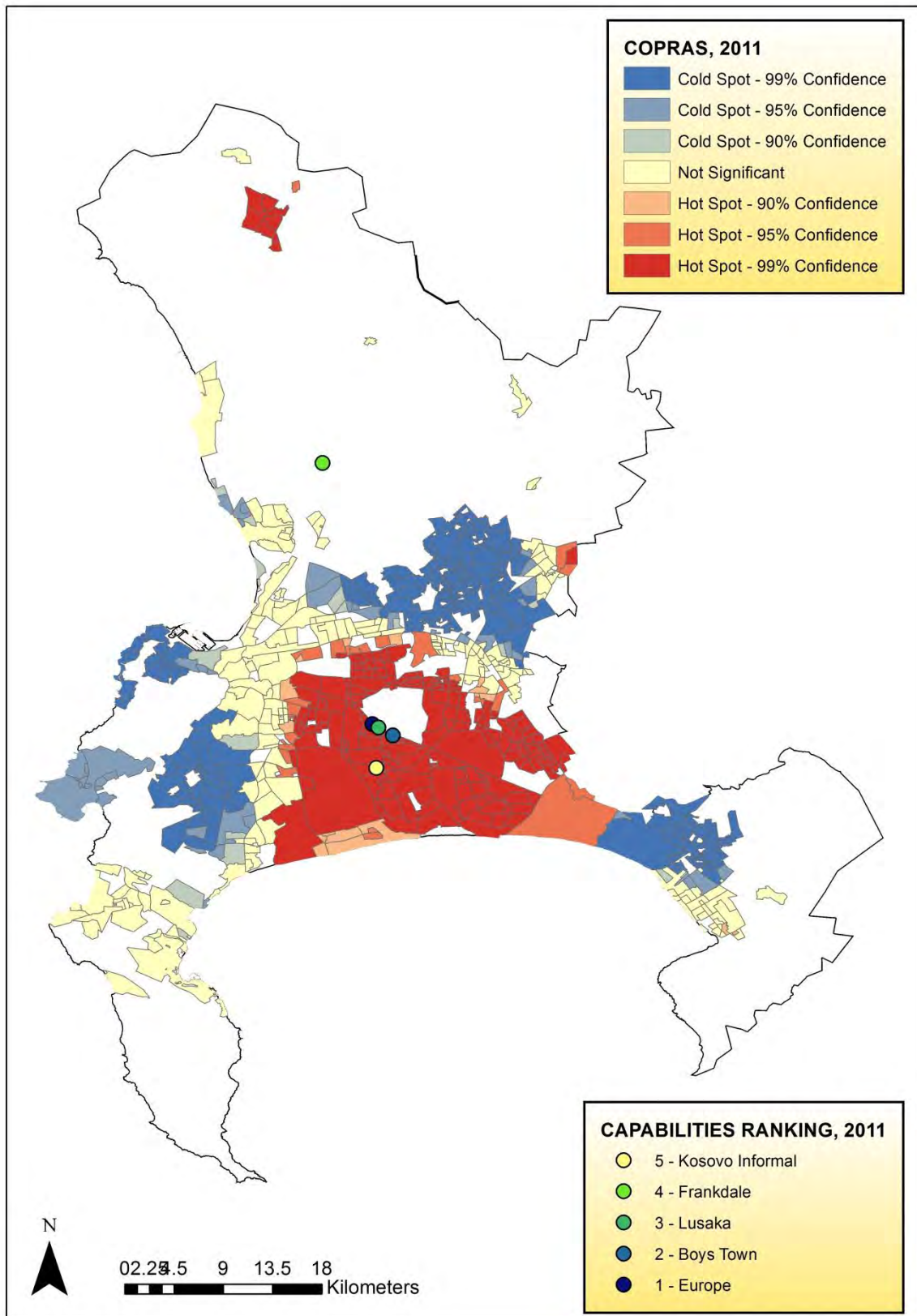
The table below presents the  $Q_i$  and  $P_i$  values for the COPRAS model used in deriving the poverty measure for 2011. The results of the COPRAS model is shown in the table below and highlights differences in the two model results with Europe being ranked as the most deprived community in the City of Cape Town.

Table 51: The distance values and the final rankings for capability deprivation for 2011

ALTERNATIVE	$S_i^+$	$S_i^-$	$Q_i$	$P_i$	RANK	PLACE
$A_1$	0.405	0.053	0.423	0.656	413	Acacia Park
....						
$A_{94}$	0.025	0.323	0.391	0.991	2	Boys Town
$A_{194}$	0.014	0.269	0.017	1	1	Europe
$A_{220}$	0.030	0.366	0.032	0.987	4	Frankdale
$A_{339}$	0.029	0.258	0.033	0.987	5	Kosovo Informal
$A_{373}$	0.028	0.243	0.032	0.988	3	Lusaka
.....						
$A_{705}$	0.335	0.042	0.258	0.711	275	Zwartdam

Map 56 below shows the spatial distribution of capability deprivation according to the COPRAS model. It shows that while the alternative rankings may differ slightly, the overall spatial pattern of deprivation within the City of Cape Town does not change. This implies that the robustness of the spatial TOPSIS decision making model is substantiated

Map 56: COPRAS, GETIS OBS comparison, 2011



Source: Own calculation

## CHAPTER FIVE: DISCUSSION

As has been highlighted thus far, Apartheid type of segregation interventions gave rise to the clustering of communities experiencing high levels of concentrated poverty and inequality. Typically, these communities were characterised as being particularly vulnerable and having significantly low levels of basic capabilities that included low income levels, high unemployment, poor education and inadequate health care services. To address these social ills, the democratically elected government implemented the RDP with the objective of mobilising “all our people and our country’s resources towards a final eradication of the results of apartheid and the building of a democratic, non-racial and non-sexist future” (The Office of the President, 1994:7). To date, it is well-known that the objectives as set out in RDP have not been adequately achieved. According to Corder (1997:189), one of the major constraints in meeting the main objective of the RDP has been government’s inability to consistently and accurately identify who was poor and where they were located. This resulted in post-Apartheid programme resources going disproportionately to minority or less vulnerable groups, resulting in the further concentration of high levels of poverty and inequality specifically in capability deprived communities.

Table 52 below presents the Global Moran’s I values derived for each of the capability sets used in this study to measure the extent of community segregation. These results show that between 2001 and 2011, community segregation along capability lines had increased in the City of Cape Town, thus resulting in the further proliferation of poverty and inequality levels. Also, when comparing the local spatial autocorrelation results for all metropolitan communities across the four capability sets, the Khayelitsha, Philippi, Crossroads, Gugulethu, Delft, Nyanga and Mitchells Plain areas had consistently exhibited the greatest overall degree of segregation and deprivation for all four capability sets. These overlapping results indicate that these severely deprived communities are characterised by a particularly severe form of segregation or isolation which Massey and Denton (1989:373) refer to as “hyper segregation”. Conversely, the less deprived or more affluent communities such as Durbanville, Rondebosch, Constantia and Newlands were randomly distributed into regions with minimal exposure to severely deprived citizens subsuming large portions of land further away from the centre and typically clustered near to other affluent communities.

Table 52: Global Moran’s I for each capability set

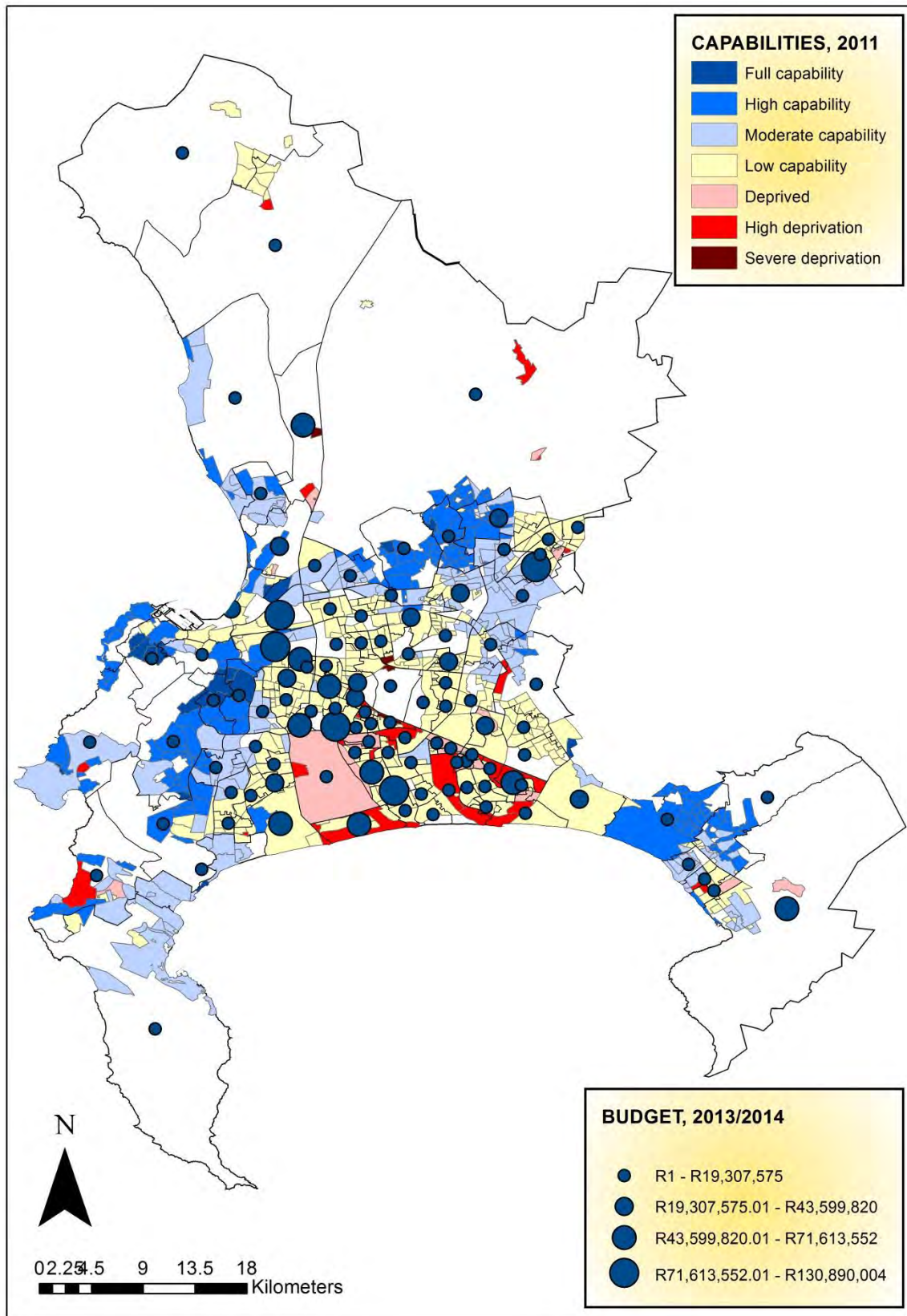
YEAR	BASIC SERVICE	LABOUR FORCE	EDUCATION	HOUSING	POVERTY
2001	0.142	0.410	0.535	0.244	0.396
2011	0.191	0.491	0.532	0.280	0.451

While this study primarily focuses on identifying the most severely deprived communities in the City of Cape Town using a predefined set of capabilities, the findings highlight the need for further research into the understanding of which underlying criteria best delineates the nature of segregation

in the City of Cape Town. As a point of departure in understanding the underlying segregation factors, Map 57 below depicts the spatial spending patterns for the City of Cape Town 2013/2014 (spending patterns for 2011/2012 was not available at time of request) at ward level (City of Cape Town, Internet source: 19 March 2013). These spending patterns are overlaid with the 2011 poverty (capabilities) index to understand the extent of accurate targeting at local government level. While the measurement period may differ, the spatial pattern analysis show a significant proportion of fiscal spent already going towards communities with severely levels of capability deprived yet community segregation along capability lines and concentrated poverty in the City of Cape Town is shown to be on the increase. These increases in concentrated patterns of poverty are then likely the result of various incentive effects brought about by local government's effective community targeting of efficient basic services provision programmes. The effective geographical targeting of poor communities has prompted the in-migration of the poor from poorly serviced provinces to serviced regions within the City of Cape Town (see Map 58). This in-migration trend has resulted in the basic services programme having to extent its coverage, thus placing significant strain on the already limited services budget of the City of Cape Town. This type of evidence-based conclusion, resulting from the spatial MCDM is critical, if government were to realistically eradicate poverty by 2030 by:

1. Addressing the current spatial divisions brought about as a result of Apartheid planning legacies as the spatial MCDM output helps to identify previously disadvantaged communities that are deeply entrenched in poverty. This allows planners and decision makers to implement necessary community based interventions to assist in breaking down spatial divisions.
2. Unblocking the multiple bottlenecks that exist in terms of hindering communities' development potential by identifying criteria that significantly affect community development. This could be achieved by utilising different simulations scenarios using the spatial MCDM model to evaluate the effects of selected criteria on poverty and development.
3. Assisting in the development of an evidence-based approach used to inform infrastructure development and investment by using each of the four domain spatial MCDM model outputs to identify communities that require certain infrastructure development or improvement interventions such as a new school or improved access to piped water.
4. Monitoring on-going socio-economic shifts in communities. As indicated in the previous sections, data governance issues remain a huge challenge for the South African government. For that reason, the South African Government must begin to invest more in the development of credible data systems in order to measure the on-going socio-economic shifts in communities.

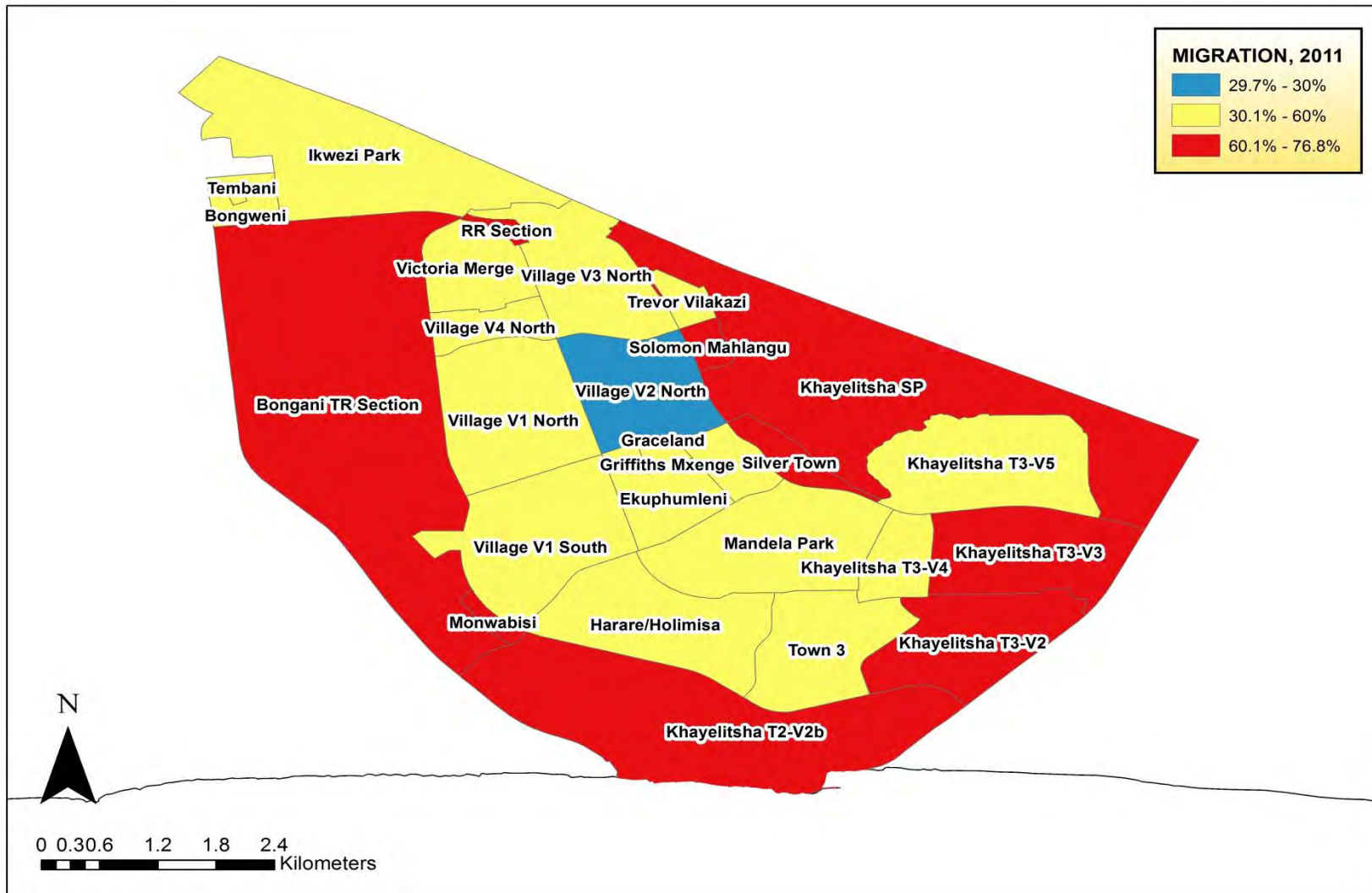
Map 57: City of Cape Town budget 2013/2014 overlaid with the 2011 poverty (capabilities) index



Source: Own calculations and City of Cape Town Capital Adjustment budget 2013/2014-2015/2016



Map 58: Percentage of persons living in Khayelitsha which was born in another Province in 2011



Source: Statistics South Africa, 2011

## **CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS**

### **6.1 INTRODUCTION**

This chapter discusses the extent to which the purpose and research questions have been addressed throughout this study. As detailed in Chapter one, the focus of this study has been on the development and implementation of a spatial-MCDM methodology. This methodology is to be used to analyse a complex multi-criteria decision making problem such as poverty eradication so as to assist government in future planning and decision making. Lastly, broad recommendations to improve the decision making process in government specifically related to poverty eradication are outlined and discussed.

### **6.2 ADDRESSING THE PURPOSES OF THE STUDY**

The main purpose of this study was to explore the potential benefits of integrating GIS with MCDM techniques for effective poverty eradication planning using the capability approach as an overarching framework to inform criteria selection. Based on the observations outlined in Chapters two and three of this study, it can be deduced that the complexity of poverty eradication planning and decision making is furthered by multiple conflicting evaluation criteria having to be used in the analysis; different theoretical opinions relating to poverty having to be integrated into the decision making environment, and the changing distribution of poverty.

These complexities are adequately addressed by integrating GIS with MCDM techniques as they provide a rigid mathematical framework for an unstructured decision problem such as poverty by enabling for the amalgamation of multiple conflicting evaluation criteria. This rigid framework also allows for the assimilation of multiple beliefs and judgements of various policy experts and stakeholders that is guided by Sen's capability approach. Furthermore, the integration of GIS with MCDM techniques allows for planners and decision makers to assess the changing patterns of poverty so as to better inform the reallocation of shrinking resources.

The other purposes of this study were to:

- Analyse the changing spatial distribution of poverty in the City of Cape Town between 2001 and 2011. This was addressed in Chapter four, and showed that in the City of Cape Town Metropolis poverty and segregation along capability lines is on the increase;
- Develop a simple, transparent and adaptable planning tool that all decision makers can utilise and understand. This was done using two simple ranking MCDM methods in conception and application that allows decision makers to rank the various impoverished communities;
- Define appropriate evaluation criteria relating to Amartya Sen's CA Framework. This was achieved using the NDP as overarching framework to inform the different capability sets to be used in the analysis, coupled with using the Census 2001 and 2011 results to define the related evaluation criteria, and;

- Demonstrate whether both Provincial and Local Government spending are spatially correlated with the locations of ‘poor’ communities. This was highlighted in Chapter Five by overlaying the City of Cape Town’s 2013/2014 budget with the poverty index developed. This spatial output demonstrates the extent of government spending in the poorer regions of the Metropolis. The analysis also shows how other demographic factors such as in-migration, if not controlled, could further drain government’s fiscal reserves.

### 6.3 ANSWERING THE RESEARCH QUESTIONS

The following research questions guided this study and were consequently addressed throughout, namely:

#### 1. How are appropriate alternatives ranked and selected in this study?

The procedure for ranking and selecting the appropriate alternatives were done based on information sourced from multiple domains (i.e. basic services; labour force; education, and housing). These domains were selected based on a stakeholder engagement involving multiple stakeholders from different spheres of government. These provided sufficient insight and a knowledgebase for criteria selection and model development. The spatial-MCDM model was developed using the appropriate insight and knowledgebase, to rank the appropriate alternatives based on varying poverty levels. To validate these results, sensitivity testing was conducted. This was done using two alternative weighting schemas generated using Monte Carlo simulation. These weighting schemas were applied to the spatial-MCDM model and the results again showed similar spatial trends and alternative rankings.

#### 2. Do the proposed spatial multi-criteria decision making model outputs conform to the five normative principles as set out in the NDP?

The NDP calls for the development of a new National Spatial Framework that specifies broad normative principles for both provincial and local development (van Niekerk, 2014: 11). Thus, any spatial decision making model that assists in informing development must inform and support the five normative principles as proposed in the NDP. The spatial-MCDM model informed and supported these five normative principles in the following ways, namely:

- *Spatial justice*: The coupling of GIS spatial analytics with MCDM outputs allowed for cluster analyses to be performed using Global and Local Moran’s I. These results spatially demonstrated the extent of residential segregation in the City of Cape Town Metropolis and could allow planners and decision makers to direct appropriate resources to communities in need, thereby restoring spatial justice.
- *Spatial sustainability*: While the spatial-MCDM model lacked an environmental component, it does however assist in promoting the sustainable use of services and products that respond to basic needs and improving the quality of life. For example, the education spatial-MCDM model

identified communities with low levels of basic education. These low levels of basic education might be a result of poorly located schools in relation to where the actual needs are. Thus, introducing different learner transport and education advocacy initiatives might result in the sustainable use of education services.

- *Spatial resilience*: As stated above, the spatial-MCDM model lacked an environment domain because of insufficient and outdated land cover data, as the most recent land cover for the Western Cape was conducted back in 2000. The housing spatial-MCDM model does however provide the spatial extent of poor housing in the Metropolis. This could be used as a proxy for environmental degradation as the expansion of informal settlements typically results in natural eco-systems being destroyed so as to construct informal dwelling structures.
- *Spatial quality*: The housing spatial-MCDM model identified communities experiencing poor housing conditions. This model could assist decision makers and planners in apportioning essential resources to communities in need so as to improve the visual and functional structures of housing and the built environment, and in doing so, stimulating vibrant and inclusive communities.
- *Spatial efficiency*: The spatial-MCDM model provided a spatial multi-criteria analysis of communities based on their levels of poverty. By overlaying this spatial poverty analysis with various transportation routes layers, such as bus and railway transportation, authorities can put in place reliable transportation plans so as to promote efficient commuting patterns amongst the poor. Also, the spatial poverty analysis can be used by government to identify regions or communities in the City of Cape Town where productive activity and employment can be supported through various employment initiatives such as the Expanded Public Works Programme, and in doing so, reduce the burden on the private sector businesses.

### **3. How are biased decision making avoided?**

In the context of spatial-MCDM, bias decision making often occurs during the criteria weighting procedure as this procedure frequently involves multiple content experts providing insight into why criteria are to be weighted a specific way. These debates are habitually highly contentious and generally result in bias decision making. To overcome this, this study employed posteriori criteria weights that were developed using the average of the first principal component for 2001 and 2011. The rationale was that this approach is broadly accepted as a more conventional way for generating unbiased decision making outcomes.

### **4. Does the capability approach add anything to the ability of planners to attempt to eradicate poverty?**

Yes the capability approach does add to the ability of planners, as this approach helps to expand the notion of poverty beyond commodities and to open it to more interdisciplinary collaboration. This

approach stimulates more useful empirical work and policy initiatives which planners and decision makers can use to formulate appropriate policies to address poverty eradication. This capability approach opens the door for planners to integrate more types of data and information, and more importantly stresses the way citizens live as opposed to what they earn.

### **5. Can GIS spatial analytical tools be incorporated with MCDM techniques to improve decision making?**

The findings presented throughout this study demonstrated that GIS spatial analytical tools could indeed be incorporated with MCDM techniques to improve decision making. GIS spatial autocorrelation tools such as Global and Local Moran's  $I$  allow for decision makers to spatially analyse the extent and statistical significance of residential segregation along capability lines in the City of Cape Town. The use of  $G_i(d)$  and  $G_i^*(d)$  statistics and KDE estimates identified hotspots and cold spots of capability deprivation, thus planners and decision makers can amend resource allocation plans so as to reflect the appropriate needs of different communities in the City of Cape Town.

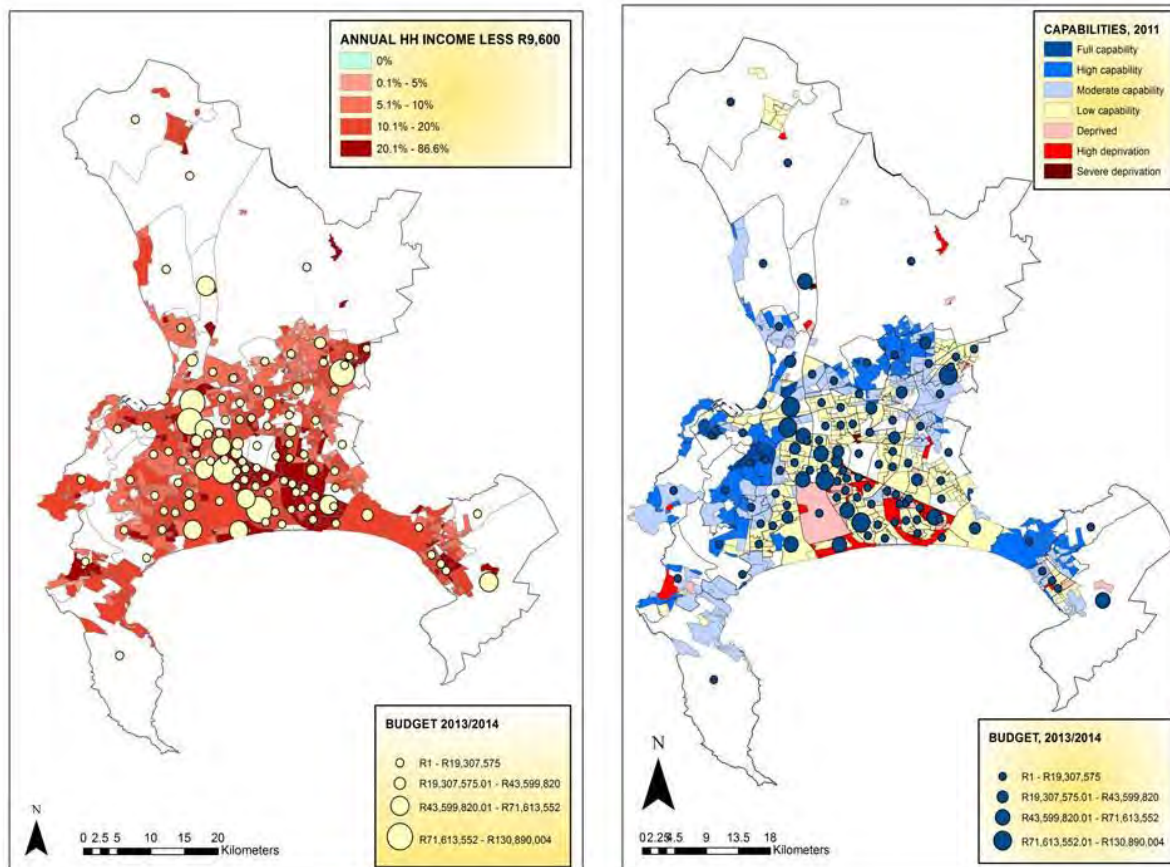
### **6. Can the capability approach be operationalised adequately to assess poverty?**

This study has shown that the CA could indeed be operationalised adequately to assess poverty. The reason for that is that the CA, by its very nature, is an open framework. However, the biggest concern is the availability of appropriate social, economic and environmental data at community level to operationalise the capability approach. The geographical mismatch between administrative data and official data does not allow for other capabilities such as safety and security, clean environment, nutrition, health care, and recreation and leisure to be incorporated into the spatial-MCDM model.

### **7. Does the use of MCDM provide planners with any apparent advantage?**

Yes, the use of multiple criteria decision making does offer significant advantage over single criterion decision making given that MCDM models have the ability to gyrate complex problems characterised by multiple conflicting evaluation criteria thereby allowing a more integrated assessment of the decision problem at hand. This allows the planner to establish problem objectives and criteria, estimating criteria weighting schemas and assessing the influence of each option to each of the evaluation criterion. Map 59 shows the spatial comparison between the criterion household income less than R9,800 and the composite capability measure. The map below demonstrates these advantages as it shows that if budgetary allocations were based solely on income, government could experience significant fiscal losses.

Map 59: Single criterion versus multiple criteria decision making



### 6.3 RECOMMENDATIONS

Through the development and implementation of the spatial-MCDM model, certain data and inter-governmental relationship shortcomings have come to the forefront. The following section will attempt to pin down these shortcomings and propose certain broad recommendations to address these issues. The following shortcomings and the related recommendations are:

1. Both Statistics South Africa and all spheres of government do not have a standardised geographical measurement tool or service delivery boundary for data collection and dissemination. From an official data perspective (i.e. data collected by Stats SA), this is challenging for decision makers as it is difficult to monitor, evaluate and understand the extent of different outcomes generated between inter-Census periods by different government programmes and interventions, for example the reduction of illiteracy in Delft, Belhar and Nyanga communities. From an administrative data perspective (i.e. data collected by government departments), it is difficult for both local and provincial government to coordinate integrated service delivery because of each department having its own unique service delivery boundaries. Therefore, government is unable to measure the impact of integrated service delivery at community level. To address this issue it is recommended that a standardised geographical boundary be developed for Census to be used specifically to assess socio-economic changes at

community level. Further work is needed to begin to link Census questionnaire attributes to cadastral information.

2. A standard poverty definition for the country. Since the dawn of democracy in 1994, the same democratically elected party has been in power. Over the last two decades, poverty has been legislated in different ways through the RDP, GEAR, ASGISA and most recently the NDP. Nonetheless, government has been unable to efficiently and effectively track the progress made in terms of eradicating, and reducing for that matter, poverty. It is recommended that the Constitution of South Africa be amended to incorporate an inclusive and thorough consultative definition of poverty that all organs of state as well as the private sector can use so as to create a sustainable platform for poverty eradication planning in South Africa.
3. A decision support tool is developed in this thesis to simultaneously assess multiple conflicting social and economic criteria. This is done to identify and rank different deprived communities across the City of Cape Town Metropolis, using the NDP as the underpinning framework. To date, there has been no other decision support tool like this developed for the City of Cape Town. It is recommended that this model be applied broadly across the Western Cape and/or South Africa so as to get a comprehensive overview of capability deprivation/poverty to improve poverty eradication planning.

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