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A Method for Identifying Potential Sites for Brownfield Development for Social Housing in the Johannesburg CBD

by

Joyce Agommuoh
Student No. 104518

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the degree of
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Advisor:

Place and Date:

Science Pledge

By my signature below, I certify that my thesis is entirely the result of my own work. I have cited all sources I have used in my thesis and I have always indicated their origin.

(Place, Date) (Signature)

Abstract

South Africa has a housing backlog of 2.1 million units. The majority of this backlog lies in the Low-Income bracket. The chief intervention used to address the backlog is the Republic of South Africa's Social Housing Act No. 16 of 2008, which provides for institutions and programs to supply Affordable Housing to Low-Income groups through a system of municipal Capital Grants (RCGs) and subsidies. The legislation was also promulgated to redress the spatial fragmentation of cities, a dividend of South Africa's social engineering experiment called apartheid. The literature points to a misalignment between these objectives, and resultant projects on the ground. Observers have commented on how the 'separateness' introduced be apartheid is seemingly perpetuated through the inappropriate selection of social housing project locations – far from the amenities required for the very target group the legislation is intended to benefit. In contributing to research acknowledging these dynamics, this research applies a number of technical approaches to firstly, identify the best potential sites for brownfield redevelopment, and secondly, to measure their accessibility to amenities required by the social housing target market: 1) Metro ARIA 2) Service Area size and Standard Distance 3) Kernel Density Estimation. The methods are run parallel in order to observe the extent to which they confirm each other's results.

The key trajectory of the research is localizing the work of Somenahalli, S. V. C., Taylor, M. A. P. and Susilawati, S. (2016), on the Metro ARIA accessibility measure, a derivative of Australia's watershed measurement of remoteness and accessibility – the Access Remoteness Index of Australia (ARIA). The results show that the approaches – with the exception of Standard Distance analysis – indeed confirm each other's' results. A selection of the best sites for access to the amenities required by the target market was identified.

Foreword

"*Our vision has always been that the Inner City can truly be something it has never been before - an inclusive, modern and diverse heart-beat of Johannesburg. I am pleased to present to you a plan to achieve this through increased funding for Johannesburg Social Housing Company (JOSHCO) amounting to R 219 million. This increase will be for the purpose of purchasing buildings that will be refurbished within the Inner City. These buildings are to be converted into low-cost rental stock …*".

These were the words of City of Johannesburg Mayor Herman Mashaba, on the occasion of the City's Budget Speech on 23 February 2017. South Africa has a housing backlog of 2.1 million units. Most lie in the low income (less than R3,500 pm – government subsidized) and Gap or non-subsidized/non-financeable (R3,500pm to R15,000pm) brackets. Beyond these thresholds, families are expected to self-fund for housing, or approach the finance houses (recently, the government introduced an income-based subsidy to address the Gap market).

On the 5th of May 2017, The Business Day (South Africa) ran a story about a pair of entrepreneurs who were converting old factories and warehouses on the periphery of the Johannesburg CBD to cater for income earners in the R2000-R3000 per month bracket. The pair indicated that *"while there were many underperforming properties across Johannesburg that were ripe for redevelopment, the challenge was picking up the right price in the right location*".

The focus of the research is the "right location" aspect. With this research, I put forward that sustainable locations are those meet the costs and socio-economic needs of the target market. While it is acknowledged that there will always price negotiations, site availability and other realities of property rights and tenure to be contended with once such have been identified, the method presented here is meant to demonstrate that 1) So-called Brownfield Development - in the Johannesburg CBD for re-development to Social Housing is highly appropriate and that 2) Specifically taking into consideration the social and economic needs of the social housing target market form the perspective of accessibility, is and should be a policy imperative.

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To Bella, my German shepherd – for your unconditional love, even when you went ignored when you wanted to go out and play. Sorry. No more of that now!

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List of Abbreviations

ABA	-	Activity Based Modelling Approach
ABM	-	Agent-Based Modeling
ARIA	-	Accessibility Remoteness Index of Australia/Adelaide
BIDs/CIDs	-	Business/ City Improvement Districts
BNG	-	Breaking New Ground
CA	-	Cellular Automata
CBD	-	Central Business District
COJ	-	City of Johannesburg
GWR	-	Geographical Weighted Regression
HDA	-	Housing Development Agency
JOSHCO	-	Johannesburg Social Housing Company
KDE	-	Kernel Density Estimation
LUTI	-	Land Use Transportation Interaction
NASHO	-	National Social Housing Organization
NNh	-	Hierarchical Nearest Neighbor (analysis)
OSM	-	Open Street Map
PPA	-	Point Pattern Analysis
RCG	-	Restructuring Capital Grant
RZs	-	Restructuring Zones
SA	-	Service Area
SD	-	Standard Deviation
SAPOA	-	South African Property Owners' Association
SI	-	Spatial Interaction
TUHF	-	Trust for Urban Housing Fund

1. Introduction

1.1 Introduction

In this introductory chapter of the research, the research problem and resulting research question are presented. Why any research is undertaken is due to its scholarly and practical importance to society. These are highlighted in the chapter.

The chapter begins with a section motivating why this research is important. Next, the research problem and the question that arises from it are presented. Next is a discussion of the technical methods to be used in answering the research question. From this section, the objectives of the research are elicited. This is followed by a section addressing the limitations of the research. The chapter concludes with an overview of the thesis structure.

1.2 Preamble: Motivation for the Research

South Africa has a housing backlog of 2.1 million units, while the number of informal settlements has gone up from 300 to 2225, an increase of 650% (Tomlinson, 2015). The majority of this backlog lies in the Low-Income population bracket. The chief intervention being used to address the housing backlog is the Republic of South Africa's Social Housing Act No. 16 of 2008, which provides for institutions and programs to supply Affordable Housing to low-income groups through a system of Municipal Restructuring Capital Grants (RCG) and Subsidies. Over and above this, the legislation was also promulgated to redress the spatial fragmentation of cities, the dividend of South Africa's social-racial engineering experiment called apartheid. The literature points to a misalignment between this objective and resultant projects on the ground, with a preference for projects on the urban fringe where land is cheaper, far from amenities for the very target group the legislation is intended to benefit (HDA Report, 2013). Moreover, The literature points to brownfield development or refurbishing and repurposing of existing buildings, especially for housing, as one method of arresting urban degeneration (Meyer, 1998).

In realizing this anomaly, the City of Johannesburg, in its 2017/18 adjustment budget, increased the amount given to the Johannesburg Social Housing Company (JOSHCO) by R219 million for the purpose of purchasing buildings to be refurbished for Social Housing within the Inner City (Mashaba, 2017).

This is not a significant amount, judging from the overall budget. It calls for prudent fiscal decision-making regarding which properties to purchase.

For this reason, the research aims to put forward a method to identify where amongst the possible sites within the Johannesburg to optimally locate social housing. The purpose is to contribute towards sound fiscal spending through rational decision-making and to contribute methodologies for implementation with existing housing policies and spatial planning efforts, specifically those that are aimed at rejuvenating the Johannesburg CBD.

1.3 The Problem and Research Question

The first Restructuring Capital Grants (RCG) were issued in 2006. The Housing Development Agency (HDA) Report of 2013 showed that only 15% of 20 projects (for which they received survey responses) nationally, were physically located in inner cities (HDA Report, 2013). In response, the Johannesburg Social Housing Company (JOSCHO) spent 41% of the 48% spent in the 2015/16 budget, buying CBD buildings for social housing. Studies show that rising costs of living impact particularly low-income households, especially food and transport costs which take up a large portion of low-income households budgets (Ismail, Mkhwanazi, & Silberman, 2016), (Battersby, 2011),(Peyton, Moseley, & Battersby, 2015).

Therefore, the research problem is:

> *The costs of Housing Location for low-income Populations*: that social housing projects so far, have tended to favor suburban locations which are far removed from basic amenities and services that are needed by low-income populations.

It is partly this realization that caused the City of Johannesburg (COJ), to set aside R219 million for JOSHCO, specifically to purchase buildings that will be refurbished for Social Housing within the Inner City (Mashaba, 2017).

As such, the research question is as follows:

> *"Where are the best potential sites for re-development for social housing in the Johannesburg CBD located?"*

This question is asked in the context of the further mandate to help trigger rejuvenation in the inner city, and bearing in mind access to the most crucial economic needs of low-income groups.

Firstly, this research departs from traditional site-selection studies and approaches. There isn't a single, definitive work that pre-empts this research. It addresses two interrelated themes –that of accessibility of economic needs of the poor and brownfield development for social housing. From an accessibility point of view, the work conducted by Somenahalli, Taylor, & Susilawati (2016) is applied in this research. The Metropolitan Accessibility/Remoteness Index of Adelaide (Metro-ARIA) developed by National Centre for Social Applications of GIS (GISCA) at the University of Adelaide, which in turn is based on the Accessibility and Remoteness Index of Australia (ARIA), tests a number of socio-economic variables for ease of access across the metropolitan area of Adelaide:

> "*The index aims to reflect the ease or difficulty people face accessing basic services within metropolitan areas, derived from the measurement of road distances people travel to reach different services*" (Somenahalli et al., 2016). (p.15).

Measurements are taken from the centroids of residential parcels to the nearest (1) Hospital (2) shopping centre (3) education (schools) (4) public transport hubs and (5) financial and postal services. These categories are further broken down into sub-types. A capped, weighted score is assigned to each category of services and an overall ARIA is derived for the metropolitan area. This method is discussed in further detail in section 1.4.2. Metro ARIA reveals the ease of access to each site to amenities.

1.4 Approach

The previous section was an overview of the rationale of this research; the societal problem that has been identified, and the research question that this problem raises. This section details the technical approaches that will be taken in order to answer the research question. The methods selected for this research are intended to complement and triangulate each other. It could be argued that Accessibility Analysis, Kernel Density Estimation (KDE) and Service Area demarcation serve the same end. They are run parallel with each other in order to observe the extent to which they confirm each other's results.

1.4.1 Change in Johannesburg CBD Property Values

The relevance of change in property values comes into play in the prioritization of areas for the field study, whose aim it is to physically locate 'low-value' buildings, on the basis of observed building grade. Over several decades, the Johannesburg CBD has evolved into a number of functional 'districts' with specific impacts on the unfolding geography of the inner-city (Rogerson, 1996). For many years, ownership of CBD buildings was concentrated in the hands of a few institutional owners, mainly banks and pension funds. In recent times however, a lot of CBD buildings have fallen into disrepair and many simply abandoned through a combination of factors such as capital disinvestment as suburban commercial nodes became more popular, crime and uncleanliness amongst others (Larsen, 2004; Coovadia 1995; Heine, 1995; Shiceka, 1995 in Rogerson 1996). The profile of owner has also changed to include smaller entrepreneurs and private individuals. Even more disconcerting is the phenomenon of ‘building hi-jacking’, where tenants forcibly take over ownership of buildings by boycotting rent payments, at times, at the behest of criminals. Ultimately owners default on payments and the building falls into disrepair, become occupied by vagrants and the homeless and oftentimes in winter, fatal building fires occur (Cox, 2015; Moagi, 2017; Steyn, 2017).

As a result of all these factors, property values in the Johannesburg CBD have diminished. This will be demonstrated through an analysis of:

- Ideally, building **valuations** over the years, from the Deeds Registrar’s office should be analysed. But due to limited data availability, property sales over the years will be studied.
- A trend analysis of **office vacancy** figures: The SAPOA (South African Property Owners’ Association) Office Vacancy Survey has been running since 1992. It monitors office building occupancy rates in 16.2 million square meters of stock across 51 commercial nodes. Together with occupancy figures, rental rates are also monitored.
- **Field study**: buildings in the area under research will be reviewed, photographed and categorized . Two generic types of buildings will be identified, with more refinement within the groups: 1) dilapidated and abandoned buildings and 2) dilapidated and sub-optimally utilized. The categories will be discussed in further detail in Chapter 3.

1.4.2 Measures of Accessibility for Low-income Households

Next, a detailed study of accessibility to basic services. The Metro ARIA concept was introduced in section 1.3. It is an appropriate measure of remoteness for this research, as it aligns with the aim to assess the nearness of essential services. With a range of values from zero (high accessibility) to 12 (high remoteness), it is based on road network distance measurements from the centroid of a property parcel to the nearest services (e.g hospitals, shopping centers, schools etc.) (Somenahalli et al., 2016). Once measurements are derived, they are standardized to a ratio by dividing by the weighted mean for that service. A capped maximum value is applied to each service type (0-2 or 0-3), and they are summed to get an overall measure of accessibility, which is a score out of 12.

The table below explains in detail, the included services and their weightings:

Table 1 Metro ARIA as it was applied in the Adelaide research

Service type	Service facilities and weighting	Score range
Health (Health ARIA)	(Major Hospital + All Hospital + GP)/3	0–3
Shopping (Shopping-ARIA)	(CBD + Major Shopping Centre + Supermarket)/3	0–3
Education (Education-ARIA)	Primary School + High School + TAFE + University)/6	0–2
Public transport (Public Transport ARIA)	(All transit stops + Go Zone (high frequency) stop + Interchange)/4.5	0–2
Financial and postal (Finance-ARIA)	(Bank + Post Office)/3	0–2
Metro-ARIA = Health-ARIA + Shopping-ARIA + Education-ARIA + Public Transport-ARIA + Finance ARIA		0–12

Source: Somenahalli et al., 2016, p 15

The standardization is done because ARIA distance values are strongly skewed. The higher weighted services assume a greater necessity for accessibility. It is a network distance approach to measuring accessibility, the tenets of which are expounded upon in chapter 2. In order to apply this method to the South African situation, firstly an investigation of the amenities and services that are most required by the urban poor locally will be made from the literature, and then the weightings will be tweaked accordingly. The analysis will be done using ESRI's Spatial Analyst extension to ArcMap 10.2, which can assess the travel cost (time and distance) to the closest facility using the Closest Facility solver.

Service area demarcation is a natural follow-on to working out time or distance cost to the closest facility. Its relevance to this research is explained below. A large number of studies pertaining to measuring accessibility using GIS tools in South Africa relate to measuring accessibility to health care facilities (Bhana & Pillay, 1998),(Frank Tanser, Hosegood, Benzler, & Solarsh, 2001),(FC Tanser, 2002), (Tsoka & Le Sueur, 2004), (Frank Tanser, Gijsbertsen, & Herbst, 2006), (Mokhele, Weir-Smith, & Labadarios, 2012), (Mokgalaka, 2014). Distances measured are Euclidean. In none of the studies is *spatial extent* expressed as catchment area size or compactness put forward for further analysis.

Service area *size* analysis can give further insight into time and distance costs of access. In a study of catchment areas around stops at high-quality public transport systems in Denmark, Landex, Hansen, & Andersen (2006) demonstrate the stark contrast, not just between Euclidean and service area buffers, but also *amongst* the latter. In drawing 600m buffers of both types around the stops, the Euclidean buffers had the same[1] area size in square metres, but the service area buffers ranged in size from approximately 400,000m^2 to slightly over 850,000m^2.

[1] With two exceptions which were not explained.

In this research, for each of the locations that will be identified as being potential re-development sites, a "service area", based on all the closest facility results (i.e. by amenity type) will be created. Other than finding the shortest route or closest facility, ESRI's Spatial Analyst extension to ArcMap 10.2 can also build service areas from time or distance cost on a network. Since the functionality keeps a running total of the length of road segments as it runs, it investigates the maximum distance along each available route, the endpoints of which become the perimeter of the service area (*Proximity Analysis*, n.d). The spatial extent of each service area will then be calculated, and the most compact (smallest size) ones will be identified. These will then potentially be the most efficient in terms of travel costs.

The idea of service area compactness will be further analysed using ***standard distance***, a widely used indicator to estimate the dispersion of points around a geographic centroid (Myint, 2008; Lee and Wong, 2001; Ebdon, 1982) in (Flores et al., 2013). It provides a spatial measurement that synthesizes the distribution of points around its centroid, similar to using the standard deviation in conventional statistics, which measures the data dispersion around an average value. A smaller standard distance means greater clustering of service points and potentially better travel cost value. Moreover, the service area with the greatest number and most variety of services will further entrench (re-development) location attractiveness.

1.4.3 A Measure of Service Distribution: Kernel Density Estimation

Point density measures can be used to isolate facility distribution characteristics such as hot-spots and density and trends, which play an important role in CBD analysis (Yu, Ai, & Shao, 2015a). Work has been done to estimate the *clustering tendencies* of services and land-uses using network Kernel Density Estimation (KDE) methods (Borruso, 2003) (Yu et al., 2015) (Timothee, Lachance-Bernard, Strano, Porta, & Joost, 2010). KDE works by weighting and counting the number of occurrences [services] in a region called a *kernel* around which the estimation is made. The resulting smoothed surface is descriptive of peaks and planes in the distribution of occurrences. KDE has been found to be a superior method of spatial density evaluation, because it considers the distance decay of occurrences according to Tobler's *First Law of Geography* (Tobler, 1979; Silverman, 1986; Bailey and Gatrell, 1995 in (Yu et al., 2015). KDE can run either on the basis of Euclidean distance, or network distance. The literature tends to highlight the efficiency of network methods over Euclidean, as they take into account 'natural barriers' such as roads, and are a truer reflection of man's interaction with the natural environment. The analysis will assess whether or not redevelopment sites are located within a 'hot-spot' or cluster of services.

Using ESRI ArcMap, Spatial Analyst once the KDE tool has been run for each service layer, the layers will be reclassified to a common (1 to 5) scale, and an overall, weighted layer generated. Each potential re-development) location will be assessed for 1) whether or not it falls within a 'hot-spot' and 2) where more than 1 site is within a 'hot-spot', the extent to which they overlap the highest part of the scale, in order to determine the most favorable locations.

ESRI Spatial Analyst KDE runs on Euclidean distance. Plug-ins such as SANET can be used to run network KDE.

1.4.4 Study Area Demarcation

The Field of Study is located *within* the central Johannesburg Business District, an 18 by 26 block area bounded by the following streets:

- Noord Street (in Doornfontein)/Carr Street (in Newtown) to the North;
- The Francois Oberholzer Highway to the South;
- Siemert/End Street (in Doornfontein) to the East and
- Miriam Makeba Street in Newtown to the West.

(See Maps Overleaf)

This area is not the inner-city in its entirety, but part of the core of it. It is selected for its representativeness of the different issues that plague the inner city, and indeed the city as a whole. It manifests various degrees of building decay, grime, crime, hi-jacked buildings and the like.

The actual inner-city consists of the following suburbs: Central Johannesburg; Marshalltown; Ferreirasdorp; Newtown and City & Suburban which form the core. The immediate periphery of the CBD consists of Doornfontein and New Doornfontein; Hillbrow; Fordsburg and Selby.

While this is the actual study area, the service points which will be tested for accessibility are selected for the entire City of Johannesburg (COJ).

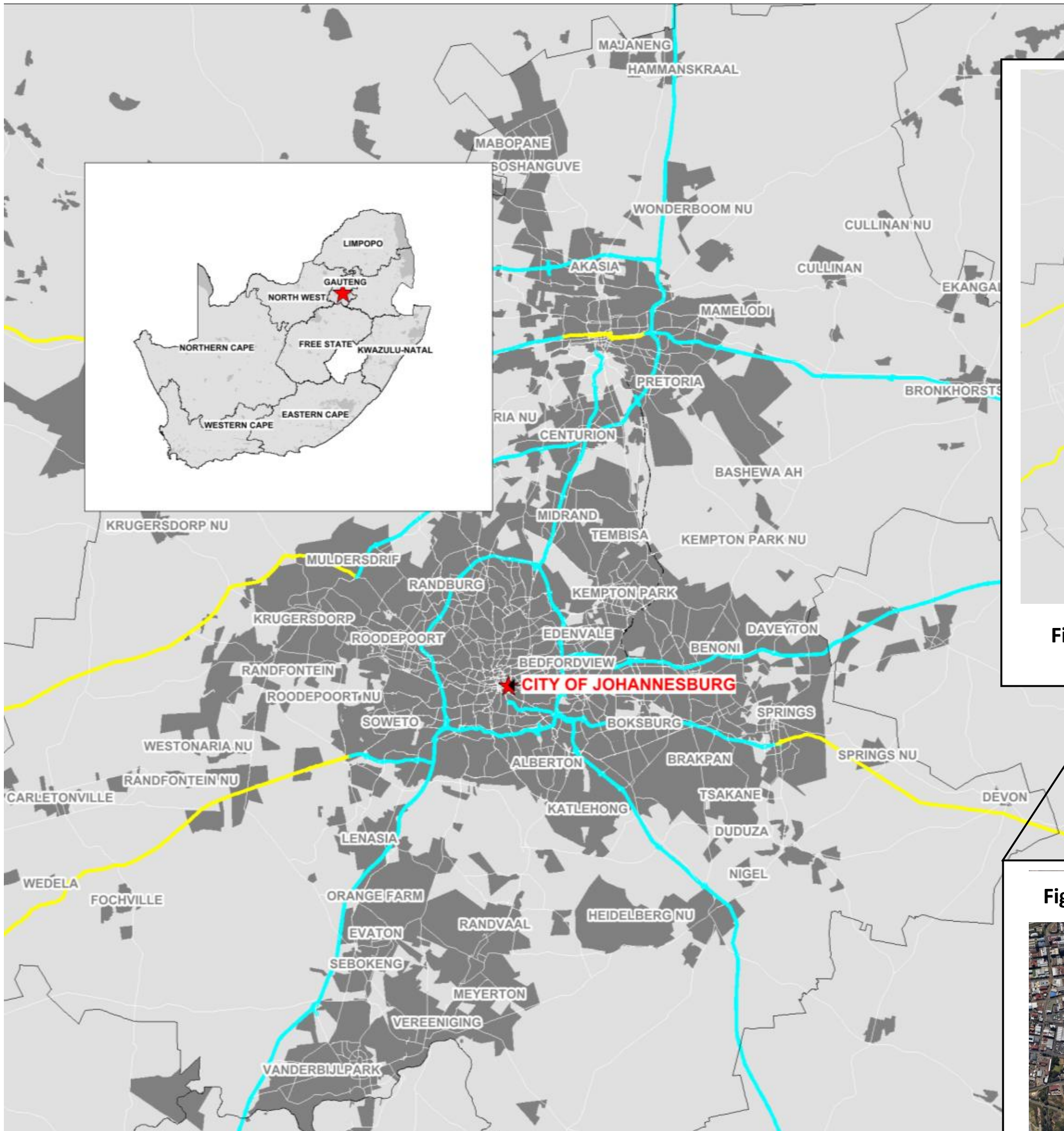


Figure 3 The City of Johannesburg Within Gauteng Province of South Africa

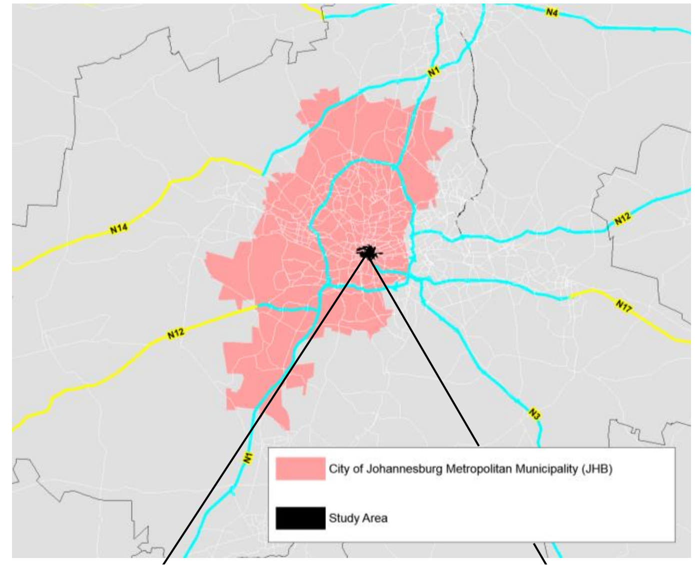
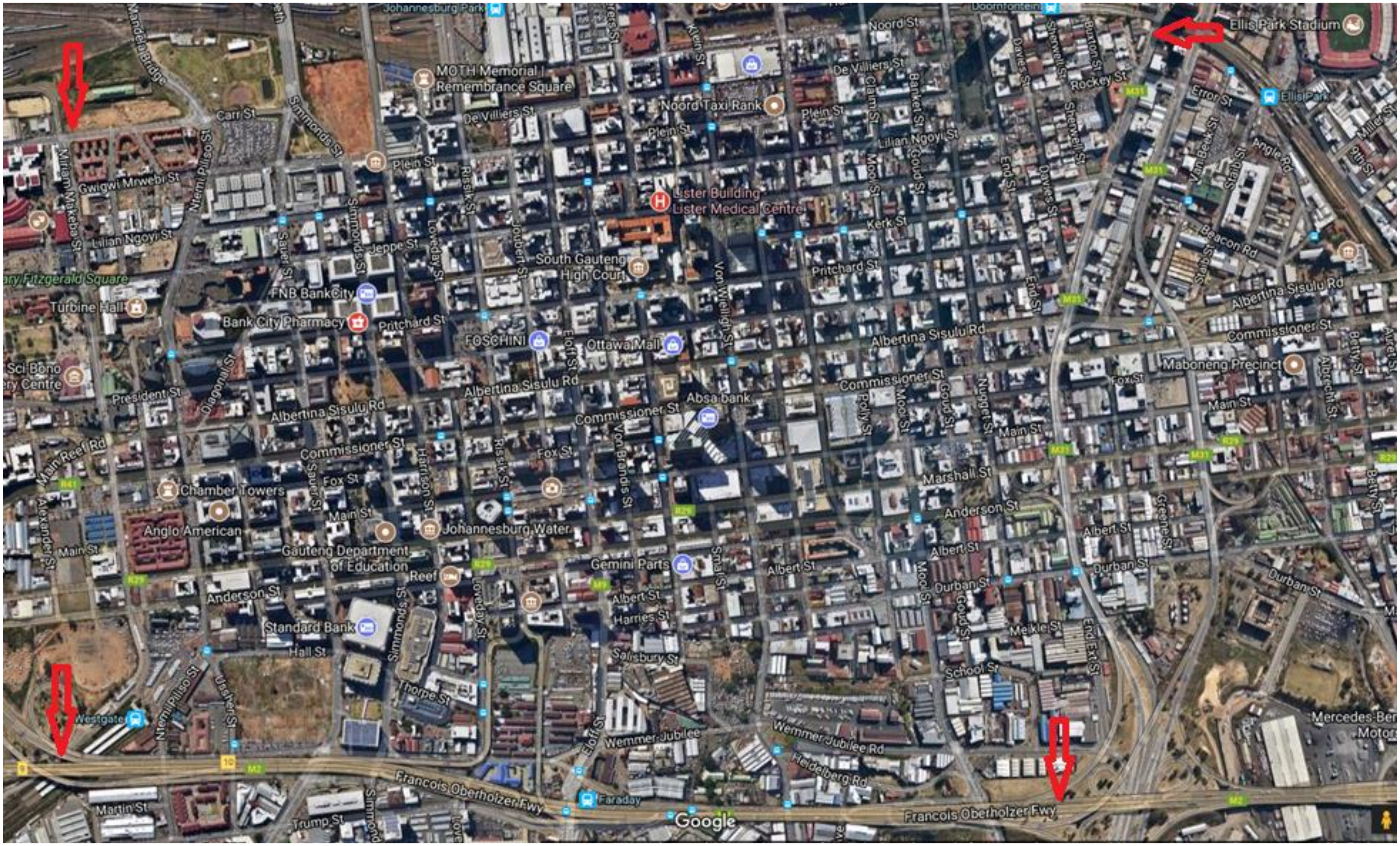


Figure 1 The Study Area Within the City of Johannesburg

Figure 2 The Study Area Divided by Field Work Days

Source: Google Maps

Figure 4 The Study Area and Street Boundaries



Source: Google Maps

1.5 Statement of Objectives

The objectives of the research are as follows:

- To determine which properties have not been on the market in the last 3 decades and the current condition of such properties;
- To identify potential buildings and sites for redevelopment to social housing from such sites;
- To assess how far each potential site is, from amenities and services or service clusters, that are required most by low-income populations;
- To identify the sites which are closest to most amenities as the best sites for re-development to social housing;

1.6 Limitations of the Research

The research is conducted in the geographical area of the City of Johannesburg, Gauteng Province, South Africa. A portion of the City of Johannesburg's CBD or inner city was selected as the study area, for its representativeness of the character of the inner city.

In this research, the importance of the CBD as a center of employment and economic activity, with dividends in the way of amenities and services (which ultimately provides a conducive environment for social housing) is taken as a given and is not addressed directly. Furthermore, the central role that accessibility in the way of roads and transport hold in realizing said benefits of the CBD is also implicit in this argument, and is therefore not directly addressed. Mobility, specifically mobility in the form of transport costs, is the second aspect of the transport component of landuse-transport interaction modeling (LUTI) [together with accessibility], but it falls outside the scope of this research. Regarding urban renewal, only 'new-build' gentrification is addressed in this research; therefore, suburbanization and rural forms of gentrification are excluded. The review of urban form literature, including processes of decentralization, decay and urban renewal are addressed in terms of how they specifically impact social housing issues. In the analytical part of the research, the inability to obtain building valuation data from the City of Johannesburg has meant that deeds data was used instead.

1.7 Thesis Structure

Below is a summary of the chapters to be included in this research:

- Chapter 1 – Introduction
- Chapter 2 – Literature Review
- Chapter 3 – Method/Application
- Chapter 4 – Results Analysis
- Chapter 5 – Conclusion and Future Work

1.8 Conclusion

In this introductory chapter of the research, the research problem and related research question were presented and practical and importance of this study is highlighted. With the City's aim to make housing provision closer to centres of economic activity, it is important to investigate methods of best investing limited municipal budgets, as well as continuously improving best spatial planning practice. Next, the research problem and the question were raised. In the context of constrained household budgets of poor families, the lion's share of which is taken up by food and transport, how best can inner-city sites that can be re-developed for social housing be selected, to the end that access to such services are minimised. Next is a discussion of the technical methods to be used in answering the research question. The methods selected for this research are intended to complement and triangulate each other. It could be argued that both methods serve the same end. They are run parallel with each other in order to observe the extent to which they confirm each other's results.

From this section, the objectives of the research were elicited. This is followed by a section addressing the limitations of the research. The chapter concludes with a diagrammatic explanation of the thesis structure.

The next chapter discusses the theoretical background of:

- The themes of Urban form: centricity, decentralization, decay and renewal, with specific reference to social housing and the Johannesburg CBD;
- Social Housing Spatial in the South African context;
- The technical approaches mentioned in this chapter: Accessibility Analysis and Kernel Density Estimation (KDE).

2. Literature Review

2.1 Introduction

The first chapter was an introduction highlighting the practical and scholarly importance of this research, and how it will be approached from a technical perspective. In this chapter, the literature on urban form dynamics, that is, the forces that shape the pattern of the city is reviewed. Especially how they play out at the local level in the City of Johannesburg and how this affects social housing. The literature on the technical approach of the research is also examined.

In the first section, the history of urban form research is examined through the lens of brownfield development. Within this section, the meaning of brownfield development is dissected and its concomitant effect: the urban renewal processes of gentrification, are investigated for their impacts on social housing. This is followed by an examination of how these dynamics have manifested in the inner-city of Johannesburg and what it means for social housing at the local level.

The next section draws on the practical experiences of efforts to reverse urban decay, through the provision of social housing as legislated by the Social Housing Act No. 16 of 2008. The target market, the recipients of social housing are profiled and a short review of the spatial distribution of housing projects to date is presented.

Finally, the question of accessibility for poor households is addressed. Its importance as a policy imperative is highlighted and, the different measures of accessibility employed here in this research are critically examined.

The literature on urban morphological processes and associated research approaches is wide-ranging, hence the narrow focus on how the processes have localized to shape the Johannesburg CBD, and what that means for social housing. Social Housing as an urban renewal strategy in the inner-city of Johannesburg, as well as a means of driving GDP growth is very topical at the moment, and has attracted a tremendous lot of attention from both the City and national government. This is a timely research that lends itself to fine-tuning existing site-selection approaches and emphatically supports the idea that gentrification is not to be allowed to displace poor urban households.

2.2 Urban Renewal: Brownfield Development for Social Housing

This introductory section revisits the classic concept of urban form, specifically the issue of urban growth, decay and renewal as expressed in brownfield development. The focus is upon the definition of the concept of urban form, which provides the theoretical context of this research. The ambiguity surrounding the meaning of 'brownfield' is also addressed. Of importance and in the next section, is a set of processes seen as a natural dividend of urban renewal: gentrification. Specifically, the tendency of gentrification to displace incumbent, usually poorer populations and what this means for social housing. And finally, the evolution of the Johannesburg CBD is placed against this backdrop, and what it all means for social housing in that locality.

2.2.1 Urban Form: The Neighbourhood and CBD in Context

Cities are extremely complex phenomena, and studying their spatial structure and patterns is of paramount importance in understanding human choice behaviour. This in turn, is important for conducting analyses to isolate and reverse spatial problems. This study of the city or urban morphology is historically drawn from many disciplines, languages and cultures (Oliveira, 2016) (Kropf, 2009) (Gauthiez, 2004)(Conzen, 2001)(Moudon, 1997) . Indeed, the use of the word "morphology" was originated by Johann Wolfgang Von Goethe (1749–1832) the famous German writer, while studying biology (Oliveira, 2016).

Marshall and Çalişkan (2011 in Oliveira, 2016) have identified three main approaches to defining the concept in the literature and the associated researchers 1) a general approach; 2) one that focusses on the object of study (i.e. land, buildings etc.); 3) one that focuses on the intent or purpose of studying urban morphology.

In the first group, it is the study of city 'form' or structure; the fabric of the city and the processes and people forming it (Cowan, 2005; Lozano, 1990; Urban Morphology Research Group, 1990; Mayer, 2005). In the second group of definitions, it means understanding the complexities at various scales of streets, plots, buildings, blocks etc. that help us to understand how towns have grown (Larkham, 2005; Smailes, 1955). Lastly, it is described as a method of analysis tracing the evolution of a city from its formative years and transformations to its present, moreover, to use such information to determine how the city should be planned and built going forward (Gebauer and Samuels, 1981; Moudon, 1997; Gauthier and Gilliland, 2006).

It is the last group of definitions that hold relevance for this research.

From the literature, it seems that “morphology” and “form” are used interchangeably. However implicit in the word “morphology” is the suggestion of “change over time” whereas “form” seems to suggest a product of the completed process. It would seem the former definition is more appropriate for describing the dynamic forces the shape the formation of a city. Indeed, Oliveria (2016) indicates that ‘form’ refers to the physical elements that shape and structure the city. Streets, erven, plots, and buildings; so-called “urban tissue”.

Simply put, urban morphology is the study of urban form, that is, the agents and processes that form and transform human habitats over time. According to Moudon (1997, p.7) “form [buildings, open spaces, plots or lots], resolution [the block, the city, and the region] and *time* constitute the three fundamental components of urban morphological research”.

Modern urban morphological research has three broad approaches, founded on specific schools of thought (Kropf, 2009; Oliveira, 2016):

1) Spatial Analytical
2) Configurational or Space Syntax
3) Process Typological
4) Historico-Geographical

This research emanates from the first approach. The evolution of spatial analytics can best be described by the transition from land use transportation interaction models (LUTI) to Spatial Interaction (SI) models, to Cellular Automata (CA) and Agent-Based Models (ABM) (Oliveira, 2016).

The standard reference point for classic LUTI theory emanates from deterministic models with simple assumptions about monocentricity, spatial homogeneity and rationality (Alonso, 1964; Ricardo, 1821; Von Thunen, 1826 and Wingo, 1961 in Acheampong & Silva, 2015; Burgess, 1925; Harris and Ullman, 1945; Hoyt, 1939 in Friedmann & Weaver, 1980). It posits that peoples’ travel choices are **a function of travel cost and travel distance**, which in turn, impacts on the location of activities and ultimately, city formation. Indeed, CA and ABM theory in seminal work by Michael Batty describes the city as a ‘problem of complexity’ to be understood by disassembling processes of emergence and evolution (2008, 2012 in Oliveira, 2016; Kropf, 2009). It is micro-economic theory that provides a framework for analyzing the relationship between transport and location.

A criticism has been the inability of the field to find a home in urban economic theory, because of the restriction of econometrics tradition, and its inherent limitations capturing urban and regional geographic nature of the subject matter (de la Barra 1989, Waddell 1997 in Acheampong & Silva, 2015).

Spatial Interaction (SI) models emerged in the 1960s with the most notable contribution from Lowry's 1964 analysis of the city of Pittsburgh, combining the Newtonian concept of gravity and human spatial interaction behavior(Acheampong & Silva, 2015). The model stated that the amount of interaction between any two land-use zones of a city was directly proportional to the number of activities in them and inversely proportional to the relative amount of impedance. The model was criticized for lacking a theoretical foundation (Berechman and Small 1988, Waddell 1997 in Acheampong & Silva, 2015), which was proposed by Widdell (1970) in the way of 'entropy' maximization. A theory about the degree of disorder in a system. He expressed these as the relative location of workers, jobs and housing in the city (de la Barra 1989 in Acheampong & Silva, 2015). SI models were criticized for having weak assumptions, and unable to capture the complex human behavior related to travel and location choices.

The 1970s were dominated by a series of theories that incorporated economics, human cognition and heuristics, all in aid of better understanding location and travel choices under **uncertainty** (Acheampong & Silva, 2015). Utility-based theory, based on assumptions about rationality and perfect choice, became popular. These models were criticized for not being able to accurately capture the characteristics of observed location-travel decisions.

The original work by Hagerstrand (1970) and Chapin (1974) introduced the concept of **space-time geography** (Acheampong & Silva, 2015). Grouped into three categories, it held that there are *time* costs involved in overcoming space: 1) capability constraints. The impedance to covering a distance in a specific amount of time 2) coupling constraints which are associated with having to undertake a certain number of activities while covering space in a given time and 3) authority constraints which are associated with legality and rules such as property or travel laws and regulations. This has led to activity-travel research such as the work of Ben-Akiva and Bowman (1998), McNally (2000). A key criticism has been the difficulty of modeling activity-travel behavior in practice (Acheampong & Silva, 2015). This concept is explored further in section 2.4.1 (p.37).

The classic LUTI models have evolved to pave the way for aggregate utility-based models and micro-simulation models, to overcome the weak assumptions of the former (Acheampong & Silva, 2015) (Batty 2008, 2012 in Oliveira, 2016). Cellular Automata (CA) and Agent-Based Models (ABM) approaches to simulating spatial interaction sit in the realm of space-time geography and are concerned with understanding a city's complexity from the perspective of emergence and evolution (Batty 2008, 2012 in Oliveira, 2016). The modern LUTI models attempt to capture individual behavior and rational choice of people. CA for example, which first emerged in urban studies with the work of Waldo Tobler, titled 'Cellular Geography' (1979), in turn influenced by the "Game of Life" a work by John Conway (1970) highlighted, the importance of the '**neighbourhood'** to the functioning of cells or parcels: the growth of a cell is dependent on the state of Neighbouring cells or model inputs. 'Agents' can be independent entities such as people, buildings, plots). These principles are further examined in section 2.4.1. The new research trajectory is to attempt to incorporate activity-based modeling (ABM) into LUTI models; how vehicle allocation, activity and for example, how mobility dependent individuals such as children affect trip scheduling. According to Clarke (2014), though these models have been criticized as greatly oversimplifying reality, complex to run and data hungry, they have enjoyed increasing popularity in urban and regional modeling for the past 2 decades, managing to capture the complexities inherent in urban processes. New directions in research, necessitate rigorous testing for further accuracy, causative investigations and policy-related linkages (Clarke, 2014). These ideas however, fall beyond the scope of this research.

In conclusion, the overarching theoretical background of this research in the field of urban morphology, is a subset of space-time geography: activity-based approaches, where costs and constraints must be negotiated to overcome space. There is an emphatic and well-researched relationship between transportation, land-use and urban form in these models. These ideas are further explored the next sections. Of note is the importance of the Neighbourhood as a unit of the city, and the central role that time plays in the emergence of a city. This introductory section traced the evolution of urban morphological research, which at its essence, is an attempt to capture and explain the underlying processes (choices and behaviors), that influence the formation of a city. The next section examines the evolution of the Neighbourhoods, specifically the CBD, over time.

2.2.2 CBD Evolution: Decentralisation, Decay and Renewal

As indicated in the previous section, the first attempts to unpack the intricate relationship between land-use and transportation began in the early 1800s with the classic work of Von Thunen, followed up and built upon by Burgess (1925), Hoyt (1939) and Harris and Ullman (1945) and others (Friedmann & Weaver, 1980). These models sought to shed light on the way cities grow and develop. The ever-important *time* dimension especially for the purposes of urban planning.

Von Thunen's agricultural location model; Christaller's Central Place Theory; Webers' theory of industrial location; Burgess's Concentric Zone model; Hoyt's Sector model; and Harry and Ullmans's Multiple Nuclei model all have in common, the influence of location and accessibility on land-use. The models did not contradict one another, but rather complemented, and further developed preceding ideas (Friedmann & Weaver, 1980).

The models presented a generic city structure and growth trajectory (Friedmann & Weaver, 1980; (Hoover & Giarratani, 1984): at the heart of a city lies its Central Business District (CBD). This is typically the commercial heart of the city, with the highest density of the tallest buildings. A mixed land-use zone of high and low order functions. Behind this lies a 'zone of transition' or 'urban blight zone' where the land-use is changing. It is characterized by deteriorating low-income residential and competition for land-use with light manufacturing and other activities establishing in the core CBD. Indeed, it is presented that the lowest income Neighbourhoods are those located closest to the CBD. It was Burgess (1925) and McKinsey (1926) (in Friedmann & Weaver, 1980) who initially advanced the idea of a 'human ecology'. Various land-uses competing and pushing each other out, as new land-uses become more profitably located in the CBD. Their fundamental assertion was that the city grows outwards from the center (from the CBD) as a natural function of urban-industrial expansion. They put forward 'the Neighbourhood' as the natural unit or building-block of this growth.

Hoyt (1939) and Harris and Ullman (1945) simply extended this theory. The former agreed that indeed the city grows from an urban core, radiating outwards in concentric zones, but such growth followed an *axis* of growth, along transport arterials, whose direction is determined foremost by the development of upper-class residential areas. The latter saw the rise of multiple urban cores or 'nuclei' which were effectively a series of overlapping [Burgess] concentric zones (Friedmann & Weaver, 1980; (Hoover & Giarratani, 1984). Through practical research various cities, Ingram (1998) indicated that over time and due to the effects of increasing income, as well as improvements in transportation, growth in a city happens in two main ways 1) expansion at the urban fringe and 2) densification of less developed areas. Expansion at the rural-urban fringe is also driven by lower land-prices (Meyer and Gomez-Ibanez, 1981 in Ingram, 1998). He also found that In the CBD, populations tend to decline, as they are displaced by other economic and industrial activities. This has been seen in cities such as Bogota, Shanghai and Tokyo (Downs, 1994, ch. 5; Meyer and Gomez-Ibanez, 1981, ch. 2 in Ingram, 1998).

The existence of a CBD is further explained by economic theories of **agglomeration** (of labour, economic activities) and **scale**, where economic activities within cities realize certain operational cost-saving advantages by locating close together, forming **spatial clusters** (O'Sullivan, 2007; Gong and Wheeler, 2002; Keeble and Nachum, 2001 in Flores et al., 2013; Camagni, 2016). Economic theory holds that rising income levels attracts urbanization (Ingram, 1998). With greater clustering comes greater economic activity which in turn attracts greater levels of urbanization. There other views as to other causes of urbanization (see (Colding & Barthel, 2017; Henderson, 1985; Krugman, 1995 in Ingram, 1998).

As these processes came to a head in the 1960s in America, an "urban crisis" of sorts was identified, typified by high unemployment and crime rates, often with a strong racial profile, severe municipal financial problems and pollution problems (Hoover & Giarratani, 1984). It argues that such conditions persist to this day, albeit with varying intensity. As policy interventions actively implemented to slow in-migration to the large cities began to take effect, new 'urban crises' were witnessed. That of decentralization as new urban centres ('nuclei') arose, with the concomitant decay of the CBD as one group of economic activities (mainly residential) was replaced by another (mainly light industrial and manufacturing) (Hoover & Giarratani, 1984).

These theoretical foundations have long been generally accepted as being universally descriptive of how a city grows. This polycentric form of urban growth and development is perhaps the closest reflection of city growth, given the heterogeneity of city character. Not least of all between western (developed or first world) and emerging ('third world') cities. The idea of the compact, monocentric European city is seen as less adaptable in many African regions, where cities developed and grew around a number of small villages (Jenks et al, 1996; Jenks and Burgess 2000 in Jenks, Kozak, & Takkanon, 2013). Others have put forward that the Euro/US-centricity origins urban growth modeling do not create space for city evolution narratives emanating from different cultures and regions, and that what is need is a 'post-colonial' urban theory (Robinson, 2006; Bunnell and Maringanti, 2010 in Leitner & Sheppard, 2016; Lees, 2012) . They push for "a comparative analytic that destabilizes the universalism of the dominant norm" (p.228 Leitner & Sheppard, 2016). Opponents of this position hold that no single theory could ever justifiably cover the plethora of types and products of urbanization the world over (Leitner & Sheppard, 2016). Scott & Storper, (2015) hold that urban theory should always have at its centre, "conceptual cornerstones of agglomeration and clustering (and the resultant 'urban land nexus')" (Mould, 2015, p.157).

The new polemic has aroused much interest and scholarship (Amen et al., 2006; Ong and Roy, 2011; Edensor and Jayne, 2012; Miraftab and Kudva, 2014; Parnell and Oldfield, 2014 in Leitner & Sheppard, 2016).

In the modern age, processes of urbanization and globalization are identified as the key factors providing impetus to city growth. To this end, the predominant urban development themes are ‘polycentrism' and ‘fragmentation’ (Fainstein at al., 1992; Graham and Marvin, 2001; Marcuse and Van Kemepen, 1992 in Jenks, Kozak, & Takkanon, 2013). These processes are more often seen in large global cities, the result **being poorly connected nodes** that are **car-dependent**. The new “Smart City” narrative features strongly in this context, specifically with regards to the question of sustainability, and the cost of rolling out infrastructure in a polycentric, fragmented city (Colding & Barthel, 2017).

There is agreement that Asia and Africa are experiencing unprecedented rates of urbanization (Leitner & Sheppard, 2016). Beyond ‘north-south’ debates, there is a focus on shifting the post-colonial city from its present form, often plagued by challenges such as poverty and decay, to a modern global city through the promotion of neo-liberal good governance and free-market capitalism.

In conclusion, there is an intricate relationship between land and transport, which the classic deterministic models first tried to unpack. It is a relationship that persists to this day, witnessed in economic activities of cities, agglomeration and spatial clustering, and the rise and fall of the neighbourhood in general, and the CBD in particular as people exercised those choices. Further analysis on local cities using a post-colonial urban form theoretical approach is being advocated; however, such approaches must take into account the fundamental principles at the heart of urban formation. Namely the concepts of agglomeration, clustering, travel and urban land. The next section unpacks how neo-liberalism sets the context for brownfield development and its off-shoot process gentrification, and how this may affect social housing.

2.2.3 Urban Renewal: Brownfield Development, Gentrification and Social Housing

The previous section was an examination of the theories of urban growth. Rapid urbanization, economic agglomeration and spatial clustering, decentralization of economic activity and concomitant decay in out-migration areas such as the CBD. Moreover, the central role of transportation in land-use determination, against a backdrop of globalization and neoliberalism is highlighted. This section unpacks the concept of brownfield development specifically of social housing as a form of urban renewal, as well as the processes of gentrification (a dividend of urban renewal), and their tendency to displace resident, usually poorer populations. Firstly, the definition of "brownfield" is discussed, and then the epic London Docklands project is taken as an example of how brownfield development and subsequent gentrification can negatively affect social housing. The meaning of "neo-liberal" for the Global North and South is also evaluated. Next the concept of "gentrification" is discussed, and what it means for efforts to establish social housing within the context of the neo-liberalism.

Urban Brownfield Development is an approach to urban regeneration, often believed to refer to site-specific, clean-up of contaminated land and water (Meyer, 1998). However, the definition goes *beyond* the environmental, to incorporate an array of other factors **regarding regeneration of previously used urban lands**. By this, the meaning of "contamination" is extended to cover crime, over-crowding, old infrastructure — a new form of economic 'spillover" (Meyer, 1998). It has two main trajectories: site-specific versus urban/region-wide impacts, the latter being the vision of the City of Johannesburg.

Meyer (1998) indicates that the definition of contamination that covers **social ills**, does not lend itself easily to piece-meal or site-by-site solutions, but sits more comfortably in the realm of regional strategies (Anderson 1964; Bellush and Hausnecht 1967 in Meyer 1998). The example he cites, the unintended consequences of the American 'negro removal' programs of the 1950s under the guise of addressing urban blight, only served to underscore the interconnectedness of property parcels within that most important element of the city. The neighbourhood and community.

Since the 1990s, he notes a perceptible shift in US governmental policies of urban renewal, away from a site-by-site approach, to the Empowerment Zones/ Enterprise community programs (Meyer 1991 in Meyer 1998). He emphasizes that brownfield policies now have to do with more than just land contamination removal. They incorporate a broad set of economic development imperatives that meant **to impact neighbourhoods** (Foxen and Knauerhase 1995 in Meyer 1998).

Meyer (1998, p.7) highlights the following three evaluative criteria that help to distinguish between site-specific and urban/region-wide approaches to brownfield development:

Table 2 Site-specific vs Urban/region-wide Evaluative Criteria for Brownfield Development

	Site-specific	Urban/region-wide
Environmental objectives	Limited to those with immediate economic consequences	Includes ecological or bioregional considerations
Economic objectives	No focus on any economic impact, beyond value to be realized for the concerned site	Concerned with economic spillover effects and externalities for the neighbourhood
Community objectives	Relatively little or no community consultation. However, there are instances where redeveloping a single site creates knock-on effects.	Degrees in the level of community participation, where they influence the scope of objectives and plans.

Source: Meyer 1998, p.7

Turning to brownfield redevelopment in housing, in the same period (1995) in the United Kingdom, the government announced that it aimed for 50% origination of new urban housing from re-used urban land (Wong & Ba, 2012). Perhaps the most widely touted, and best known example of brownfield redevelopment, is the London Docklands project promulgated in 1971 (Brownill & O'Hara, 2015).

The lessons to be learnt from this project are manifold. Firstly, it is an example of how **policy changes and inconsistencies** can result in fragmented and even unintended results on the ground. Moreover, it demonstrates how the neo-liberal narrative (free flows of global capital looking for investment destinations, at times with a set of conditions attached) dominates urban renewal policy setting and implementation, often to the detriment of those with the lowest incomes.

The Development Agency charged with getting the development of the ground the LDDC (London Docklands Development Corporation), despite initial government plans and social survey evidence to the contrary, instituted a market demand approach to providing housing in the area (Brownill & O'Hara, 2015). An initial ministerial survey taken in the 1970s indicated that residents wanted housing as a top priority in developing the area. A civil action group in partnership with government in 1975 concluded that ''All speed should be shown in getting land into housing use'… 'of all amenities it is good housing which most is at a premium in London ... [so] the share of land to be dedicated to housing should be the greatest which sound planning would allow" (Brownill & O'Hara, 2015, p.561).

The vision was to balance the **tenure-mix** or socio-economic **balance** of the population in the area. This meant that the entire area could not be used for council housing; otherwise the area would not be able to attract higher income, upwardly mobile white collar workers (Brownill & O'Hara, 2015). The project would not be sustainable. On paper, 40 to 50% of the housing was to be owned by local authorities, and 30 to 40% for hybrid types of shared ownership period. A remaining 20% would be owner occupied. What ultimately transpired however, as a result of LDDC strategy, was a large number of high-density extremely high value residential and gated communities. Some would argue that Canary Wharf represented the epitome of that strategy. However unintended or controversially implemented as some would argue, there is no question that Canary Wharf made region-wide, even global impacts (Brown, 2017; Brownill, 1990; Foster, 1999 in Butler, 2007). The LDDC wanted 75% housing for sale, but later revised it to 50%. At the demise of the LDDC in 1998, housing tenant mix was 74% owner occupied and 23% local authority. Only 3% was shared ownership. There was a substantial under-representation of social housing.

The London Docklands example is a typical example of the neo-liberal approach to urban renewal and brownfield redevelopment taking place in a policy, or at least, policy-implementation vacuum. Lees (2000) calls for an unpacking and localizing of the term ‘neo-liberal’ which has had different manifestations in the Global North, as compared to the Global South. In developed market economies:

> “…the long economic expansion and globalized credit boom across urban systems of the Global North drove gentrification outward from the urban core. The leveraged real-estate frenzy set the stage for an unprecedented crash and a wave of foreclosure driven displacements [in the 1990s] across many kinds of city neighbourhoods ...” (Wyly et al., 2010 in Lees, 2000 p. 160)

Whereas, in the Global South, in countries such as Brazil, China and India, state-led redevelopment schemes see efforts to re-align the local economy to the global economy, and to attract direct investment (Lees, 2000; Shin, 2016).

Processes of gentrification are a form of urban renewal, often rapid, where working-class Neighbourhoods are rehabilitated into middle-class residential through capital investment by home-buyers, developers and landlords (Visser, 2002; Visser & Kotze, 2008). Bounds & Morris (2006, p.99) observe: “[gentrification] has become principally a strategy for redevelopment of brown field sites by the state and capital interests. This is the classic interpretation. Researchers argue that in South Africa, there is a departure from the ‘classic’ interpretation, with only certain aspects of the processes visible. Firstly, the linking of inner-city rejuvenation to gentrification, both as a term and in the debate, is missing in the local research (Visser, 2002; Visser & Kotze, 2008). Nevertheless, there is agreement that gentrification holds meaning for the South African context.

Researchers point out that the meaning of *gentrification* has changed markedly since its first coining in the 1960s: the so-called ‘first wave’ of gentrification (Lees, 2000). In its classic meaning, processes of gentrification are a form of urban renewal, often rapid, where working-class Neighbourhoods are rehabilitated into middle-class residential through capital investment by home-buyers, developers and landlords. A central element of gentrification is its propensity to bring social, cultural displacement, whether directly or indirectly, at times, with a lot of resistance on the part of local communities (Hirsch, 27 Jul 2017; Lees & Ferreri, 2016; Visser & Kotze, 2008).

Widening the meaning, is gentrification occurring in cities further down the urban hierarchy, such as rural locations, in-fill housing and pollution contaminated land, as well as and non-US and UK cities. The 'second wave' of gentrification. In contemporary gentrification scholarship, it is argued that 'new-build' developments in cities also qualify as gentrification (Davidson and Lees , 2005 in Visser & Kotze, 2008).

That gentrification is marked by exclusion is now commonly accepted as part of the debate(Lees, 2012; Visser & Kotze, 2008). In this contemporary or "third-wave" of gentrification debates, the relationship between neo-liberalism, global capital flows and the changing role of the state in gentrification processes is highlighted. Indeed, researchers point to the emergence of a 'fourth-wave', where local and regional governance structures place the drive to rejuvenate city-centres in the context of global connectivity, to benefit from global capital flows (McDonald, 2008; Miraftab, 2007 in Visser & Kotze, 2008; Shin, 2016) . The positioning of Johannesburg as "a world class African city" is one such example. The mayor of Johannesburg visited several countries including the United States during June 2017, to promote the city as a global investment destination: he said, "…to realise our vision of ensuring a five percent growth rate by 2021, we need to create an enabling environment for business..." (Fourie, 2017, June 23, p.6)

In the context of neoliberalism, gentrification processes have found a ripe "**fast-policymaking**" climate, where post-ideological, pragmatic and self-propagating policies are intended to travel fast (Peck, 2010 in Lees, 2000). With technological advances, gentrification in this context has picked up quickly around the world, meaning that policies themselves are mobile and global. The danger here is that they can be easily co-opted by political players with no clear focus on social imperatives. This has serious implications for social housing-led urban renewal strategies, since it is proven that gentrification has the effect of driving out poorer incumbent populations. With no clear focus or the political will to emphatically place social housing initiatives at the heart of these processes, populations that stand to gain the most from better living conditions created by positive spillover effects lose out the most. Lees (2000) challenges these developments with a call to create a new literature that compares policies with practical examples from around the world, to test what kind of fit and results they produce.

In conclusion, gentrification is identified as a principal strategy for redevelopment of brown field sites, because of a propensity to generate economic spillover effects for the neighbourhood. Contemporaries of the gentrification debate argue that context and temporality is important in policy-making and implementation (Lees, 2012).

This is important in the drive to attract global capital flows that facilitate gentrification, which often happens at the expense of poor urban communities. The next section places the evolution of the Johannesburg CBD in the context of these debates.

2.2.4 The Evolution of the Johannesburg CBD

The previous section discussed the idea that redeveloping locations within the CBD can help to trigger renewal beyond the individual site, positive externalities which if not harnessed properly for poorer communities from a policies and implementation point of view, hold negative implications for the success of social housing development. In this section, the evolution of the Johannesburg CBD examined, and placed in the context of gentrification and neo-liberalism. The City's urban renewal plans and the place of social housing is discussed. Firstly, the city's urban formation is traced from its genesis as a mining camp in the late 19th Century, to apartheid and post-apartheid spatial development. Of particular importance, is the unfolding development of housing in the CBD. Lastly, the plan to revitalize the CBD is examined through the lens of social housing, and placed in the neo-liberal context.

2.2.4.1 Evolution: The Unfolding Urban Form

Johannesburg was proclaimed in 1886 as a mining camp in the richest goldfields of the world of the time. The Witwatersrand (Beavon, 2006). With it came a vast labour-force ready to exploit the mining opportunities, settling in and around what is now the core CBD. Initially, settlements were racially integrated, as in the example of Kliptown. The earliest known racially integrated settlement (*Johannesburg, The Segregated City,* n.d). The Union of South Africa was declared in 1910 and with it, harsh racial divides, **apartheid**, which related mainly to access to economic opportunities. As a result, there was a deliberate **undersupply of housing** for black-Africans in the urban areas. These were given spatial expression in the first Group Areas Act, promulgated on 7 July 1950. It empowered the government of the day to set aside particular geographical areas for residence by specific race groups. The legacy of this socially construed urban form persists to this day, and remains the focus of planning and policies that CBD reform and renewal attempts to **redress**.

According to Larsen (2004), the **decentralization** of the Johannesburg CBD began in the 1950s, predominantly with the move of council offices, and the establishment of new municipal councils such as Sandown and Bryanston (which later amalgamated to form Sandton) in the suburbs. After the initial gold rush of the late 19th Century, residential development had begun speculatively in the 1960s, catering mainly for European immigrants to the city.

Very little development was taking place beyond the borders of the core area (Bremner, 2000). This first wave of decentralization in the 50s was later followed by a more rapid decentralization in the 1970s.

Suburban residential development in the way of flats gained impetus during the **1970s**, as Sectional Title ownership was promulgated in 1971 (Beavon 2006, Larsen 2004). Many of the buildings in the CBD were also converted to Sectional Title and today, many have been abandoned by their owners (Winkler, 2013). It is argued that although there were some ‘push’ factors to re-locate from the CBD, they were not as pronounced in the 1970s. In fact, the ‘pull’ to the suburbs far outweighed the push factors. An example is given of similar size and quality buildings, one in the CBD and another in Milpark (a suburb of Johannesburg). In the former, the rates bill amounted to R60,000 per annum, whereas the latter building was only paying R6000 per annum (Segall, 1979 in Larsen 2004). In 1972, some 358 firms expressed a wish to relocate to the suburbs (Cohen, 1973 in Larsen 2004). The following factors cited as being chiefly responsible (Cohen, 1973; Segal 1979 in Larsen 2004).

- Expansion (land available in the suburbs). Competitive **land prices**;
- Reduce costs (suburbs **cheaper**). Attractiveness of potentially lower rentals;
- Integrate with existing office or factory Improve working conditions;
- Work close to home.

In Segall (1979, in Larsen 2004), indicates only two key push factors from the CBD at this time: **traffic congestion** and **parking** difficulties in the inner-city. This was possibly the first factor in the decline of the Johannesburg CBD. The perception of the premier position of the CBD as a commercial and residential location persisted to as long as 1989 (Mandy 1989 in Larsen 2004).

The decline of the Johannesburg CBD began in earnest during the **1980s** (Robinson 2000 in Beavon 2006; Larsen 2004; C. M. Rogerson & Rogerson, 2015). It was in 1986 that the Influx Control Act (an adjunct of Group Areas) which limited movements of races into prohibited areas was abolished. Coupled with the tense security situation of the time and the contraction in the national economy as a result of international sanctions against South Africa, many companies left the more expensive buildings of the CBD. The decline intensified with the scrapping of the Group Areas Act in **1990**, and with it, a massive influx of immigrants local and continental black-African **immigrants**, complemented by ‘White Flight’ decentralization (emigration of Caucasian populations) from the inner-city. Some landlords took this opportunity to raise rents, further pushing businesses and incumbent populations out to the suburbs. With rising rents, many of the buildings were not maintained, apartments became overcrowded leading to further CBD decline (Adler, 1997; Morris, 1996 in Bremner, 2000; Winkler, 2013).

Backlash came in the way of rent-boycotts, as people began to realise they were being exploited. Buildings were vandalized and many were abandoned by their owners (Mosselson, 2017a). This opened up the way for criminal syndicates and the now near common phenomenon of 'building hi-jacking' (Cox, 2015).

By the year 2000, the city had expanded its boundaries to incorporate independent municipalities such as Sandton and Randburg. The rich (mainly Caucasian) areas north of the CBD (Carruthers 1980, 1981 in Beavon 2006). As such, they created **'new' CBDs** some 10km away from the original one, further exacerbating Johannesburg CBD decay. As the decay intensified, banks began to 'redline' the CBD and surroundings, marking them as "no-go" areas for any kind of financing (Mosselson, 2017a).

Within the first 10 years of the proclamation of Johannesburg, the core area had housed banks, finance houses and mining company headquarters (Chipkin, 1993 in Bremner, 2000). At the start of the **1990s**, JSE listed companies, national enterprises, professional firms and their head-offices had called the CBD home. By the end of the 90s, **institutional capital disinvestment** from the CBD, and suburbanization of high-order services was a key factor contributing to CBD decay (Beavon, 2005; McDonald, 2008 in Visser & Kotze, 2008). The flight of capital from the CBD at this time is well documented (C. M. Rogerson, 2000a; J. M. Rogerson, 1995; C. M. Rogerson & Rogerson, 1995, 1997a, 1997b, 1999; Murray, 2011 in (C. M. Rogerson & Rogerson, 2015). Bremner (2000, p. 187) summarises it thus:

> *"Between 1982 and 1994, 17 of the 65 top 100 national public companies located in Johannesburg moved from the Central Business District (CBD) to decentralized locations (Tomlinson et al, 1995). Similarly, of a total of 104 top national business enterprises located in Johannesburg, in 1994, only 27% were located in the CBD. Of the top 10 retail companies in the country having their head offices in Johannesburg, only two remain in the CBD. In the area of accounting, all leading accounting firms in the country have retained their head offices in Johannesburg, but, whereas in 1982, all seven were located in the CBD, by 1994, only three remained. In the advertising industry, of the top 15 firms in the country, 14 are based in Johannesburg. In 1994, these were all located in decentralized areas; whereas in 1991, seven were located in the CBD…a clear picture emerges of capital flight from the CBD"*

One of the biggest transformations of the CBD post-1990, was the growth of **informal trading** and commerce in an already congested, dilapidated CBD (Biller, 1997 in Bremner, 2000). It was also at this time that the phenomenon of the City or Business Improvement Districts (CIDs/BIDs) arose, and not just in the Johannesburg CBD. Self-initiated and governed bodies made up of local businesses, geared mainly at reduction of crime, cleanliness, creating an environment to attract more businesses (Fraser, 1997).

A detailed audit of commercial property ownership in 1995 observed that the majority of buildings in the CBD still belonged to banks, insurance companies and mining houses (Rogerson 1995a, in Rogerson, 1996).

To summarize: Johannesburg was proclaimed as a mining camp in 1886; the Union of South Africa was declared in 1910 and with it, harsh racial divides. Apartheid. As a consequence, there was a deliberate undersupply of housing for black-Africans in the urban areas. The decentralization of the Johannesburg CBD began in the 1950s, but only picked up in the 1970s as decentralized locations became more financially competitive. The most notable push factor at that time was traffic congestion and a lack of parking. The building decay in the CBD began in earnest in the 1980s, exacerbated by the now established exodus of business, the tense security situation and the economic embargo brought on by the sanctions on South Africa. With a repealing of the key personal movement-related apartheid legislation by the 1990s, a massive influx of black-African populations happened on the heels of 'white flight' from the CBD, followed by rent-boycotts and building vandalism in response to exploitation. Decay was further exacerbated by capital disinvestment by large corporates in the 1990s. Today, the CBD suffers from such as ills as congestion, overcrowding, crime and grime as well as building decay.

2.2.4.2 A Way Forward: Revitalization Plans

Both in South Africa and abroad, governments at various levels have introduced urban regeneration programs, the heart of which is to 'reverse' inner-city deterioration (Atkinson and Bridge, 2005; Harvey, 1989, 2000; Lees et al., 2008; Smith, 1996 1996 in Visser & Kotze, 2008; and in South Africa: Dewar, 2004; Dirsuweit, 1999; Lemanski, 2007; Marks and Bezzoli, 2001; McDonald, 2008; Pirie, 2007 in Visser & Kotze, 2008). Up until 2016, there was no national policy framework on urban renewal, but most regeneration efforts by municipalities emphasized attracting sustained private investment, in order to create functioning property markets that lead to a rise in property values [in order to attract private capital investment] (HDA Report, 2013). The social housing sector was directly linked to these initiatives (Adler, 1997).

Central to these initiatives was positioning Johannesburg as a "gateway" into the rest of the African continent, true to the neo-liberal style of urban regeneration (Harvey, 1989; Imrie and Thomas, 1993 in Bremner, 2000). A view asserted by Suborg's (2011) analysis of the position of Johannesburg among world cities (in C. M. Rogerson & Rogerson, 2015). Bremner (2000, p. 187) posits:

> "*It had very little to do with the economic, social and physical changes which had taken place in the city over time, instead seeking to capitalize on South Africa's imminent re-entry into the world as an opportunity for re-imaging and regenerating the city*".

An aspiration was for Johannesburg to acquire "World City" status, and was marketed thus (Shachar, 1994 in Bremner, 2000; Rogerson, 1996 in Rogerson & Rogerson, 2015). The inner-city was presented as a "showroom" of the economic center of the sub-continent. Among the top ten strategic projects was a **housing initiative**; a light rail initiative linking the CBD to Soweto, now known as the Gautrain, the development of a "Jewel City" on the eastern side of the CBD and various other initiatives. To date, only some of these projects have come to fruition and the deterioration in the CBD persists (Winkler, 2013). Mossleson (2017, p.1283) summarizes: "This was…the time in which neoliberal policies and practices became entrenched in South Africa".

The Bad/ Better Building Program (BBP), was launched in 1999, and ended in 2007 and has since been resurrected (HDA Report, 2013; Mosselson, 2017a). Buildings that were in a particularly bad state of repair and in arrears in rates and taxes were identified. The council would take them over (through rehabilitation or demolition) then hand them over to the private sector. Again, commentators noted that there was **no enabling environment** for social housing in the CBD that is supported by a **policy framework** (HDA Report, 2013; Mosselson, 2017a). Projects are ad-hoc and sporadic, there is no sustainability. Companies acquiring buildings through this program are expected to cater to the social housing market (income earners of between R3500 and R7000 per month). Mosselson (2017a) points to a rent-gap in the inner city that attracts gentrification. Depressed buildings can be unlocked with relatively little capital outlay, and this makes the inner city ripe for social housing. In reality, ironically, one of the factors highlighted as making social housing unaffordable to the very target market it seeks to serve, is the unexpectedly high initial capital outlay actually required (Tomlinson, 2015). In this project, local government played a limited role, focusing predominantly on infrastructure provision and creating a positive environment for capital investment, with the aim of increasing the value of property (Mosselson, 2017b, Mosselson, 2017c).

Because the large retail banks still redline these areas, it has opened opportunities for **new financiers** such as African Housing Company (AFHCO); Trust for Urban Housing Finance (TUHF); the National Housing Finance Corporation (NHFC) and GPF. These specialize in social housing provision. Households below this bracket qualify for a free house provided by government (RDP), whilst those that earn R7000 to R14,000 per month are expected to acquire a house through normal market mechanisms. However, they are often rejected by banks as being too risky to lend to. This is the so-called “gap-market”, and it is to these households that the new financiers strictly cater. They are able to obtain lenient loan terms, which they on-sell to their clients. Typically, rents charged are not higher than R4,500 with rent increases no higher than 8% per annum (TH 09/03/2013 in Mosselson, 2017a).

However, the role of local government is not only limited to infrastructure investment, as it gets involved directly through its social housing arm; Johannesburg Social Housing Company (JOSHCO). The Mayor announced, in the 2017 adjustment budget presentation, increased funding to the JOSHCO amounting to R 219 million, specifically for purchasing buildings that will be refurbished and converted into low cost rental stock (Mashaba, 2017). A further R5.8-million has been set aside for an investment masterplan, R9-million for informal trading and R35-million for the development of small business (*Private Sector sign MoU to Revive Inner City,* July 30 2017). In 2015, JOSHCO was allocated a budget of R493m against a target of 95% (JOSHCO, 2016). So the new inner-city funding is virtually half the previous budget. Forty-eight percent was on construction, with 41% spent in the inner-city, including the buying of 5 buildings (812 units) for refurbishment. By the end of 2016, three of these buildings were in construction. In 2007 the target was at least 50 000 (and ideally 75 000) new residential units by 2015, either in the Inner City or near to it (Inner City Charter, 2007)(HDA Report, 2013). The Housing Minister, Lindiwe Sisulu on the back of a policy meeting requested that council-owned land that is located close to cities and city centers must first be offered to the housing ministry for purchase (Kekana, July 5, 2017).

It is acknowledged that for Johannesburg to develop, it requires a **range of interventions**, that includes issues of housing, labor market policies, improved mobility by enhanced transport and growth management, integrating the informal economy and immigrants into the economy (OECD, 2011; Todes, 2012a in C. M. Rogerson & Rogerson, 2015).

In conclusion, in the absence of a national policy framework on urban renewal (until recently), the common theme for urban renewal across municipalities was economic growth; sustained private investments and **integrating non-housing initiatives**. There are a number of initiatives underway in the CBD involving both direct investments by local government, as well as indirectly creating a positive environment for private sector investment. Mosselson (2017a, p.1281) states “…developmental ambitions cannot escape the constraints of neoliberalism and the benefits of the renewal process are limited by the prevailing socio- economic and political conditions”.

Beall et al., (2000) and Bremner (2000, 2004) in Mosselson (2017a) argue that too much emphasis is placed on Johannesburg attaining a "world city" status, at the expense of poverty alleviation in the city (see also Mosselson, 2017b, 2017c).

It is an observation of this research that there can be a happy medium between all players and stakeholders in the CBD, where property values do not need to be impinged upon by dereliction, lawlessness and neglect, nor do the urban poor need to be excluded from spaces. The role of local government in this scenario is crucial to almost 'force' an accommodation of social imperatives in the unfolding betterment of the city, and to resist the displacing mechanism of global capital for the sake of poor urban South Africans.

2.3 The Social Housing Target Market

The previous section was a review of the development of the Johannesburg CBD, and some of the initiatives that are planned to rejuvenate the CBD. Especially from a social housing perspective. A caution was raised around the displacement of the urban poor, both as a dividend of gentrification and by planned removals. This section highlights the important elements of the South African Social Housing Act (16 of 2008) as they specifically relate to projects that help to bring about renewal in CBDs. Firstly, a review of Social Housing Supply since 2006, looking at the geographical spread of projects. Next, the legislation's mandate to trigger urban regeneration is discussed. Lastly, the profile of the social housing target market is dissected, to gain an understanding of the key amenities they require access to.

2.3.1 Social Housing Supply Since 2006: The Mandate to Trigger Urban Regeneration

As discussed in previous sections, one of the most patent results of apartheid-era legislation is a massive housing backlog, particularly in the urban areas (Sipungu & Nleya, 2016). Although more than 3 million houses have been supplied since 1994, the backlog is at its highest margin than ever: a backlog of 2.1 million units, while the number of informal settlements has gone up from 300 to 2225, an increase of 650% (Tomlinson, 2015). The housing backlog in Johannesburg stands at 158 000 units, with 80 000 units in the inner city alone (*Private Sector sign MoU to Revive Inner City,* July 30 2017). Nationally, there is an undersupply of rented accommodation for low to middle-income earners. The Social/Affordable Housing Legislation (Act 16, 2008) provides for a subsidy for households earning less than R3 500, and support to gain access to housing loans for households earning between R3 500-R7 000 (Mosselson, 2017a; Tomlinson, 2015). The program has been in inception since 2006.

There are five types of subsidies: individual and project-linked, consolidation, rural and institutional subsidies (Sipungu & Nleya, 2016). The institutional grants are given to social housing agencies for initial capital costs and equity contributions when developing social housing (Mosselson, 2017a; Sipungu & Nleya, 2016).

The Act defines social housing as:

> "*a rental or co-operative housing option for low to medium income households at a level of scale and built form which requires institutionalized management and which is provided by social housing institutions (SHI) or other delivery agents in approved projects in designated restructuring zones with the benefit of public funding*" *(Sipungu & Nleya, 2016, p.10).*

The rental option as particularly important, as it renders choice mobility to households with insecure incomes (Mayson & Charlton, 2015; Eastern Cape Human Settlements, 2014 in Sipungu & Nleya, 2016).

The act emphasizes that housing units are to be rolled out in "designated restructuring zones" or RZs (HDA Report, 2013). There are 16 RZs in the City of Johannesburg **including the CBD**. In 2013, the National Social Housing Organization (NASHO) undertook a study to understand whether the RCG subsidies were being used in the right parts of cities (HDA Report, 2013). Tomlinson 2015 explains: "there is a major push in the National Housing Policy for a better integration of housing within inner cities…the Breaking New Ground (BNG) policy of 2004 puts great emphasis on the role of social housing as a driver for urban regeneration" (p.7). From 2006 to 2012, approximately R2.1bn was spent on RCGs (HDA Report, 2013). The NASHO study found that only 15% of 20 projects (for which they received survey responses) nationally, were physically located in inner cities. The HDA Report (2013, p.26) states: "Eight of the 32 projects were in Urban Development Zones (UDZs) and only two were linked to broader municipal programs for 'urban regeneration"'. The report indicates that a major reason for this is the difficulty of acquiring well-located land at a price to make projects financially viable.

The mandate to trigger urban regeneration is emphatic in the legislation. By 2017, the number of RZs had been increased to 138 nationally (from an initial 127) (Tshangana, 2017). In the Gauteng province, the additional RZs are outside Johannesburg. NASHO has highlighted deficiencies with the RZ policy and its implementation, indicating that it needs to be "reviewed to assess whether it is properly helping to target RCG investment in areas that could benefit most" (NASHO 2012, p.13) .

Furthermore, that the RCG application process by municipalities should also be reviewed to better select projects with links to other government initiatives, and potential to have more impact on surroundings.

In conclusion, the Act mandates designated restructuring zones as hotspots of sorts to redress apartheid-era spatial formation and housing shortage. The Johannesburg CBD is one such RZ. Until of recent, there's been an imbalance in the spatial distribution of social housing projects away from CBDs. Initiatives are underway to reverse this trend. Of significance is the call to forge stronger linkages between social housing investment and other government programs; understanding the impact of social housing developments on their surroundings, as well as understanding why tenants choose to live in social housing in a particular location and what affects this choice. In the next section, the profile of the social housing target market is dissected, to gain an understanding of the key amenities they require access to.

2.3.2 Basic Services and Amenities for Low-income Groups

The previous section examined social housing supply since 2006, specifically looking at the geographical spread of projects. In this section, we study the beneficiary of social housing policies: the urban poor, to better understand their basic needs and dissect the current location-choices they make.

According to the Bureau for Market Research (BMR), there are eight income classification groups for households. The lowest (poorest) and second lowest income households earn (R0-R19000 and R19,001-R86,000 per annum respectively (R0-R1,583 and R1,584-R7,167 per month) (Ismail et al., 2016).

Table 3 South African Households Annual (Monthly) Income Categories According to Bureau for Market Research (BMR)

- Low Income
  - R0 - R19,000 (R0 - R1,583): Lowest income group
  - R19,001 - R86,000 (R1,584 - R7,167): Second lowest income group
- Middle Income
  - R86,001 – R197,000 (R7,168 – R16,417): Low emerging middle
  - R197,001 - R400,000 (R16,418 - R33,333): Emerging middle
  - R400,001 - R688,000 (R33,334 - R57,333): Lower middle
  - R688,001 - R1,481,000 (R57,334 - R123,417): Upper middle
- Upper income
  - R1,481,001 - R2,360,000 (R123,418 - R196,667): Emerging affluent
  - R2,360,001+ (R196,668+): Affluent earning

Source: Ismail et al. 2016, p.2

Research by Ismail et al. (2016) revealed that low-income households tend to spend most of their income on transport and food costs. Their research found that the R0-R86, 000 per annum group spend 29% to 34% of their budget on food (meaning they are extremely exposed to food inflation).

Transport expenditure takes up 11% to 12%, and on average, very little is spent on education and health-related costs (1-1.5%). Their work further revealed that the primary source of income for all income groups is salaries and wages (64% of households), with the remainder dependent on social grants. They indicate that the low-income group makes up nearly two-thirds (62.3%) of the national population.

In furthering understanding around food expenditure patterns, data from the African Food Security Urban Network's 2008 study indicated that as much as 80% of the sampled population could be classed as virtually 'food insecure' (Battersby, 2011), defined by the World Food Program as poor or no access to, availability and utility of food. According to Battersby (2011), in urban areas, food insecurity relates more to **lack of access to food** rather than food availability (Battersby & Peyton, 2014). Furthermore, that the more food insecure a household is, the more they are likely to depend on informal means of securing food. In the South African context, such informal shops are known as "Spaza Shops".

The research showed that mark-up of products at informal shops could be as much as 20-30%, compared to 13% at formal supermarkets (Wilkinson & Makgetla 2002:6 in Battersby 2011). The research also showed that although the households had sourced food from supermarkets in the past year, and on an on-going, day-by-day basis, they were more likely to access food from informal shops, despite the price differences. Weatherspoon & Reardon (2003, pg. 338) in Battersby (2011) indicate that supermarkets only started rolling out in former black-African Townships in the 2000s. Because their roll-out models are based on profit maximization, they are often inaccessible by the urban poor (Battersby & Peyton, 2014; Peyton, Moseley, & Battersby-Lennard, 2015). However, the case may be slightly different in CBDs, whereas incomes may be low, but foot-traffic is high.

A key differentiator between formal supermarkets and spaza shops, is that the former are unlikely to operate a credit system, as the latter are inclined to do (Ligthelm, 2005:210 in Battersby, 2011). Reardon et al. (2003:1142) in Battersby (2011); Battersby & Peyton (2014); Peyton, Moseley, & Battersby-Lennard (2015) indicate that as much as there has been growth in the significance of supermarkets amongst the urban poor (1,700 supermarkets compared to 350,000 spazas), spaza shops still remain the main source of food security for poor urban households.

Such resilience is also evident with social housing provision. Mosselson (2017a) conducted a 9-month ethnographic, survey supported by housing ownership interviews, as well as interviews with housing providers, security personnel and government. His study focused on the CBD, Jeppestown (eastern side of the CBD); Hillbrow and Berea (both north-east of the CBD, but in close proximity).

The study revealed that while landlords conduct the necessary due-diligence to ensure that tenants can afford the required rentals, there is also a trust relationship that allows for some leniency: a single tenant lets the premises and is allowed to sub-let to other tenants. “Rooms and Spaces” as they are termed by Mayson & Charlton (2015), are a common informal means of accommodation in the inner-city: “housing providers do not simply impose exclusionary visions and practices, but rather adopt pragmatic approaches which adapt to the needs and realities of the inner-city and its inhabitants.” (Mosselson 2017a, p. 1287).

Regarding wage-earning and employment, the HDA Report (2013) indicated that ironically, many of the inhabitants of social housing do not actually work in the CBD, but as domestics and casual labourers in the suburbs. Nevertheless, Gotz and Todes (2014) in Mosselson (2017a,b) indicate that most employment opportunities are concentrated around the CBD, and towards the north of the city. Shen (1998) examined the employment accessibility of low-wage workers living in Boston's inner-city Neighbourhoods. In it, he concluded that on average, low-wage workers living in inner-city Neighbourhoods don’t have high employment accessibility because a large majority of them do not own cars. In a later study, Shen (2000) stated that urban spatial structure bore great importance in explaining variation in commuting times of low-income workers in the inner city. He observed that treating the city as a single spatial entity tended to understate the [commuting] difficulties of the poor. The findings implied that enhancing the mobility needs of the poor and land-use planning were both worthwhile exercises for increasing access to jobs and shortening commute times for the poor. Shen used regression modeling to assess his results.

Respondents to Mosselson’s (2017a) survey pointed to ease of access to transport facilities and the necessary interchange nodes in the CBD, as a key factor in their ability to save money, despite rentals (in social housing facilities) being ‘pricey’. Mossleson (2017b) indicated that many of the respondents were studying[2]; others were not working because their partners were employed. He further indicated that 19 out of 57 respondents explicitly stated that **they came to live in the CBD to be closer to employment opportunities**. Many of the respondents also alluded to the ease of proximity of other amenities such as shops. While respondents acknowledged the negative circumstances of the nodes where building projects are located (e.g. drugs, crime), good access to their needs, outweighs the option to leave;

[2] JOSHCO wants to pilot students’ accommodation in the CBD (2017/18 budget cycle).

summed up in the following words: 'It's not a place I like, but I can live with it' (Tenant Six, Rochester, June 26, 2013 in Mossleson 2017b, p.155).

The BNG policy for sustainable human settlements promulgated in 2004 which included the development of social housing as a catalyst for inner-city regeneration expressly sought the creation of "ancillary facilities", such as schools, clinics, community halls, and informal trading facilities, around social housing facilities, as well as integration with other housing-types, ultimately creating a neighbourhood (Tomlinson, 2015). These observations assert the theory that the CBD is of prime importance in redressing the spatial imbalance introduced by legacy legislation and attacking the housing back-log, the bulk of which lies in the low-income bracket.

In conclusion, research has found that poor households tend to spend most of their income on transport and food costs. For this reason, access to key amenities and mobility are crucial for poor urban households, as they serve to lower commute costs. Household resilience strategies play a large role in meeting basic needs, whether for food or accommodation. It is therefore, an aim of this research to incorporate the distribution of spaza shops in the analytical section. The next section presents the analytical approach of the research.

2.4 Methodology and Application

In the previous section, the basic needs of poor urban households were examined. The central role that mobility and accessibility plays in availing the social and economic benefits to be had in cities and CBDs was also discussed. This section presents the analytical approach of the research. Firstly, GIS studies of accessibility in South Africa are discussed. The HDA 2013 survey results are looked at as an example. Furthermore, accessibility as the link between transport and land-use is discussed. Next, the technical approach is discussed: 1) ARIA measure of Network time-distance 2) service area shape and size and 3) measuring the spatial distribution of services and amenities using KDE.

2.4.1 Measures of Accessibility

That the South African Social Housing Act (16, 2008) mandates the roll-out of affordable housing in designated restructuring zones speaks to an awareness of the importance of accessibility for the urban poor. Sipungu & Nleya, (2016) indicate that social housing extends affordable, *well-located* accommodation to poor households. The NASHO agrees that "CBD areas have significantly easier access to a range of important socio-economic opportunities" (HDA Report 2013, p.4). Giuliano, Redfearn, Agarwal, & He (2012) have conducted research on the relationship between accessibility and the growth of employment centres, and concluded that labour force accessibility and network accessibility are significantly related to employment growth. Shen (1998, 2000), Sanchez, Shen, & Peng (2004), have also highlighted the relationship between employment and accessibility.

There have been a number of studies in South Africa pertaining to measuring accessibility using GIS tools. A large proportion of them relate to measuring accessibility to health care facilities (Bhana & Pillay, 1998),(Frank Tanser et al., 2001),(FC Tanser, 2002), (Tsoka & Le Sueur, 2004), (Frank Tanser et al., 2006), (Mokhele et al., 2012), (Mokgalaka, 2014). In these studies, accessibility is measured in terms of distance from health facilities, and frequented health facility. These are used to draw service areas.

Other studies relate to accessibility to services in rural areas, and focus on optimizing facility location, or improving rural mobility infrastructure (Naude et al., 1999), (Nhemachena, Chakwizira, Dube, & Mokonyama, 2011). A police station siting study in Bushbuckridge, South Africa, used siting optimization techniques as a measure of accessibility. The FlowMap GIS extension developed at Utrecht university was used to optimize average distance and worst case distance in each siting scenario (Jong, Maritz, & van Eck, 2001). In another study, Community Neighbourhood Park (CNP) proximity was measured as the maximum acceptable distance to walk to the nearest CNP (Willemse, 2013).

The HDA Report (2013) which was compiled to understand whether the RCG subsidies were being used in the right locations, used a sample of 20 respondent projects to assess the quality of access to social and economic amenities in different spatial locations. The methodology was a simple 1,5-km buffer drawn around each project, to calculate how many amenities were near:

Table 4 HDA 2013 Survey: Amenities located within social housing surroundings

Spatial type	SAPS	Post office	Private hospital	Public hospital	Medical clinic	Total medical facilities	Secondary school	Primary school	Combined schools	Total schools
Suburban Outer	1 Less than one per project	3 Less than one per project	0	0	0	0	3 Less than one per project	11 About 3 per project	1 Less than one per project	15 About 4 per project
Suburban Inner	3 Less than one per project	6 About one per project	5 One per project	4 Less than one per project	3 Less than one per project	12 **About 2,5 per project**	8 About one per project	27 About 5,5 per project	6 About one per project	41 **About 8 per project**
CBD	6 Less than one per project	20 2 per project	36 About 3,5 per project	5 Less than one per project	6 Less than one per project	47 **About 5 per project**	46 About 4,5 per project	62 About 6 per project	20 About 2 per project	128 **About 13 per project**
Greyzone	0	0	0	0	0	0	0	0	0	0

Source: HDA Report, 2013 p.26

Source: HDA Report, 2013 p.27

Table 5 HDA 2013 Survey: Transport facilities located in social housing surroundings

Spatial type	Taxi rank	Railway station	Bus stop	Total transport facilites
Suburban Outer	1	2	0	3 **Less than 1 per project**
Suburban Inner	0	3	0	3 **Less than one per project**
CBD	70	18	146	234 **About 23 per project**
Greyzone	2	0	3	55 **Around 1 project**

Even with this simple method, significant insights are obtained: the CBD is by far the location of choice when it comes to proximity to amenities. The study by Mosselson (2017a) confirms that people are influenced more by ease of access to amenities and employment than negative externalities that exist in the CBD. The Gauteng City Region Observatory (GCRO), Quality of Life (QoL) survey uses a similar methodology, where accessibility is measured as percent (%) of dwellings/population within walking distance/ 3km from social amenities (Venter, 2014).

According to Venter (2014), (in)accessibility is a key component of urban poverty and social exclusion. Accessibility impacts land values and influences the location decisions of households and individuals. Accessibility is the key concept that links land-use with transportation (Acheampong & Silva, 2015; Liu & Zhu, 2004). Section 2.2 of this Chapter highlighted the intricate relationship between **land-use** and **transport** in urban spatial formation. Transport involves both accessibility and mobility.

Land-use incorporates a number of activity locations: primarily residential, employment, and adjunct activities e.g. shopping, schools, and recreation (Acheampong & Silva, 2015). According to Yang and Ferreira (2008 in Acheampong & Silva, 2015), the two combined provide the spatial anchor to understanding commuting patterns and their impact on urban form over time, conventionally described by the classic monocentric urban economic models of the Burgess (1925) era. Initially the literature pointed to residential choice, a long-term decision, as being independent of employment location choice (Waddell 1993, Waddell et. al 2007 in Acheampong & Silva, 2015). More recent work however, indicates that “residential and job location choices as well as subsequent housing and job mobility decisions are jointly determined” (see Boschmann 2011, Habib, Miller, and Mans 2001, Kim, Pagliara and Preston 2005, Pinjari and Bhat 2011, Tilahun and Levinson 2013, Waddell et al. 2007, Yang, Zheng and Zhu, 2013 in Acheampong & Silva, 2015, p.17). This behaviour is reflected also, in Mosselson’s survey (2017b) of the Johannesburg CBD.

The **transport** accessibility component involves understanding *travel demand* from two main approaches: the four-step model (FSM) and Activity-Based Approach (ABA) (Acheampong & Silva, 2015). The fundamental difference between the two is that FSM does not consider travel to be a derived demand, and therefore ignores the motivation behind trips, whereas ABA does. ABA sits in the realm of space-time geography and integrates aspects of human behavior modeling and economic choice theory (utility maximization). Of the various approaches to measuring accessibility identified in the literature: "person-based," "location-based," "infrastructure-based," and "utility-based' measures, the latter are considered to be the most satisfying (Geurs, De Bok and Zondag 2012 in Acheampong & Silva, 2015). They originate from random utility maximization theory, which was mentioned in section 2.2.1. According to classical utility maximization theory, people select the most accessible residential locations to their workplaces to minimize commute costs, all things being equal (Acheampong & Silva, 2015).

ABA has a simple assumption that travel is a derived demand, where people undertake interrelated activities (McNally and Rindt 2007 in Acheampong & Silva, 2015):

- It integrates time-constraints of travel
- Demand for activity participation
- Assesses complex interpersonal relationships between households and individuals
- Trip-scheduling and chaining behavior in time and space

Measures of accessibility are important from the point of aiding policy-maker to easily identify gaps in service provision, planning, identifying areas where new services are needed and confirming the effectiveness of existing service distribution. They offer "a means by which access inequalities can be measured" (Taylor & Lange, 2016).

According to Taylor & Lange (2016), 'accessibility' is complex and multi-faceted concept that includes both spatial and a-spatial dimensions. The aspatial can include such factors as availability, affordability and adequacy, while the spatial tends to refer to distribution of services. In his 2002 paper, Geurs indicated that from a time-space geography point of view, accessibility tends to be measured in terms of infrastructure-based measures such as the level of service of the road network, congestion levels or average travel speed. But that it tends to exclude the spatial aspect of accessibility. He points out that the conventional method is focused on the enablement of individuals to carry out desired activities in space. However, these activities are distributed geographically in space, and this makes a significant impact on studies about accessibility.

It is the distribution of activities in space that Activity-Based (ABA) measures of accessibility focus upon. He further divides up the concept of ABA into two approaches: 1) potential accessibility measures; 2) time-space measures (i.e. how many activities can an individual participate in a given time), used in time geography (Miller, 1991; Wang and Timmermans, 1996 in Geurs 2002). In his study of the accessibility of jobs in the Netherlands from 2005 to 2020 is a potential activity approach, which he indicates has been used since the 1940s (Hansen, 1959; Stewart, 1948; in Geurs 2002). They describe the level of access to opportunities or activities that are spatially distributed. The Metro ARIA measure falls in this category.

The ABA approach has been criticized for "lack of sound theoretical and rigorously structured methodological foundations" (McNally and Rindt 2007, p.19 in Acheampong & Silva, 2015). Other criticisms relate to the way activities are scheduled and choosing heuristics and decision rules (Ax-hausen and Gärling 1992 in Acheampong & Silva, 2015).

In conclusion, this section reviewed GIS studies of accessibility in South Africa. The HDA 2013 survey results are a good point of departure for the results expected in this research, though the methodology was a simple one. Next, accessibility as the link between transport and land-use was discussed. Land-use represents a number of different activity locations: primarily residential, employment, and ancillary activities e.g. shopping, schools, and recreation. Residential and employment locations choices tend to be made in conjunction. They are the target of travel demand choices which involves overcoming space-time constraints within complex human inter-relationships and desires, which the ABA approach caters for. The utility maximization theory of ABA holds that people aim to minimize commute costs, by choosing the most accessible locations. Geurs (2002) indicated that ABA potential accessibility approaches describe the level of access to opportunities or activities that are spatially distributed. The Metro ARIA method falls in these approaches. In the next section sub-sections, the technical approach is discussed: 1) ARIA measure of Network time-distance 2) service area shape and size.

2.4.1.1 Measuring Accessibility: ARIA Measure of Network Time and Distance

According to Kwan, Murray, Kelly, & Tiefelsdorf (2003), simple spatial measures of distance or time cost interaction of network interaction are 'first level' measures of more complex spatial interactions (usually cognitive or heuristic).

The Metro ARIA concept based on the work of Somenahalli et al. (2016) a network distance (and conceptually time) measure was introduced in section 1.3. It measures the proximity of essential amenities and services. With a range of values from zero (high accessibility) to 12 (high remoteness), it is based on road network distance measurements from the centroid of a property parcel to the nearest services (e.g hospitals, shopping centers, schools etc.). Once measurements are derived, they are standardized to a ratio by dividing by the weighted mean for that service. A capped maximum value is applied to each service type (0-2 or 0-3), and they are summed to get an overall measure of accessibility

– a score out of 12, derived by the Jenks' natural break method in the 0-12 continuous variable (DHAC, 2001).

Table 6 Explanation of ARIA Scores

1. **Highly Accessible** (ARIA score 0 - 1.84) - relatively unrestricted accessibility to a wide range of goods and services and opportunities for social interaction
2. **Accessible** (ARIA score >1.84 - 3.51) - some restrictions to accessibility of some goods, services and opportunities for social interaction
3. **Moderately Accessible** (ARIA score >3.51 -5.80) - significantly restricted accessibility of goods, services and opportunities for social interaction
4. **Remote** (ARIA score >5.80 - 9.08) - very restricted accessibility of goods, services and opportunities for social interaction
5. **Very Remote** (ARIA score >9.08 - 12) - very little accessibility of goods, services and opportunities for social interaction

The scores were generated for an overall picture of accessibility for the entire geography of Australia. The table below explains in detail, the included services and their weightings, as they were applied:

Table 1 Metro ARIA as it was applied in the Adelaide research

Service type	Service facilities and weighting	Score range
Health (Health ARIA)	(Major Hospital + All Hospital + GP)/3	0–3
Shopping (Shopping-ARIA)	(CBD + Major Shopping Centre + Supermarket)/3	0–3
Education (Education-ARIA)	Primary School + High School + TAFE + University)/6	0–2
Public transport (Public Transport ARIA)	(All transit stops + Go Zone (high frequency) stop + Interchange)/4.5	0–2
Financial and postal (Finance-ARIA)	(Bank + Post Office)/3	0–2
Metro-ARIA = Health-ARIA + Shopping-ARIA + Education-ARIA + Public Transport-ARIA + Finance ARIA		0–12

Source: Somenahalli et al., 2016, p.15

Note: The higher weighted services assume greater need for accessibility to those services, as the higher weights mean the final scores for them will be lower (i.e. reflecting greater access).

The work of Somenhali et al. (2016) did not apply the same interpretation of the scores as in table 6, instead, the results were used as an input into a Geographically Weighted Model (GWR), together with other exploratory variables (e.g. distance to the CBD, population density etc.), to test the strength of the relationship between them. In this research, the 5-class Jenks' natural break method of scoring is applied. Furthermore, there is particular interest with services that are most significant for urban poor households locally, as identified in section 2.3.2 of this chapter. Research by Ismail et al. (2016) revealed that low-income households (R0-R86,000 per annum) tend to spend most of their income on transport and food costs. Their research found that this group spends 29% to 34% of their budget on food.

Transport expenditure takes up 11% to 12%, and on average, very little is spent on education and health-related costs (1-1.5%).

For this reason, a tweaking of the weightings was applied in this research, to slightly adjust the Adelaide index, to reflect this reality of the South African urban poor. That is access to food and transport were given the highest weights:

Table 7 Application of Remoteness Index for this Research

Service type	Service facilities and weighting	Score range
Health (Health ARIA)	(Major Hospital + All Hospital + GP)/3	0–3
Shopping (Shopping-ARIA)	(Spasa + Major Shopping Centre + Supermarket)/6	0–3
Education (Education-ARIA)	Primary School + High School + FET + University)/3	0–2
Public transport (Public Transport ARIA)	(All transit stops + Go Zone (high frequency) stop + Interchange)/4.5	0–2
Financial and postal (Finance-ARIA)	(Bank + Post Office)/3	0–2
Metro-ARIA = Health-ARIA + Shopping-ARIA + Education-ARIA + Public Transport-ARIA + Finance ARIA		0–12

Source: Somenahalli et al., 2016, p 15 *Note: Education and shopping have swapped weights.

Furthermore, distance measurements to the CBD (see table 2) have been excluded, since the study area in its entirety is within the Johannesburg CBD (figure 6). Clinics will be included for this research. It is noted that Australia's TAFE (Technical and Further Education) institutions, serve the same purpose as South Africa's FET (Further Education and Training) colleges. On the basis of the literature on urban poor food security issues in section 2.3.2, 'spaza' (informal) shops are also included.

ESRI's Spatial Analyst extension to ArcMap 10.2 can assess the travel cost (time and distance) to the closest facility using the closest facility solver. It works out and displays the best routes between two locations, while reporting on travel costs. It is possible to specify the number of facilities to be found. For this research, only the closest location of each service type will be extracted.

The ARIA calculation will be applied as follows:

$$ARIA_{Li} = \sum_{L} \min\left\{3, \frac{x_{Li}}{\bar{x}_L}\right\} + \sum_{L} \min\left\{2, \frac{y_{Li}}{\bar{y}_L}\right\} \qquad (1)$$

i = parcel location and L is the service type
x_{Li} = distance to the nearest service from each parcel for Health and Shopping services
y_{Li} = distance to the nearest service from each parcel for Education, Public Transport and 'Financial and Postal' services
$\bar{x}_L$ *and* $\bar{y}_L$ is the mean road distance of all parcels to the nearest category *L* service type within the metropolitan area.

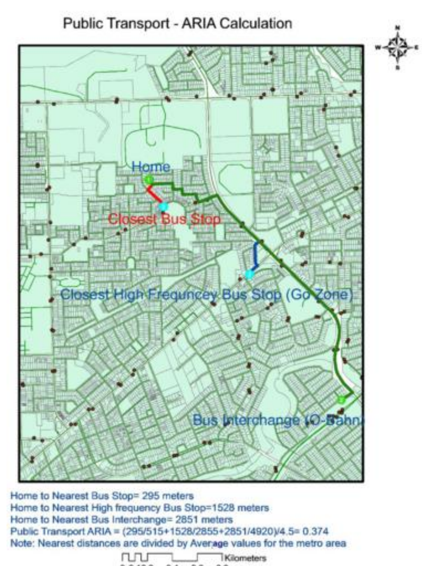


Figure 5 ARIA Calculation formula and worked example

Source: Somenahalli et al., 2016, p.15

In the next sub-section, the service area approach to measuring accessibility is discussed.

2.4.1.2 Service Area Shape and Size (Standard Distance)

"Service area" and "Catchment area" can mistakenly be used interchangeably. Landex, Hansen, & Andersen (2006) for example, use the former to refer to network distance buffers, and the latter to circular buffers. However, the former relates to a natural region in which services are rendered by an institution, as a result of its 'drawing power' on clients living in specific geographical areas on the one hand, and the cost (time, distance, price) limit clients are willing to pay to access the services or goods on the other. The latter term comes from the field of hydrology, and refers to the land area from which run-off water finds its way to a particular watercourse (e.g. a river). Therefore, in this research, only "service area" (SA) is referred to.

SA demarcation is a natural follow-on to working out time or distance cost to the closest facility. In the South African studies pertaining to measuring accessibility using GIS tools mentioned previously, generally distances measured are Euclidean. It is however, also possible to generate SAs from time-distance travelled, using isochrones or lines of equal time distance from a point (Landex et al., 2006; Liu & Zhu, 2004; Naude et al., 1999) . For example, lines of equal 30-minute intervals can be drawn around locations.

A "Service area" in this research is used to describe the area in which tenants will need to travel from their residence, in order to go and acquire services and amenities. In none of the previously mentioned studies was *spatial extent* expressed as SA size or compactness put forward for further analysis. SA *size* analysis can give further insight into time and distance costs of access. In a study of catchment areas around stops at high-quality public transport systems in Denmark, Landex, Hansen, & Andersen (2006) demonstrate the stark contrast. Not just between Euclidean and service area buffers, but also *amongst* the latter. In drawing 600m buffers of both types around the stops, the Euclidean buffers had the same[3] area size in square metres, but the service area buffers ranged in size from approximately 400,000m^2 to slightly over 850,000m^2.

Borruso, 2003; Flores et al., 2013; Garrocho-Rangel, & Álvarez-lobato, 2013; Garrocho, 2016; Gutiérrez et. al, 2008 concur that Euclidean methods tend to overestimate results. In this research, for each of the

[3] With two exceptions which were not explained.

locations that will be identified as being potential re-development sites, an SA, based on all the closest facility results (i.e. by amenity type) will be created.

Table 8 Proportions between the sizes of the catchment area calculated with the circular buffer approach and Service Area approach for Station in Copenhagen

Station	Area (600m Circular Buffer)	Area (600m Service Area Buffer)	Proportion
Bispebjerg (S-tog)	1,130,970 m^2	419,879 m^2	0.37
Charlottenlund (S-tog)	1,130,970 m^2	728,505 m^2	0.64
Christianshavn (Metro)	1,130,970 m^2	663,117 m^2	0.59
Dybboelsbro(S-tog)	1,130,970 m^2	596,301 m^2	0.53
Hellerup (S-tog)	1,130,970 m^2	855,473 m^2	0.76
Jaegersborg (S-tog)	1,130,970 m^2	652,961 m^2	0.58
Nordhavn (S-tog)*	1,226,513 m^2	671,198 m^2	0.53
Noerrebro (S-tog)	1,130,970 m^2	842,050 m^2	0.74
Oesterport (S-tog)*	1,327,989 m^2	709,205 m^2	0.54
Sjaeloer (S-tog)	1,130,970 m^2	715,351 m^2	0.63
Svanemoellen (S-tog)	1,130,970 m^2	703,817 m^2	0.62
Sydhavn (S-tog)	1,130,970 m^2	654,828 m^2	0.58

(*) Station has more than one entrance

Source: Landex, Hansen, & Andersen (2006 p.8)

Other than finding the shortest route or closest facility, ESRI's Spatial Analyst extension to ArcMap 10.2 can also build SAs from time or distance on a network. Since the functionality keeps a running total of the length of road segments as it runs, it investigates the maximum distance along each available route, the endpoints of which become the perimeter of the service area, calculated as convex hulls (*Proximity Analysis*, n.d). The spatial extent of each generated SA in square meters or kilometers will then be calculated, and the most compact (smallest size) ones will be identified. These will then potentially be the most efficient in terms of travel costs.

The idea of service area compactness will be further analysed using ***standard distance***, is a popular indicator to estimate the dispersion of points around a geographic centroid (Myint, 2008; Lee and Wong, 2001; Ebdon, 1982) in (Flores et al., 2013). It provides a spatial measurement that synthesizes the distribution of points around its centroid, similar to conventional statistical standard deviation, which measures the data dispersion around an average value. With standard distance, the standard deviation of the distances between the points in the distribution is calculated. The resultant polygon's radius represents the standard deviation of all the points from the mean. In contrast to conventional standard deviation, the results can be presented cartographically. Outliers are excluded from the final result.

The ESRI ArcMap Standard Distance tool will be used to measure the dispersion of service points around each site. The resulting value is a **distance measure** of compactness (*How Standard Distance works*, n.d.). A smaller standard distance means greater clustering of service points and potentially better travel cost value. Moreover, the service area with the greatest number and most variety of services will further entrench (re-development) location attractiveness.

In conclusion, this section discussed the accessibility measures that will be applied in this research. Metro ARIA, is a network distance (and conceptually time) measure, which places a weighted value on access to services. From zero (high accessibility) to 12 (high remoteness). Measurements are taken from the centroid of a property parcel to the destination point. Weights are tweaked to suit the South Africa situation, on the basis of insights from section 2.3.2, regarding the basic needs of the local urban poor. The accessibility measure is extended with calculations of service area (SA) extent or size and standard distance of locations, in order to understand the *compactness* of SAs. The more compact SAs, with smaller standard distances means greater clustering of service points and potentially better travel cost value. Discussed in the next sub-section, Kernel Density Estimation (KDE) is another point dispersion measure to assess the clustering of service points and so help to make conclusions about the accessibility of each re-development site. These measurement methods are intended to complement and triangulate each other, in order to observe the extent to which they confirm each other's results.

2.4.2 Measuring Service Distribution: Goods and Services Clustering Using KDE

Agglomeration economies are economic forces that generate advantages for others in the same industry or from different economic sectors by operating together, forming spatial clusters (O'Sullivan, 2007; Gong and Wheeler, 2002; Keeble and Nachum, 2001) in (Flores et al., 2013). Within the Johannesburg CBD, there is a lot of small-scale industry and retail, which tends to co-locate. This part of the analysis is important from the perspective that a 'cluster' means a *multiplicity* of services, which means value and efficiency rendered for the cost of travel, whereas singularly located service points imply the need for multiple trips in order to realize the full spectrum of required services. It speaks to the interrelatedness of pursued activities in travel demand theory (McNally and Rindt 2007 in Acheampong & Silva, 2015).

Kernel Density Estimation (KDE) is a conventional statistical method of estimating probability distributions, which works well for sets of data that are not normally distributed (i.e. frequency distribution not in a bell-shaped curve) (Turlach, 1993). Various statistical packages enable automated running of the calculation including GIS packages, with the added benefit of visualization. Kernel smoothing methods date back to the works of Rosenblatt (1956) and Parzen (1962) (in Zambom & Dias, 2012), and is the most used method. Bierens , 1987; Silverman, 1986 and Scott, 1992 (in Zambom & Dias, 2012) presented comprehensive overviews with applications. As with most statistical methods KDE is sensitive to assumptions. The selection of bandwidth or search radius is the most crucial part of running the calculations, because it has direct impacts on the results yielded. The bandwidth is a radius within which the algorithm searches for other likely points to cluster together (Yu et al., 2015). Bandwidth controls the degree of smoothing (Guidoum, 2015; Turlach, 1993). In the ESRI ArcGIS package, the bandwidth selection is defaulted to the weighted standard distance (effectively standard deviation) of all the points in the distribution (*How Kernel Density Works*, n.d.)

KDE is a point density method. Point density methods can be used to isolate facility distribution characteristics such as hot-spots and density and trends, which play an important role in CBD analysis (Yu et al., 2015). Work has been done to estimate the *clustering tendencies* of services and land-uses using network Kernel Density Estimation (KDE) methods (Borruso 2003, Yu et al. 2015) (Timothee et al., 2010). KDE works by counting the number of occurrences [services] in a region called a *kernel* around which the estimation is made. It weights occurrences that are closer to the kernel more heavily than those that are far away, resulting in a smoothed surface, descriptive of peaks and planes in the distribution of occurrences.

KDE has been found to be a superior method of spatial density evaluation, because it considers the distance decay of occurrences according to Tobler's *First Law of Geography* (Tobler, 1979; Silverman, 1986; Bailey and Gatrell, 1995 in (Yu et al., 2015). KDE can run either on the basis of Euclidean distance, or network distance. The literature tends to highlight the efficiency of network methods over Euclidean, as they take into account 'natural barriers' such as roads, and are truer reflection of man's interaction with the natural environment. This method will be used to analyse whether or not redevelopment sites are located within a 'hot-spot' or cluster of services.

Using ESRI ArcMap, Spatial Analyst once the KDE tool has been run for the combined each service layer. All service points in one layer. Each potential re-development location will be assessed for 1) whether or not it falls within a 'hot-spot' and 2) where more than 1 site is within a 'hot-spot', the extent to which they overlap the highest part of the scale, in order to determine the most favorable locations.

Source: http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/understanding-density-analysis.htm

Figure 6 Example of OutRas for KDE

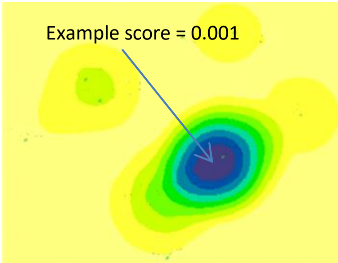


Figure 7 The general formula of a kernel density estimator

$$f(s) = \sum_{i=1}^{n} \frac{1}{h^2} K\left(\frac{s - c_i}{h}\right)$$

Source: Yu et al.,2015 p.34

ESRI Spatial Analyst KDE runs on Euclidean distance. Plug-ins such as SANET can be used to run network KDE. The general formula of a kernel density estimator is displayed in the figure 8. The explanation is as follows (Yu et al., 2015 p.34):

- *f(s) is the estimated density value at location*
- *s, n is the total number of event point under concern*
- *h is the search bandwidth e.g., for a circular kernel it is the radius of the circle)*
- *s - ci is the distance between event point ci and location s, and*
- *K is a weight function (called kernel function) characterizing how the contribution of point ci varies as a function of s - ci.*

Each calculation is weighted and estimated with events whose influence decays with distance, according Tobler's First Law of Geography (Yu et al., 2015).

In conclusion, agglomeration economic forces, expressed spatially as co-locating services in the urban context are a common phenomenon. This is an important dimension in assessing accessibility for the urban poor because a 'cluster' means a *multiplicity* of services, which potentially means value and efficiency rendered for the cost of travel. The KDE method of assessing clustering in the distribution of service points will be applied in the Johannesburg CBD for this research. It will be used to analyse whether or not redevelopment sites are located within a 'hot-spot' or cluster of services. KDE is an appropriate method for time-geography approaches (which theorize overcoming space in time, given various constraints), as it takes into account the distance decay factor according to Tobler's First Law of Geography. The next section concludes the chapter, summarizing the all discussions that were presented.

2.5 Conclusion

This chapter presented the theoretical foundations of the research, reviewing the related literature, and tracing the historical origins of some of the concepts. This concluding section of the chapter **summarizes** the discussions of the chapter, and **relates them to the analytical component** of the research in the next chapter.

The chapter began with a review of the classic concept of urban form, beginning with the definition of the urban form versus urban morphology. It was posited that “morphology” appears to be more appropriate for describing the dynamic forces the shape the formation of a city, as implicit in the word “morphology” is the suggestion of “change over time” whereas “form” seems to suggest a product of the completed process. The urban formation processes of urban core or CBD formation, decentralization, decay and renewal efforts were also discussed.

Four broad schools of thought pertaining to urban morphology research were identified. This research was placed in the context of the **spatial analytical** school of thought. Spatial Analytics can be divided into approaches: 1) those that emanate from the land use-transport interaction models (LUTI), and 2) those that are based upon simulation approaches such as Cell Automata (CA) and Agent-Based modeling (ABM). Recent research trends are marked by a transition from the former (LUTI methods) to the latter (simulation-based methods).

LUTI research encapsulates models that posit that **peoples’ travel choices are a function of travel cost and distance**. This thinking evolved over the 1960s and 70s and gave birth to utility-based theories, aimed at understanding location and travel choices under **uncertainty**. Space-time geography was born out of this thinking. It highlights the involvement of *time* costs and *constraints* of a personal or legal nature in overcoming space, as a result, people will select the most accessible locations to minimize commute costs, all things being equal (Acheampong & Silva, 2015). This is the theoretical foundation of the research.

Furthermore, the concept of **the neighbourhood** is highlighted as being **central** as a unit of analysis in understanding morphological processes acting on CBD formation, decay and renewal. The CBD lies at the heart of the idealized monocentric city. It consists of the tallest buildings, highest density development, mixed-use land-use and is (was) characterized by high rents. The formation of the CBD is further explained by economic theories of agglomeration of labour and economic activities, which in turn attracts greater levels of urbanisation. As urbanization increases, so does congestion, high rents and households begin to decentralize to cheaper suburban locations, exacerbating decay in the distressed CBD. These dynamics were identified and reflected in the evolution of the Johannesburg CBD.

It is noted in the literature that though **decentralization** began occurring in Johannesburg during the 1950s, it only picked up real momentum in the **1980s** in the context of a severe contraction of the national economy as a result of international sanctions against South Africa and a tense home security situation. Combined with the abolishment of the apartheid era legislation in 1986 and in the 1990s which had up until then, limited the movements and spatial distribution of black African people particularly in urban areas, the environment was ripe for a massive influx of predominantly black-African immigrants into the CBD. This happened alongside 'white flight' (of Caucasian minorities and businesses) from the CBD. It is noted that during the 1970s, 'pull' factors (in the way of cheaper land for development and lower rents) to suburban locations created more of an impetus for businesses to decentralize, than the key 'push' factor at the time, which was identified as limited parking availability and traffic congestion. As the influx of immigrants intensified, CBD decay became more acute from the overcrowding, and institutional capital disinvestment by mining head offices, banks and insurance houses. The original inhabitants of the CBD and the major property owners. By the 2000s, negative externalities in the CBD included limited parking availability, traffic congestion, overcrowding, crime, grime, informal trading and severe building dilapidation as a result of lack of maintenance and building abandonment.

Many African cities, often plagued by such challenges of poverty and the urban decay described above, find themselves discharging urban renewal initiatives in a rising context of neoliberal governance approaches and free market capitalism. Highlighted emphatically in the literature, is the displacing effects such approaches have on the urban poor, with examples found in China, Brazil, India, Johannesburg. These developments have serious implications for the roll-out of social housing and better access for the urban poor. Paralleled by the obsession with capturing global capital flows in the way of foreign direct investment to fund renewal efforts, without sufficient stop-gaps to ensure that the urban poor are catered for, the key beneficiaries of better, cost-effective access can easily be lost in the fray.

The literature review unpacked the concept of '**brownfielding'**, defined as the re-development, or re-using of previously used 'contaminated' urban land. Since the meaning of brownfield is normally associated with environmental contamination, it was highlighted in the literature that there are other kinds of contamination spillovers and externalities that can be **economic** in nature, such as overcrowding, old infrastructure and crime. Brownfield development can either be site-specific, or have region-wide impacts, which is why brownfield redevelopment is used by many cities as an urban renewal strategy. Once the redevelopment of heterogeneous parcels of land pick-up sufficient momentum, the 'tide' becomes renewal, but while neighbourhoods rejuvenate, they also have a tendency to gentrify at the same time.

Gentrification is a dividend of urban renewal, where working-class neighbourhoods are rehabilitated to middle-class neighbourhoods through capital investment, with the effect of replacing incumbent, usually poorer populations, with urbane, upwardly mobile households. Without any political will to temper the trend, these groups do not co-locate in space. The literature notes that in its **renewal efforts**, the City of Johannesburg has elected to take the **neo-liberal** style of urban regeneration, positioning the city as a **gateway into Africa**. The aim is to attract capital investment while the city provides a positive environment for international investors. At the same time, South Africa has no national policy Framework on urban renewal. Regeneration efforts are left up to individual municipalities, who generally are set on attracting sustained private investment in order to create functioning property markets that lead to an increase in property values.

The cautionary about the potential impact on social housing has been made by local commentators such as Mosselson (2017a, 2017b, 2017c), Winkler (2009) and Beal et al. (2000). Initially, social housing development demonstrated a preference for suburban and peripheral city locations, due to the availability of cheaper land for purchase. An HDA survey taken in 2013 showed that out of the total surveyed projects, only **15% were located in the CBD**, seemingly jettisoning the mandate enshrined in the Social Housing Development Act (16 of 2008) that social housing should help trigger urban renewal.

The same report aptly demonstrated also, that **the CBD was the best location from which to access** social and economic amenities. Seemingly heeding these calls, COJ, through its social housing arm JOSHCO in 2015, set a budget of R493 million spending 41% on purchasing buildings for refurbishment within the CBD.

It has been emphasized that for the CBD to truly regenerate, non-housing initiatives such as economic growth, migrant integration and private Investment in small businesses should also be supported.

The discussion next turned to the profile of the recipients of the Social Housing Act. The literature review revealed that most low-income households in South Africa tend to spend most of their income on **transport** and **food** costs. Twenty-nine percent to 34% of their budget is taken up by food. Transport takes up 11 to 12%. Low-income households make up nearly **two-thirds of the national population**. The literature further revealed that poorer households don't only access their food by conventional means such as supermarkets and shopping centers, but make use of informal shops known locally as “spaza” shops. The food costs more at formal shops, but they operate a credit system which makes it easier for poor urban households to secure food. Households exhibit the same **resilience** when it comes to securing accommodation. Arrangements include subletting of the rooms, and a preference for renting, which affords poor households the flexibility they require for (employment) mobility. To go where the jobs are. In a survey undertaken in the Johannesburg CBD to review the living conditions show housing recipients the majority of respondents point to the convenience of the CBD location from a transport cost point of view, indicating that it is the main reason why they choose living in the CBD, despite the circumstances crime and overcrowding.

The important **linkage between transport and land-use** (which translates as accessibility) was raised in the literature. Land-use provides the location of activities such as employment, residential and other ancillary activities, while transport provides the means for accessing them, at the same time affecting the land values. For this reason, accessibility plays an important role in assessing the location of social housing redevelopment schemes. The theory of accessibility is the Activity-Based Approach (ABA); utility maximization theory, where commuters minimize costs by choosing the most accessible locations. It is the rationale for the technical approaches selected and adopted for this research. These methods are applied for **measuring accessibility** to services and amenities by poor urban households. The methods are intended to complement and triangulate each other. They are run parallel with each other in order to observe the extent to which they confirm each other’s results.

The table overleaf demonstrates how the elements in the literature review relate to the technical approach.

In conclusion, new narratives have called for urban growth theories that will accommodate city formation in other parts of the world, that have different origins than the classic monocentric European city; the so-called postcolonial approach to urban morphology research. Nevertheless, there is recognition that no single theory could ever justifiably cover the plethora of types and products of urbanisation the world over, and that any urban form theory should always have at its centre the conceptual cornerstones of agglomeration, clustering as well as the resultant urban land-use nexus. It is a view that is carried forward and emphasized in this research.

The significance of this research lies in its timeliness regarding the current drive by COJ to refurbish buildings in the CBD for social housing. It lends itself to fine-tuning existing site-selection approaches by putting forward a site-selection approach for optimally locating social housing, so contributing to sound fiscal spending through rational decision-making. Furthermore, the research emphatically supports the idea that gentrification should not be allowed to displace poor households from the CBD. The next chapter describes the fieldwork and subsequent application of technical methods of analysis.

Technical Approach	Literature Review Elements	Description
The **Metro ARIA**, method of network distance (and conceptually, time) calculation was presented and explained as the foundational analysis of **accessibility** for this research.	• LUTI research encapsulates models that posit that peoples' travel choices are a function of travel cost and distance (Acheampong & Silva, 2015). Space-time holds that there are *time* costs involved in overcoming space: capability constraints. The impedance for covering a distance in a specific amount of time. • There is an important linkage between transport and land-use: Land-use provides the location of activities such as employment, residential and other ancillary activities, while transport provides the means for accessing them (Acheampong & Silva, 2015).	Distance measurements from potential re-development sites to amenities will yield weighted scores from zero (high accessibility) to 12 (high remoteness). Weights will be tweaked to suit the South Africa situation from the literature.
The accessibility measure will be extended with calculations of **service area (SA) extent or size** and **standard distance** of point locations, in order to understand the compactness of SAs. A "Service area" in this research pertains to the area in which tenants will need to travel, in order to go and acquire services and amenities.	• **Land-use** incorporates a number of activity locations: primarily residential, employment, and adjunct activities e.g. shopping, schools, and recreation (Acheampong & Silva, 2015). • An HDA survey taken in 2013 demonstrated that **the CBD was the best location from which to access** social and economic amenities. • The profile of the recipients of the Social Housing Act. The literature review revealed that most low-income households in South Africa tend to spend most of their income on **transport** and **food** costs. Twenty-nine percent to 34% of their budget is taken up by food. Transport takes up 11 to 12% (Ismail et al., 2016). • The more food insecure a household is, the more they are likely to depend on informal means of securing food. In the South African context, such informal shops are known as "Spaza Shops (Battersby & Peyton, 2014) • In a study of catchment areas around stops at high-quality public transport systems in Denmark, In drawing 600m buffers around the stops, the Euclidean buffers had the same[4] area size in square metres, but the service area buffers ranged in size (Landex, Hansen, & Andersen, 2006).	For each of the potential re-development sites, an SA based on all the closest facility results (i.e. by amenity type) will be created such that the endpoints of the closest route become the perimeter of the service area, calculated as convex hulls. The most compact (smallest size) ones will be identified. These will then potentially be the most efficient in terms of travel costs. A **smaller standard distance** means greater clustering of service points; the greatest number and most variety of services means location attractiveness.
Lastly, **Kernel Density Estimation** (KDE), a point dispersion measure will be used to assess the clustering of service points. This method was chosen because a 'cluster' means a multiplicity of services, which potentially means value and efficiency rendered for the cost of travel. KDE is an appropriate method for time-geography approaches (which theorize overcoming space in time, given various space-related constraints), as it takes into account the distance decay factor according to Tobler's First Law of Geography (Yu, Ai, & Shao, 2015b).	• The existence of a CBD is further explained by economic theories of agglomeration, and scale, where firms realize certain operational cost-saving advantages by locating close together, forming spatial clusters (Flores et al., 2013). • Shen (1998) examined the employment accessibility of low-wage workers living in Boston's inner-city Neighbourhoods. In it, he concluded that on average, low-wage workers living in inner-city Neighbourhoods don't have high employment accessibility because a large majority of them do not own cars. • Residential choice, a long-term decision, was initially thought as being independent of employment location choice (Waddell 1993, Waddell et. al 2007 in Acheampong & Silva, 2015). More recent work however, indicates that residential and job location choices are jointly determined. • Mossleson (2017b) indicated some respondents explicitly stated that they came to live in the CBD to be closer to employment opportunities. Many of the respondents also pointed to the ease of proximity of other amenities such as shops. While respondents acknowledged the negative circumstances of the nodes where building projects are located (e.g. drugs, crime), good access to their needs, outweighs the option to leave.	The KDE method will be used to analyse whether or not redevelopment sites are located within a 'hot-spot' or cluster of services. Each site will be assessed for 1) whether or not it falls within a 'hot-spot' and 2) where more than 1 site is within a 'hot-spot', the extent to which they overlap the highest part of the scale, in order to determine the most favorable locations.

[4] With two exceptions which were not explained.

3. Application Method

3.1 Introduction

This chapter is a presentation and critique of the technical approach of the research. Each method is presented and described, and its selection into the research is rationalised. The linkages between the methods and the research question are highlighted. Firstly, a description of the study area and demarcation for fieldwork is provided. Next, an analysis of the change in the value of CBD buildings represented by the change in commercial office rentals is presented. This, together with a temporal analysis of mortgage bond values by erf and block in the study area, sets the context of the fieldwork. An emphasis is made here, that this was a major limitation of the study. Ideally building values should be used, and not bond prices. However, as a result of the inability to acquire such data from COJ, deeds (mortgage) price data is used instead. In the last section, the technical application of 1) Metro ARIA 2) Service area size and Standard Distance and 3) Kernel Density Estimation of the service points in relation to the identified potential redevelopment sites is made. This is in order to identify the best-located redevelopment site(s) for social housing. All the necessary calculations and related mapping are set out. The conclusion summarizes the technical findings. The methods selected for this research are intended to complement each other and triangulate one another's findings. They are applied in parallel in order to observe the extent to which they confirm each other's results.

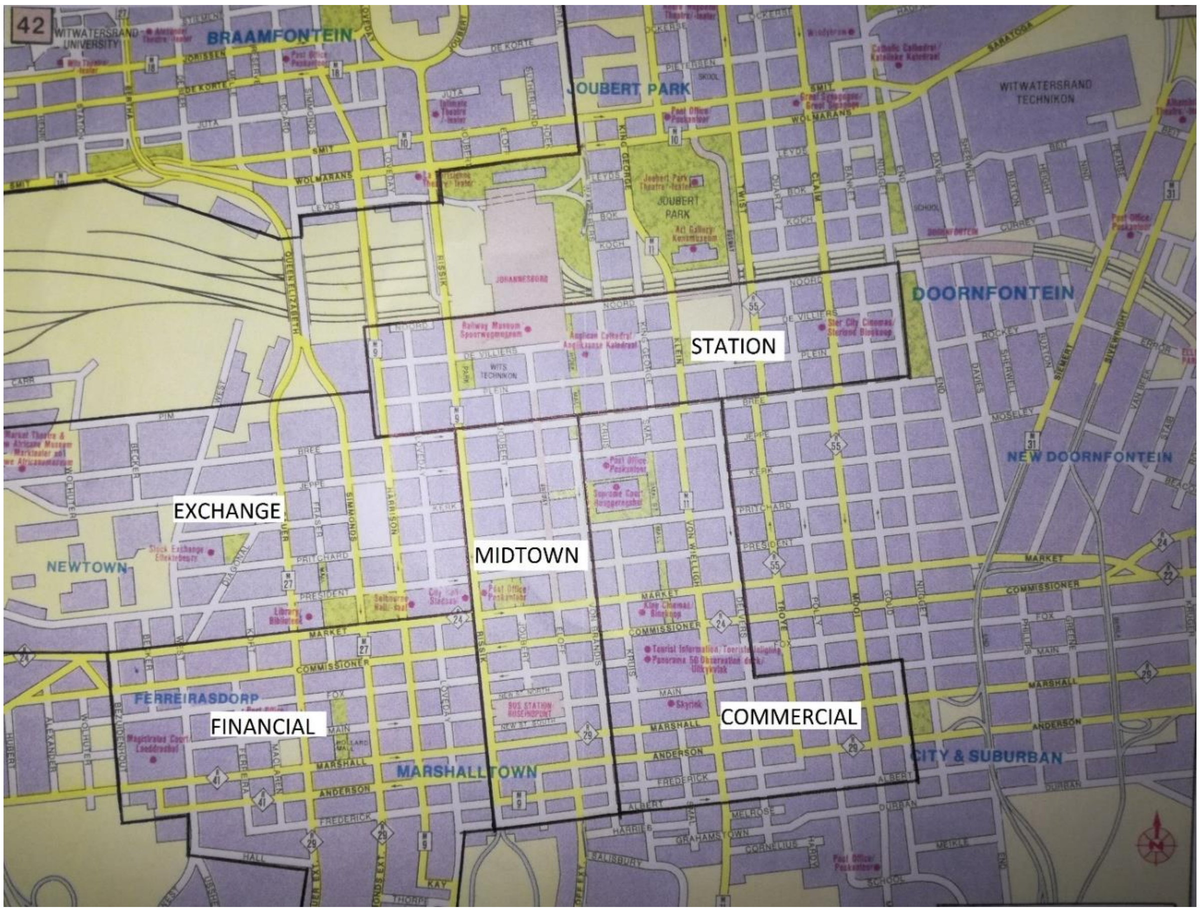
3.2 The Study Area

The structure of the CBD remains relatively the same today, as when Rogerson (1996) conducted her study at the height of business exodus, and immigrant influx into the CBD. She points out that the CBD has a number of clear 'districts', based on the general building function in those areas. She identifies six districts, namely: The Exchange District, the Financial District, the Commercial District, the Midtown District, the Station District and Braamfontein (not within the demarcated area for this research). See figure 8 below. Yu et al. (2015) describe a concentration of urban activities as units called 'districts', as such, the core of the city can be highlighted and defined zonally by the activities that occur there.

The current make-up of the CBD includes warehouses, motor-mechanic/ car workshops; small-scale manufacturing and processing and both formal and informal retail (Mosselson, 2017a). These lie cheek-by-jowl with corporate offices that stubbornly refused to follow the mass exodus of businesses from the

CBD in the 1980s and 1990s. Mossleson (2017a) goes further to note the improvised housing converted from decayed churches and old office buildings, disconnected from essential services such as water and electricity (Moagi, 2017, Jul 10; Steyn, 2015, Jul 24).

Figure 8 Property Districts of the Johannesburg Inner-City 1996



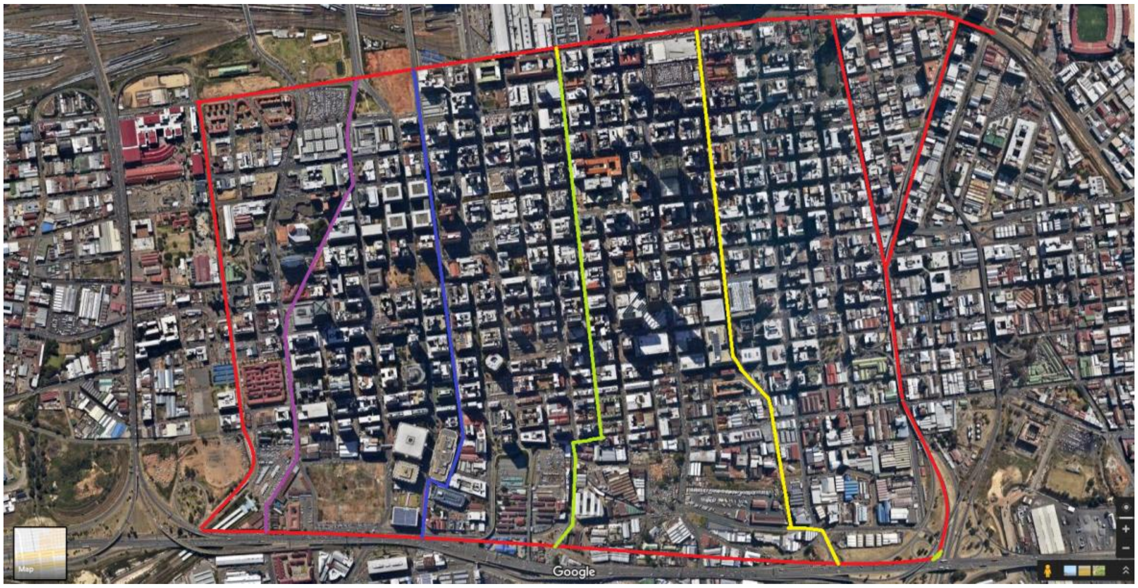
Source: This is a recreation of the map in Rogerson 1996 p.74 (Map is sourced from Stickler Cartography©)
Note: the map is old, prior to the renaming of streets

The Field of Study is located *within* the central Johannesburg CBD. It straddles all districts in figure 8 except for Braamfontein. It is an 18 by 26 block area bounded by the following streets:

- Saratoga (in Hillbrow)/Wolmarans Street (in Braamfontein) to the North;
- The Francois Oberholzer Highway to the South;
- Siemert/End Street (in Doornfontein) to the East and
- Miriam Makeba Street in Newtown to the West.

Although these districts are dated, and the CBD may now well have evolved beyond these definitions, they are retained for this research, as such an analysis is out of scope.

Figure 9 The Study Area Divided by Field Work Days

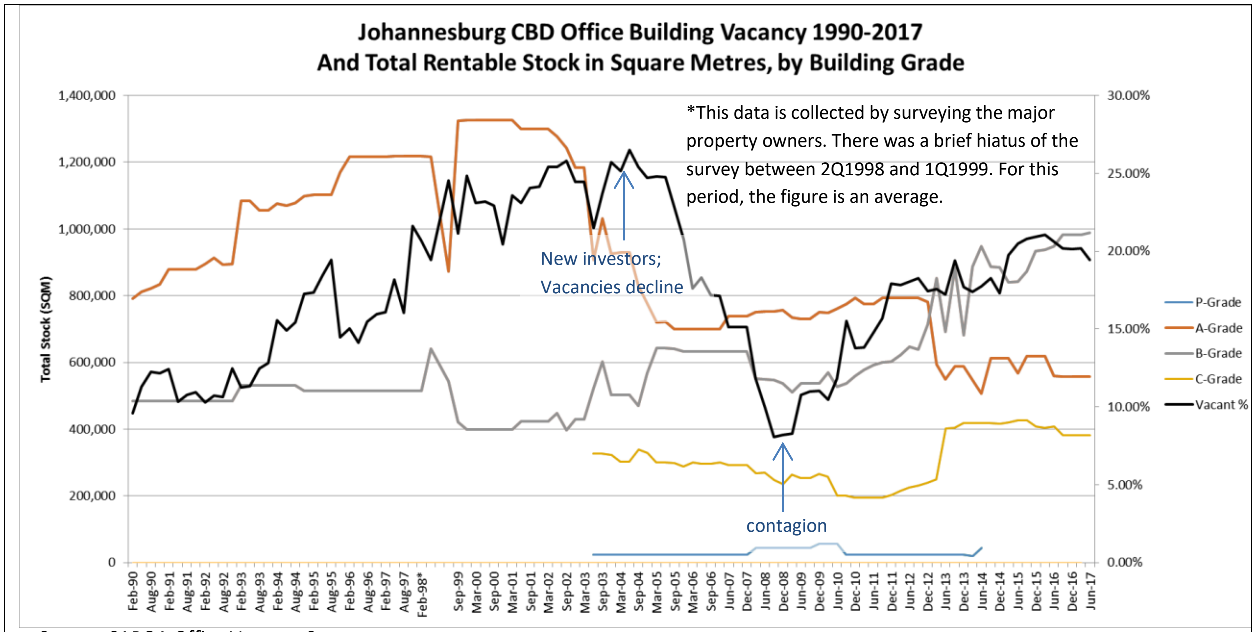


This Fieldwork was carried out as per the figure above. The purpose was to confirm in the field the condition of buildings from the results of the temporal mapping (next section) that 1) had never been sold in the period; 2) been sold for progressively less over that period; 3) Identify dilapidated buildings in the field not covered by either analysis. The next section presents this analysis.

3.3 Johannesburg CBD Building Value Change - Temporal Mapping

The previous section introduced the technical part of this research by defining the boundaries of the study area and describing its nature. In this section, the empirical evidence for the decay of the CBD described in detail in chapter two is presented. Ideally, this should be done by looking at the changing values of CBD buildings; however, such data was not received when requested. As such, property sales over the years are looked at instead. Furthermore, the commercial office property sector is reviewed for change in the quality of stock and occupancy rates. This section is divided into two parts: 1) A Trend Analysis of the CBD office rentals and vacancies (proportion % of occupied space in time) that portrays an aspect of CBD decay and 2) A Time Series mapping of property sales using deeds or mortgage bond registrations by city block, over time. The latter analysis was conducted to identify locations that have not been on the market over the years, in order to verify their condition in the field. It is from this grouping, as well as an overall survey of the study, area that dilapidated/ abandoned buildings will be identified for the test identifying the best potential brownfield redevelopment site.

Figure 10 Johannesburg CBD Office Building Vacancy and Total Stock 1990-2017



Source: SAPOA Office Vacancy Survey

C-grade buildings started being recorded in the Johannesburg CBD in 2003, virtually on the heels of the institutional disinvestment and incumbent tenant emigration of the 1990s. From that point, a ‘new’ type of investor entered the market, willing to consume lower quality stock. The vacancy cycle again turned with the economic contagion of 2008, alongside other negative structural elements of the CBD (section 2.2.4). B-grade stock overtook the amount (m^2) of A-grade stock in early 2013 and, at the same time, the amount of C-grade stock increased. P (“premium”) grade stock virtually disappeared. Rode’s definitions of office building grades are used below, since they are more nuanced than the more generalized SAPOA definitions:

Table 9 Comparative Grading of Office Space

Comparative grading of office space			
Grade P	**Grade A**	**Grade B**	**Grade C**
P Grade stands for premium and SAPOA defines P-grade office space as top-quality, modern space which is generally a pace-setter in establishing rentals and which includes the latest or a recent generation of building services, ample parking, a prestige lobby finish and good views or a good environment	Generally not older than 10 years, unless renovated; prime location; high-quality finishes; adequate on-site parking; air-conditioning.	Generally 10 to 20 years old, unless renovated; accommodation to modern standards; prime location; airconditioning; on-site parking. Commands a gross market rental as indicated in the accompanying table.	Generally 20 to 30 years old, unless renovated; in fairly good condition, although finishes are not up to modern standards; good location; may have onsite parking; unlikely to be centrally airconditioned;

Source: Rode, 2010/ JDel QS

In the period analyzed in figure 10, A-grade stock reduced by -57.88% from its highest level (December 1999) and C-grade stock almost doubled (96.15%) from its lowest level (December 2010), measured as at June 2017. In their latest survey report, SAPOA indicates that:

> "Inner City vacancy rates remain high and at 1.5 times the level of decentralized [suburban] nodes, [which are] nearing peak levels…In saying that, inner-city vacancy rates are currently lower than they were in 2003, as a result of structural change brought about by the conversion of CBD offices to residential space".
>
> (SAPOA Jun 2017, p.3)

The above results confirm the dynamics identified in section 2.2.4, the evolution of the Johannesburg CBD, and sets the context for identifying potential redevelopment sites, using the Metro ARIA calculation, services proximity analyses and KDE analysis.

The following figures demonstrate the property sales by block in the CBD from 1990.

Figure 11 Johannesburg Buildings Sold During the 1990s

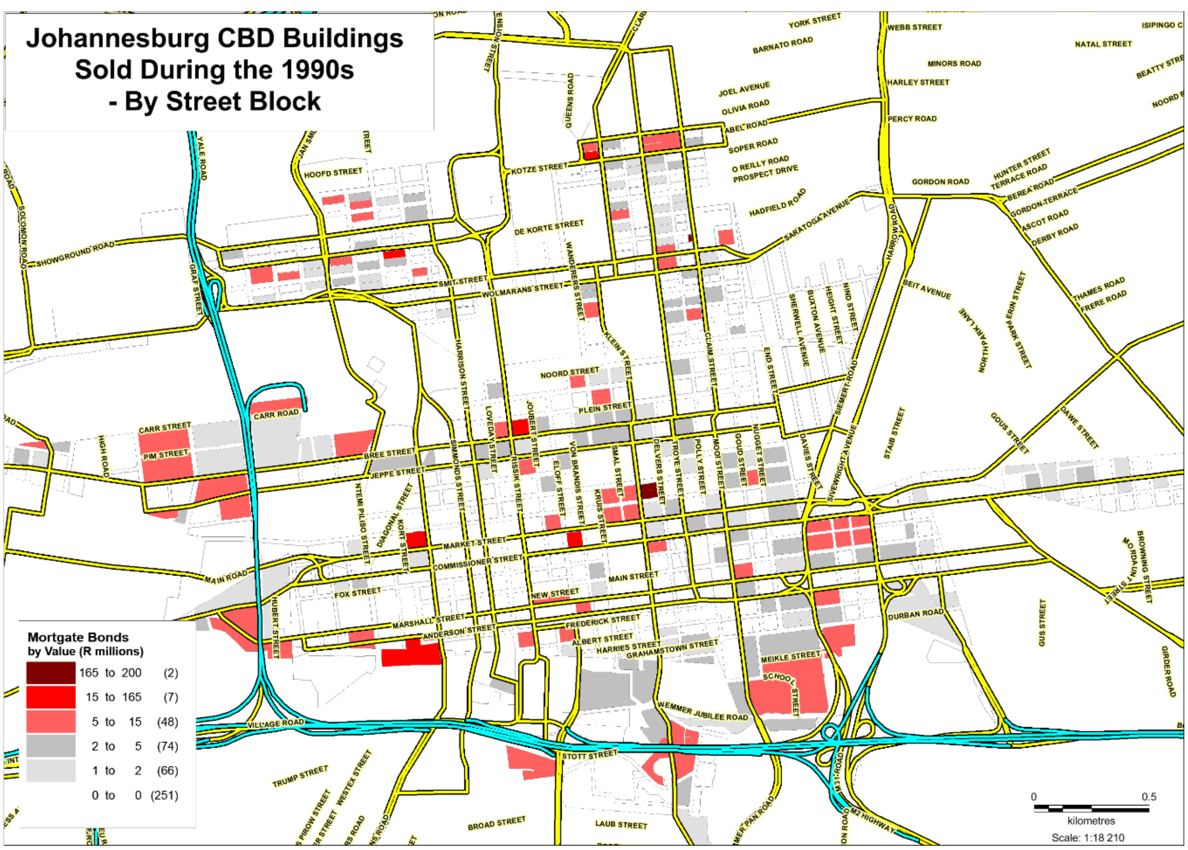


Figure 12 Johannesburg Buildings Sold From 2000 to 2010

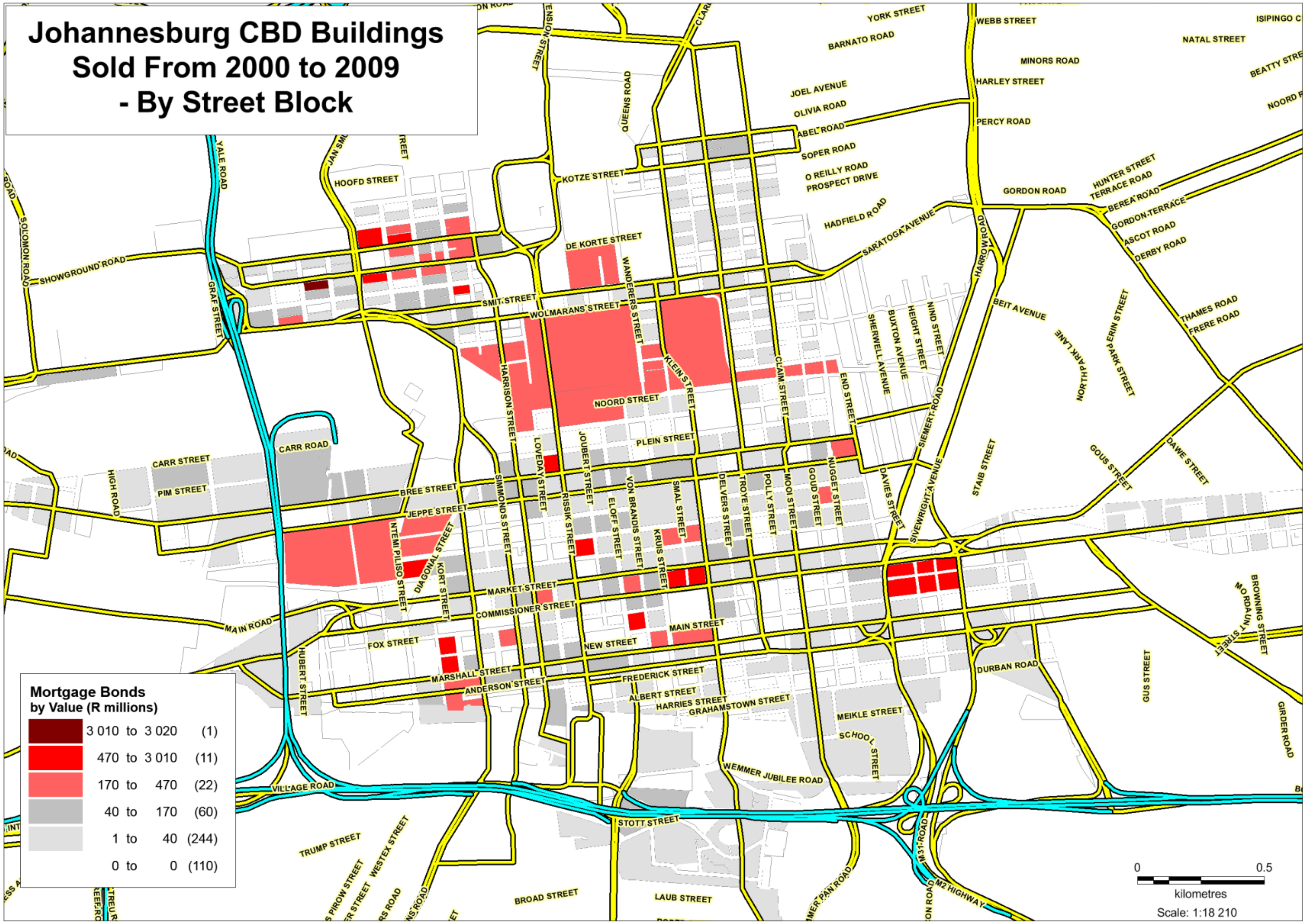


Figure 13 Johannesburg Buildings Sold From 2010 to The Present

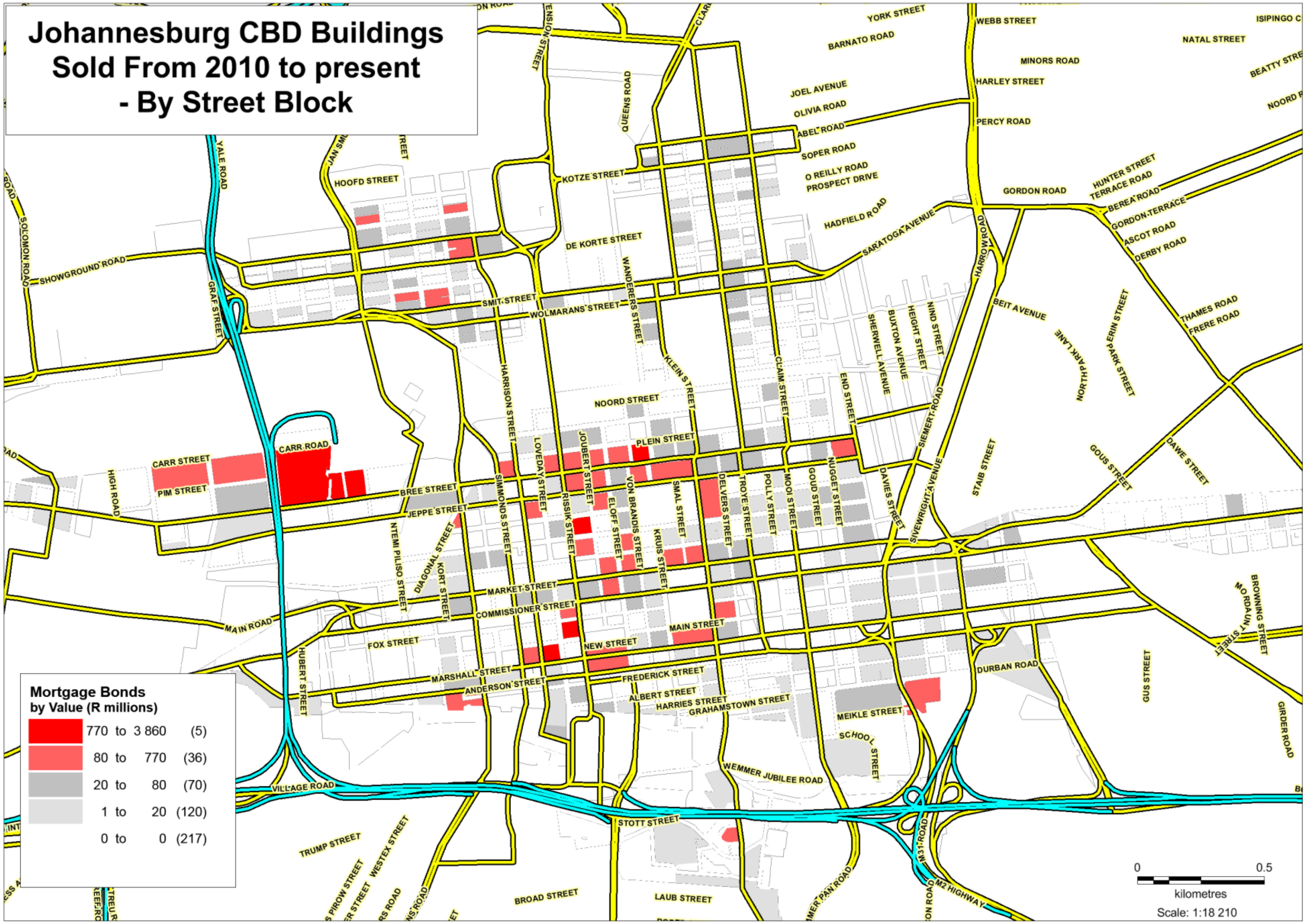
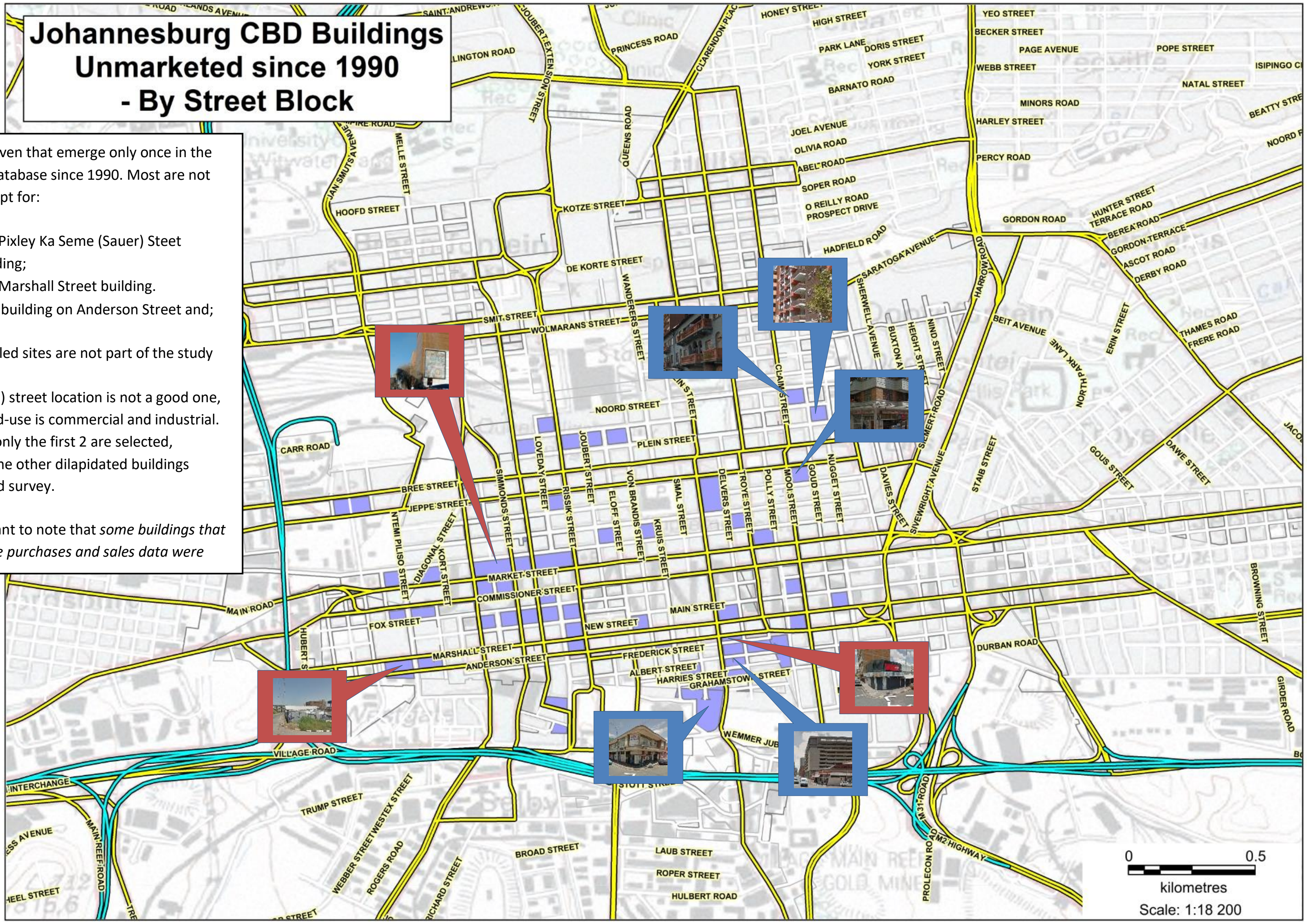


Figure 14 Temporal Building Sales Analysis Results



These are the erven that emerge only once in the purchase/sale database since 1990. Most are not dilapidated except for:

- The Pixley Ka Seme (Sauer) Steet building;
- The Marshall Street building.
- One building on Anderson Street and;

Un-tagged/labelled sites are not part of the study area.

The Anderson (1) street location is not a good one, because the land-use is commercial and industrial. For this reason only the first 2 are selected, augmented by the other dilapidated buildings found in the field survey.

It is also important to note that *some buildings that did appear in the purchases and sales data were*

<u>Fieldwork report</u>: All buildings had been bonded at least once in the period 1990-2014. Therefore, only buildings that had been bonded only once were selected into the sample. The limitation of using deeds data as opposed to building valuation data became clear during the course of the fieldwork.

It became evident that of the buildings that did not emerge in the temporal analysis (the purchases and sales data over the decades) many buildings were still occupied and were being maintained. But on the other hand, some buildings that did appear in the purchases and sales data emerged as aging/un-maintained, dilapidated or even abandoned. Nevertheless, it is from this latter grouping, that the majority of dilapidated buildings were identified and drawn into the analysis. Pictures of the buildings/ fieldwork locations were taken, and they were categorized into:

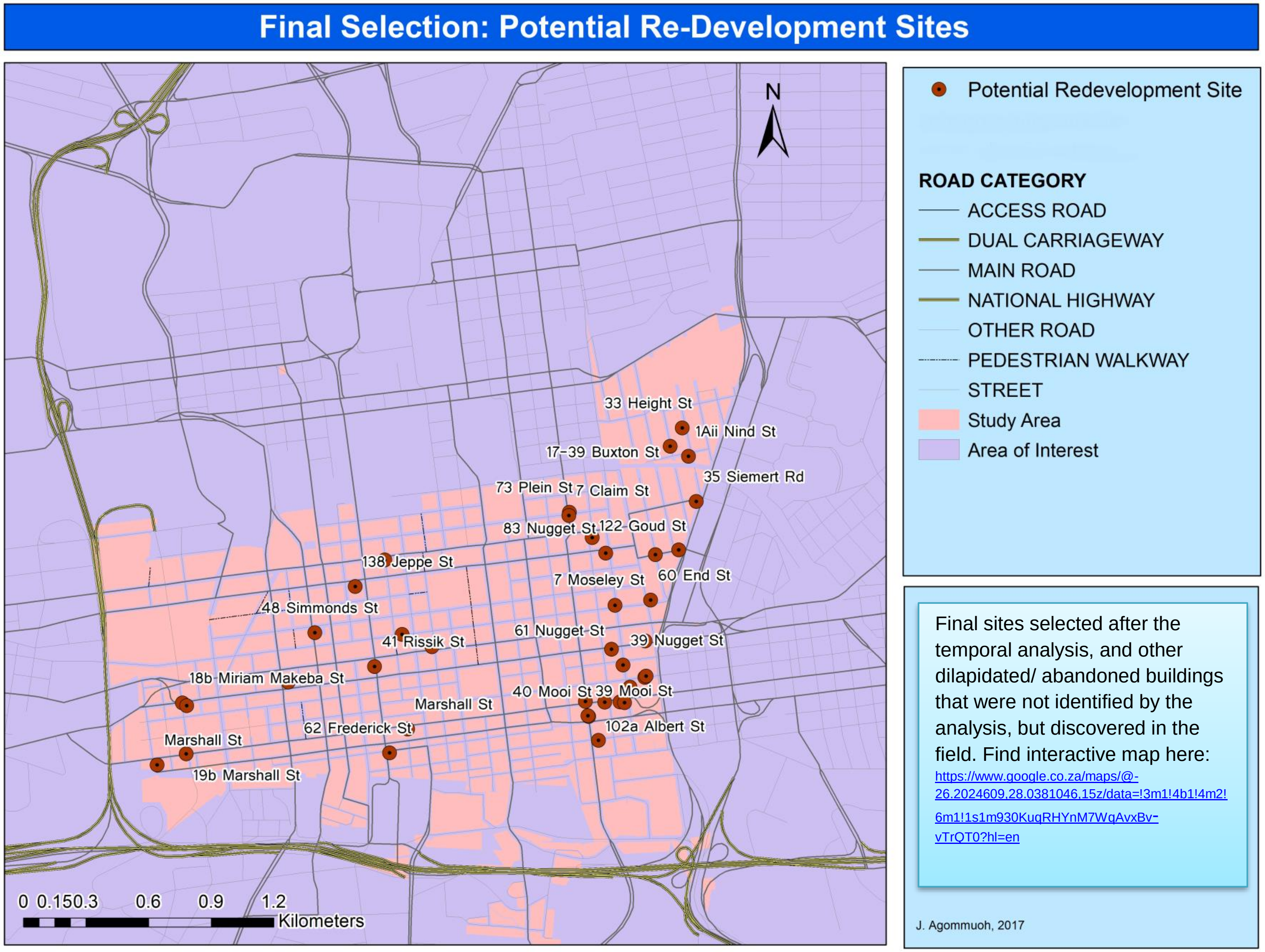
- Dilapidated/ abandoned
- Old, informally occupied
- Old, formally occupied
- Maintained, formally occupied
- Newly renovated/ constructed

It is to be noted that the geo-tagging (address) refers to the location of the camera, and not necessarily the physical location of the buildings. Comments on the overlap between database & fieldwork.

The study area included a mix of commercial, industrial and residential buildings. "Informally occupied" does not necessarily mean that vagrants have moved in, but that the tenant(s) might not necessarily be the de facto lease-holder/ owner, if there is a formal leasing/ ownership arrangement at all. Dilapidated/ abandoned buildings almost invariably housed the homeless and vagrants.

Impressions of the study were that the eastern side (Mooi Street area i.e. east of the mid-town/commercial districts) was tremendously congested and particularly unkempt, with a preponderance of residential buildings; old, dilapidated, abandoned, as well as gentrifying zones. Whereas the western part, where 2 large local banks (a third is in the eastern part), a foreign bank, some mining house head offices, a large civic library and the magistrate's court are located was fairly free-flowing (to a degree) and less dirty. Please see the **full list of selected, geo-tagged sites in appendix 1**, a sample of 39 sites. The map on the following page depicts the selection results. The next section uses these sites in the measure of accessibility to services and amenities most needed by low-income households by the Metro ARIA method, to identify sites that best satisfy these needs.

Figure 15 Final Selection of Redevelopment/ brownfield Sites



3.4 Measures of Accessibility Results

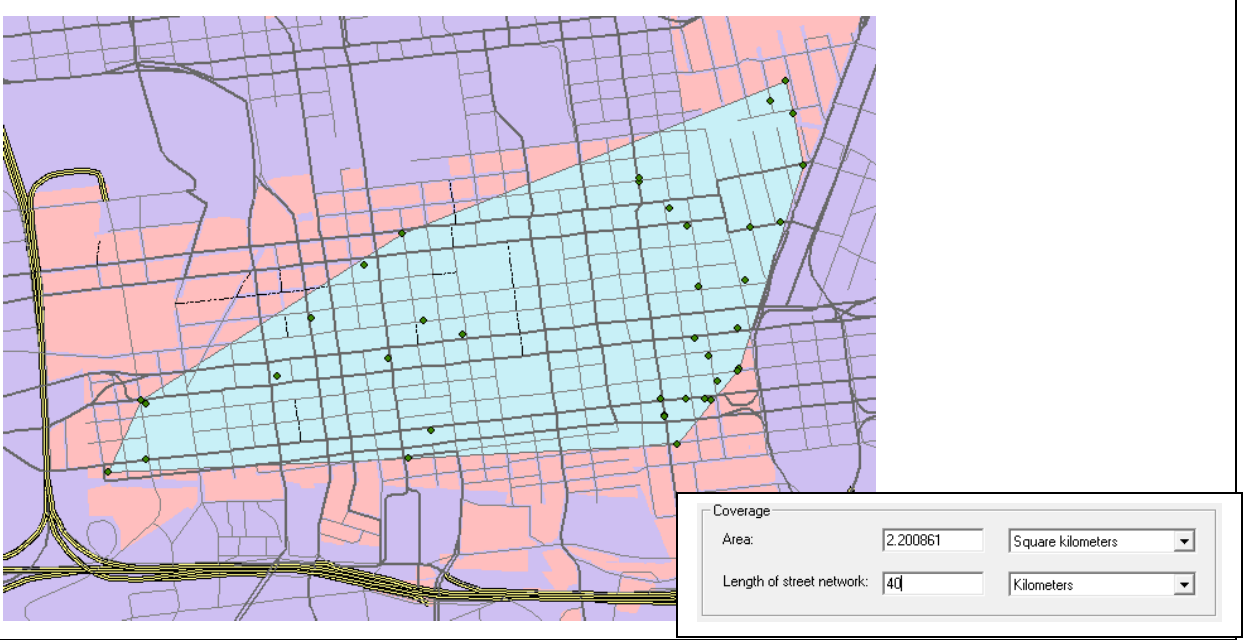
The previous section presented the temporal analysis of the Johannesburg CBD and presented empirical evidence to support the evolution of decay described in chapter 2. The potential redevelopment sites, a sample of 39 sites, were selected on the basis of the temporal desk-top analysis and a field survey. In this section, the potential redevelopment sites are analyzed in terms of their proximity to the services required by poor urban households using the following methodology: Metro ARIA; services proximity as described by service area size; the point density measure Standard Distance (SD) and KDE. The following sections describe the process engaged in preparing the data and running the calculations.

3.4.1 Pre-work

Prior to running these analyses, the sites were tested for proximity to one another, and adjacent sites are treated as a single location.

Firstly, hierarchical nearest neighbour analysis using CrimeStat IV was run on the potential sites layer, to test whether it is necessary to amalgamate some of the sites into clusters due to proximity. The measurement parameters were derived by drawing a convex hull around the selected sites and extracting the relevant statistics: applying a 500m search radius, 1 minimum point per cluster and one and standard deviations:

Figure 16 NNh Analysis for Study Area



Running the analysis generated 9 ellipses (clusters) from a sample size of 39 sites:

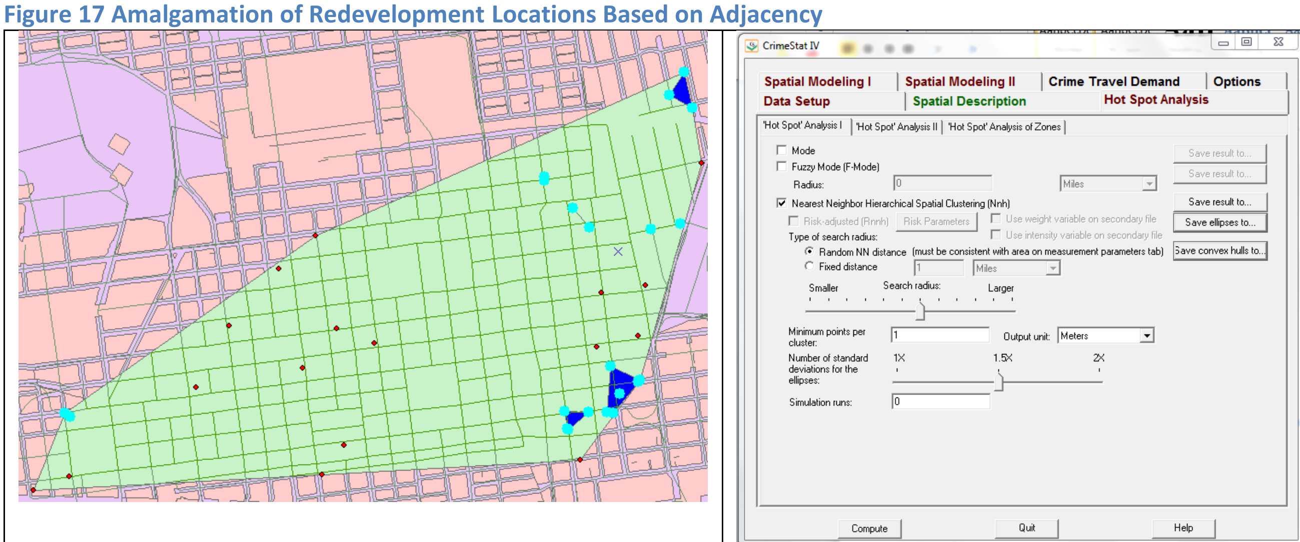
Table 10 NNh Results for Redevelopment Sites

```
Nearest Neighbor Hierarchical Clustering:
-----------------------------------------

    Sample size..................: 39
    Likelihood of grouping
      pair of points by chance...: 0.50000 (50.000%)
    Z-value for confidence
      interval...................: 0.000
    Measurement type.............: Direct
    Output units.................: Meters, Square Meters, Points per Square Meters
    Standard Deviations .........: 1.0
    Clusters found...............: 9
    Simulation runs..............: 0
    Start time.............: 11:52:45 AM, 09/23/2017
    End time...............: 11:52:47 AM, 09/23/2017

    Displaying 9 ellipse(s) starting from 1
```

Order	Cluster	Mean X	Mean Y	Rotation	X-Axis	Y-Axis	Area	Points	Density
1	1	28.05327	-26.20571	33.70321	60.26009	105.48747	19970.11480	7	0.000351
1	2	28.05148	-26.20669	49.60348	49.26729	75.29316	11653.70719	4	0.000343
1	3	28.05176	-26.20791	0.00000	160.93440	160.93440	81366.87741	1	0.000012
1	4	28.05529	-26.19638	79.04494	124.94318	77.87782	30568.64707	3	0.000098
1	5	28.05472	-26.20060	78.26465	160.93440	73.02223	36919.33231	2	0.000054
1	6	28.05233	-26.20437	0.00000	160.93440	160.93440	81366.87741	1	0.000012
1	7	28.05179	-26.20033	49.15590	62.63838	160.93440	31669.36128	2	0.000063
1	8	28.05050	-26.19911	7.01285	160.93440	9.81772	4963.74393	2	0.000403
1	9	28.03395	-26.20650	32.35079	15.27301	160.93440	7721.88485	2	0.000259

Hierarchical Nearest Neighbour analysis (NNh) is a sequential clustering algorithm that clusters points together on the basis of a threshold distance (Levine, 2006). Although the threshold distance can be statistically derived, it can also be user-defined. In this research, 500m represents walking distance. The number of minimum points per cluster is also user-defined, and in this research, 1 minimum point was the input, simply because the aim was to understand whether any site needs to be amalgamated with any other ones because of walking distance proximity. It is to be noted, that the implication of this amalgamation on the final scoring (of which site(s) is the best for re-development), is that such sites will get the same score for proximity to services. This means that any of the sites in the cluster have the potential to be the best location. The sites that were clustered into groupings are now taken as a single location going forward (i.e. the polygons and lines displayed below are converted to point locations):

Figure 17 Amalgamation of Redevelopment Locations Based on Adjacency



From 39 point locations, the cluster analysis reduced the sample to 24 locations. Please see the **final list of selected sites in appendix 2**.

Limitations of the NNh Method (Levine, 2004)

- The minimum number of points has a greater effect on the results than the threshold distance.
- Using a small minimum number of points introduces the likelihood of obtaining a cluster by chance.
- The random threshold distance is dependent on the cluster size, which in turn is dependent on the sample size. Threshold distance is bigger with smaller sample sizes. However, using a fixed distance for the threshold distance can help overcome this.
- Enforcing the minimum points criteria introduces a level of arbitrariness into the analysis.
- The method does not have a theory that explains it and it is an empirical procedure

The next section presents the accessibility measure calculations, in order to ultimately select the best redevelopment brownfield sites. The first accessibility method is the Metro ARIA method by Somenahalli et al. (2016).

3.4.2 ARIA Measure of Network Distance Calculations Description

The Metropolitan Accessibility/Remoteness Index of Adelaide (Metro-ARIA) developed by National Centre for Social Applications of GIS (GISCA) at the University of Adelaide (2008), which in turn is based on the Accessibility and Remoteness Index of Australia (ARIA) was used to test accessibility for a number of economic service points, as applied by Somenahalli et al. (2016):

> *The index aims to reflect the ease or difficulty people face accessing basic services within metropolitan areas, derived from the measurement of road distances people travel to reach different services*" (Somenahalli et al., 2016). (p.15).

The ARIA methodology is seen as the authoritative measure of remoteness in Australia. Metro ARIA was adapted and refined to measure accessibility for five specific types of service offerings, typically found in metropolitan areas. Metro ARIA was designed to be flexible and adaptable to different situations (AURIN, 2015).

Measurements were taken from the centroids of residential parcels to the nearest (1) Hospital (2) shopping Centre (3) education (schools) (4) public transport hubs and (5) financial and postal services. These categories are further broken down into sub-types. A capped, weighted score was assigned to each category of services and an overall ARIA is derived for the metropolitan area. Accessibility in this sense means the "ease of reaching" (Somenahalli et al., 2016).

Once measurements were derived, they were standardized to a ratio by dividing by the weighted mean for that service, because ARIA distance values are strongly skewed. A capped maximum value is applied to each service type (0-2 or 0-3), and they are summed to get an overall measure of accessibility, which is a score out of 12; 12 being the least accessible. Even with standardization, results of some of the categories still overwhelm the index, and for this reason, a cap or threshold (score range) is applied. The rationale behind the 0-2/0-3 threshold is that it cannot be set too low if the aim is to distinguish the least from the more accessible locations. All locations exceeding the threshold are given a value equal to the threshold. The threshold is expressed as an integral multiple of the sum of the mean distances for each category or service type, meaning smaller 'desired travel' distances for less in-demand services. It reflects the principle that people are willing to travel longer distances for higher order or high demand services (Taylor et al., 1999), (GISCA & University of Adelaide, 2008).

In this research, the Adelaide method is applied and tweaked for the local situation, to take into account the most required services and amenities by low-income households. Twenty-nine percent to 34% of their budget is taken up by food. Transport takes up 11 to 12% (Ismail et al., 2016):

Table 8 Application of Remoteness Index for this Research

Service type	Service facilities and weighting	Score range
Health (Health ARIA)	(Major Hospital + All Hospital + GP)/3	0–3
Shopping (Shopping-ARIA)	(Spasa + Major Shopping Centre + Supermarket)/6	0–3
Education (Education-ARIA)	Primary School + High School + FET + University)/3	0–2
Public transport (Public Transport ARIA)	(All transit stops + Go Zone (high frequency) stop + Interchange)/4.5	0–2
Financial and postal (Finance-ARIA)	(Bank + Post Office)/3	0–2
Metro-ARIA = Health-ARIA + Shopping-ARIA + Education-ARIA + Public Transport-ARIA + Finance ARIA		0–12

$$ARIA_{Li} = \sum_{L} \min\left\{3, \frac{x_{Li}}{\bar{x}_L}\right\} + \sum_{L} \min\left\{2, \frac{y_{Li}}{\bar{y}_L}\right\} \qquad (1)$$

Source: Somenahalli et al., 2016, p 15

i = parcel location and L is the service type
x_{Li} = distance to the nearest service from each parcel for Health and Shopping services
y_{Li} = distance to the nearest service from each parcel for Education, Public Transport and 'Financial and Postal' services
$\bar{x}_L$ *and* $\bar{y}_L$ is the mean road distance of all parcels to the nearest category L service type within the metropolitan area.

3.4.3 Data Preparation

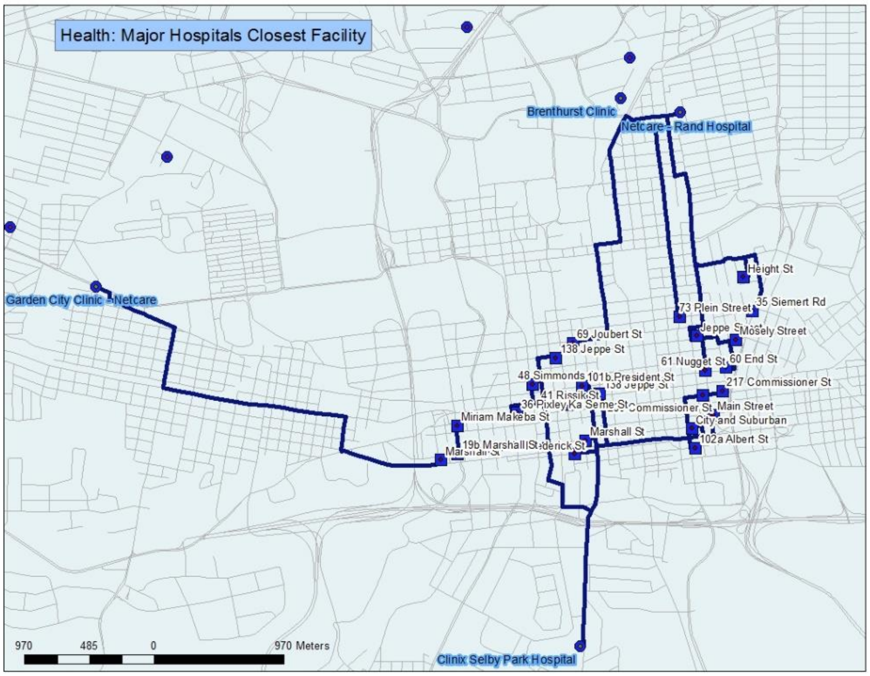
A tweaking of the weightings was applied in this research, to better reflect the reality of the South African urban poor. That is, access to food and transport were given the highest weights. Furthermore, whereas the Adelaide method included distance measurements to the CBD, they have been excluded, since the study area in its entirety is within the Johannesburg CBD. Clinics have been included for this research because the Primary Health Care system is the main means by which government extends health services to communities. It is noted that Australia's TAFE (Technical and Further Education) institutions, serve the same purpose as South Africa's FET (Further Education and Training) colleges and other private colleges. These have been included. On the basis of the literature on urban poor food security issues in section 2.3.2, 'spaza' (informal) shops have also been included.
The calculation of Metro ARIA requires the measurement of the closest service point of each type (Health, retail, education, public transport and finance) to each of the selected (24) redevelopment locations. ArcGIS Network Analyst's Closest Facility tool was used to calculate these distances:

1) All data are commercial datasets acquired from various vendors, including The Knowledge Factory, Pitney Bowes Spatial Technologies, Standard Bank etc.;
2) A network dataset was created from OSM (Open Street Map) data using ArcGIS OSM Editor, projection WGS 84 UTM 35, so that results could be measured in metres. Restrictions that were taken into account:
   - Access Roads
   - Closed Roads
   - One-way Roads
   - Turn restrictions.
3) Once the OSM layer was made routable, the Closest Facility analysis was run iteratively for each service point layer type (see the previous table), using ArcGIS Network Analyst;
4) The resulting distances were inserted into the ARIA formula, and the calculations completed;
5) Distance Cost measurement in metres.
6) The coding of the results (in chapter 4) uses a 5-point Jenks' natural break classification, from most accessible sites (closer to '0') to least accessible (closer to '12')

Sections 3.3.4 to 3.3.9 present the results.

3.4.4 ARIA Calculation: Health

Figure 18 Closest Facility: Major Hospitals

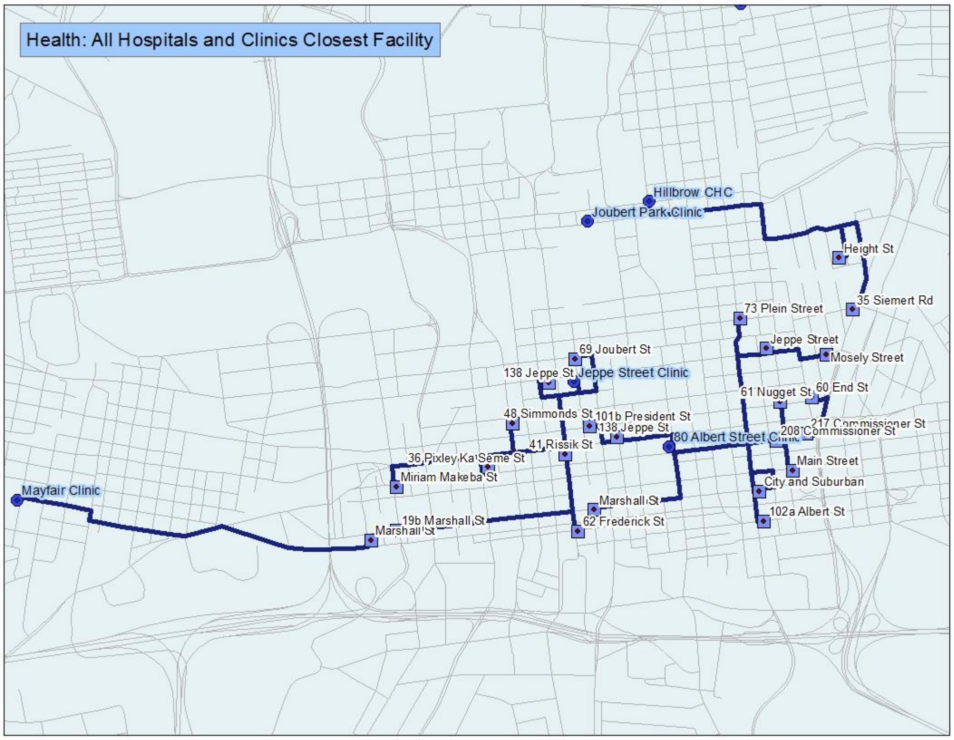


Includes all major public (government) and private (medical insurance) facilities, as listed by the Gauteng Department of health.

Table 11 Closest Facility: Major Hospitals - Distance

FID	ID	MAP	ADDRESS	HOSPITAL_FID	HOSPITAL_NAME	HOSPITAL_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	26	Clinix Selby Park Hospital	2323.254425
1	221	Dilapidated/ abandoned	60 End St	28	Netcare - Rand Hospital	2413.124566
2	232	Dilapidated/ abandoned	35 Siemert Rd	28	Netcare - Rand Hospital	2220.620734
3	278	Dilapidated/ abandoned	208 Commissioner St	26	Clinix Selby Park Hospital	2652.661726
4	288	Dilapidated/ abandoned	217 Commissioner St	26	Clinix Selby Park Hospital	2800.281675
5	292	Dilapidated/ abandoned	61 Nugget St	28	Netcare - Rand Hospital	2132.509966
6	378	Dilapidated/ abandoned	19b Marshall St	26	Clinix Selby Park Hospital	2476.888789
7	394	Dilapidated/ abandoned	41 Rissik St	26	Clinix Selby Park Hospital	2098.713929
8	403	Dilapidated/ abandoned	69 Joubert St	28	Netcare - Rand Hospital	2549.182109
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	26	Clinix Selby Park Hospital	2463.080395
10	421	Dilapidated/ abandoned	124 Marshall St	26	Clinix Selby Park Hospital	1652.341045
11	424	Dilapidated/ abandoned	62 Frederick St	26	Clinix Selby Park Hospital	1645.171038
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	26	Clinix Selby Park Hospital	1982.565291
13	455	Dilapidated/ abandoned	48 Simmonds St	26	Clinix Selby Park Hospital	2325.020105
14	461	Dilapidated/ abandoned	101b President St	26	Clinix Selby Park Hospital	2014.657132
15	462	Dilapidated/ abandoned	138 Jeppe St	26	Clinix Selby Park Hospital	2570.859512
16	778	Dilapidated/ abandoned	Marshall St	11	Garden City Clinic	3580.739891
17	325	Dilapidated/ abandoned	73 Plein Street	28	Netcare - Rand Hospital	1713.778622
18	326	Dilapidated/ abandoned	Jeppe Street	28	Netcare - Rand Hospital	2020.030384
19	228	Dilapidated/ abandoned	Mosely Street	28	Netcare - Rand Hospital	2187.76
20	384	Dilapidated/ abandoned	Miriam Makeba St	26	Clinix Selby Park Hospital	2675.024408
21	210	Dilapidated/ abandoned	204 Main Street	26	Clinix Selby Park Hospital	2571.26603
22	384	Dilapidated/ abandoned	City and Suburban	26	Clinix Selby Park Hospital	2462.905966
23	239	Dilapidated/ abandoned	33 Height St	28	Netcare - Rand Hospital	1853.237152
					Avg.	2307.736454

Figure 19 Closest Facility: All Hospitals and Clinics



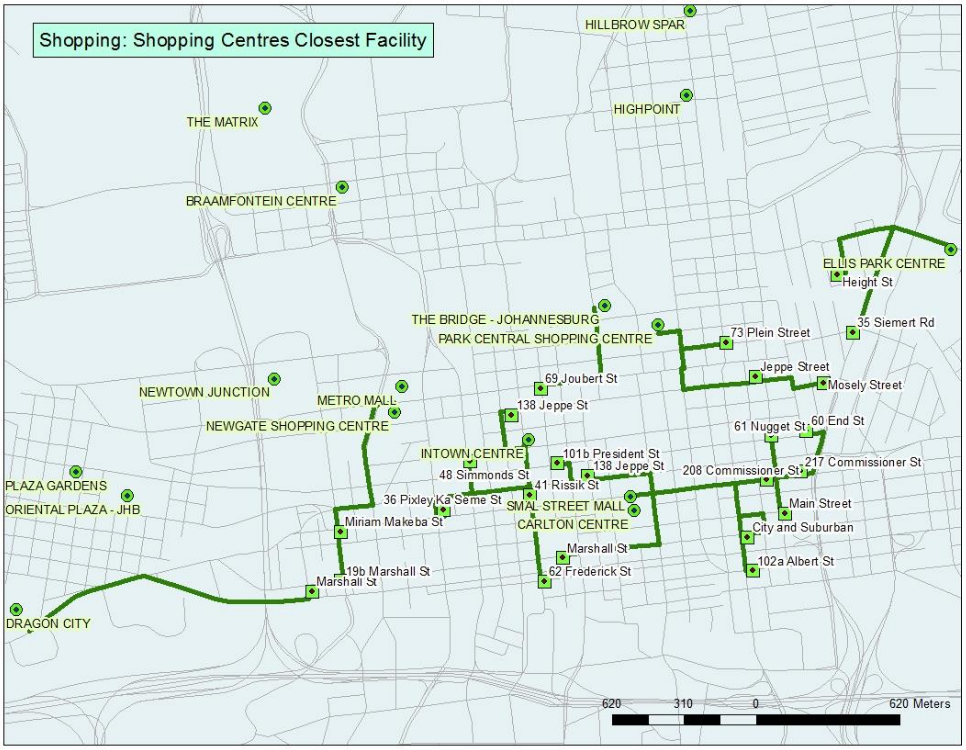
Includes all major hospital facilities, clinics and primary health care facilities.

Table 12 Closest Facility: All Hospitals and Clinics - Distance

FID	ID	MAP	ADDRESS	CLINIC_FID	CLINIC_NAME	CLINIC_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	97	80 Albert Street Clinic	799.7621285
1	221	Dilapidated/ abandoned	60 End St	97	80 Albert Street Clinic	984.8830866
2	232	Dilapidated/ abandoned	35 Siemert Rd	127	Hillbrow CHC	1672.175428
3	278	Dilapidated/ abandoned	208 Commissioner St	97	80 Albert Street Clinic	527.2449162
4	288	Dilapidated/ abandoned	217 Commissioner St	97	80 Albert Street Clinic	674.8648646
5	292	Dilapidated/ abandoned	61 Nugget St	97	80 Albert Street Clinic	749.5459512
6	378	Dilapidated/ abandoned	19b Marshall St	112	Jeppe Street Clinic	1574.454784
7	394	Dilapidated/ abandoned	41 Rissik St	112	Jeppe Street Clinic	438.3712006
8	403	Dilapidated/ abandoned	69 Joubert St	112	Jeppe Street Clinic	406.8660132
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	112	Jeppe Street Clinic	932.543464
10	421	Dilapidated/ abandoned	124 Marshall St	97	80 Albert Street Clinic	672.0317315
11	424	Dilapidated/ abandoned	62 Frederick St	112	Jeppe Street Clinic	824.6879639
12	398	Dilapidated/ abandoned	143 Jeppe St	97	80 Albert Street Clinic	333.7554763
13	455	Dilapidated/ abandoned	48 Simmonds St	112	Jeppe Street Clinic	794.4831743
14	461	Dilapidated/ abandoned	101b President St	97	80 Albert Street Clinic	527.7422357
15	462	Dilapidated/ abandoned	138 Jeppe St	112	Jeppe Street Clinic	369.1805376
16	778	Dilapidated/ abandoned	Marshall St	98	Mayfair Clinic	1824.616225
17	325	Dilapidated/ abandoned	73 Plein Street	97	80 Albert Street Clinic	1006.920273
18	326	Dilapidated/ abandoned	Jeppe Street	97	80 Albert Street Clinic	958.8810669
19	228	Dilapidated/ abandoned	Mosely Street	97	80 Albert Street Clinic	1288.041788
20	384	Dilapidated/ abandoned	Miriam Makeba St	112	Jeppe Street Clinic	1345.007082
21	210	Dilapidated/ abandoned	204 Main Street	97	80 Albert Street Clinic	730.5753191
22	384	Dilapidated/ abandoned	City and Suburban	97	80 Albert Street Clinic	787.4733403
23	239	Dilapidated/ abandoned	33 Height St	127	Hillbrow CHC	1304.791846
					Avg.	897.03749571708

3.4.5 ARIA Calculation: Shopping

Figure 20 Closest Facility: Shopping Centres



As supplied by the South African Council of Shopping Centres and other sources.

Table 13 Closest Facility: Shopping Centers - Distance

FID	ID	MAP	ADDRESS	SHOPPING_CENTRE_FID	SHOPPING_CENTRE_NAME	SHOPPING_CENTRE_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	682	CARLTON CENTRE	855.4384027
1	221	Dilapidated/ abandoned	60 End St	682	CARLTON CENTRE	1040.559361
2	232	Dilapidated/ abandoned	35 Siemert Rd	659	ELLIS PARK CENTRE	754.4437124
3	278	Dilapidated/ abandoned	208 Commissioner St	682	CARLTON CENTRE	582.9211904
4	288	Dilapidated/ abandoned	217 Commissioner St	682	CARLTON CENTRE	730.5411388
5	292	Dilapidated/ abandoned	61 Nugget St	682	CARLTON CENTRE	805.2222253
6	378	Dilapidated/ abandoned	19b Marshall St	684	NEWGATE SHOPPING CENTRE	1003.505588
7	394	Dilapidated/ abandoned	41 Rissik St	666	INTOWN CENTRE	234.8235621
8	403	Dilapidated/ abandoned	69 Joubert St	662	THE BRIDGE - JOHANNESBURG	578.1812445
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	666	INTOWN CENTRE	728.9958256
10	421	Dilapidated/ abandoned	124 Marshall St	682	CARLTON CENTRE	727.7080056
11	424	Dilapidated/ abandoned	62 Frederick St	666	INTOWN CENTRE	621.1403255
12	398	Dilapidated/ abandoned	143 Jeppe St	682	CARLTON CENTRE	450.4341208
13	455	Dilapidated/ abandoned	48 Simmonds St	666	INTOWN CENTRE	590.9355358
14	461	Dilapidated/ abandoned	101b President St	682	CARLTON CENTRE	644.4208802
15	462	Dilapidated/ abandoned	138 Jeppe St	666	INTOWN CENTRE	326.1106074
16	778	Dilapidated/ abandoned	Marshall St	689	DRAGON CITY	1310.585459
17	325	Dilapidated/ abandoned	73 Plein Street	663	PARK CENTRAL SHOPPING CEN	360.2874749
18	326	Dilapidated/ abandoned	Jeppe Street	663	PARK CENTRAL SHOPPING CEN	670.5975745
19	228	Dilapidated/ abandoned	Mosely Street	663	PARK CENTRAL SHOPPING CEN	999.7582954
20	384	Dilapidated/ abandoned	Miriam Makeba St	684	NEWGATE SHOPPING CENTRE	781.469879
21	210	Dilapidated/ abandoned	204 Main Street	682	CARLTON CENTRE	786.2515933
22	384	Dilapidated/ abandoned	City and Suburban	682	CARLTON CENTRE	843.1496144
23	239	Dilapidated/ abandoned	33 Height St	659	ELLIS PARK CENTRE	652.2434138
					Avg.	1602.29382438122

Figure 21 Closest Facility: Supermarkets

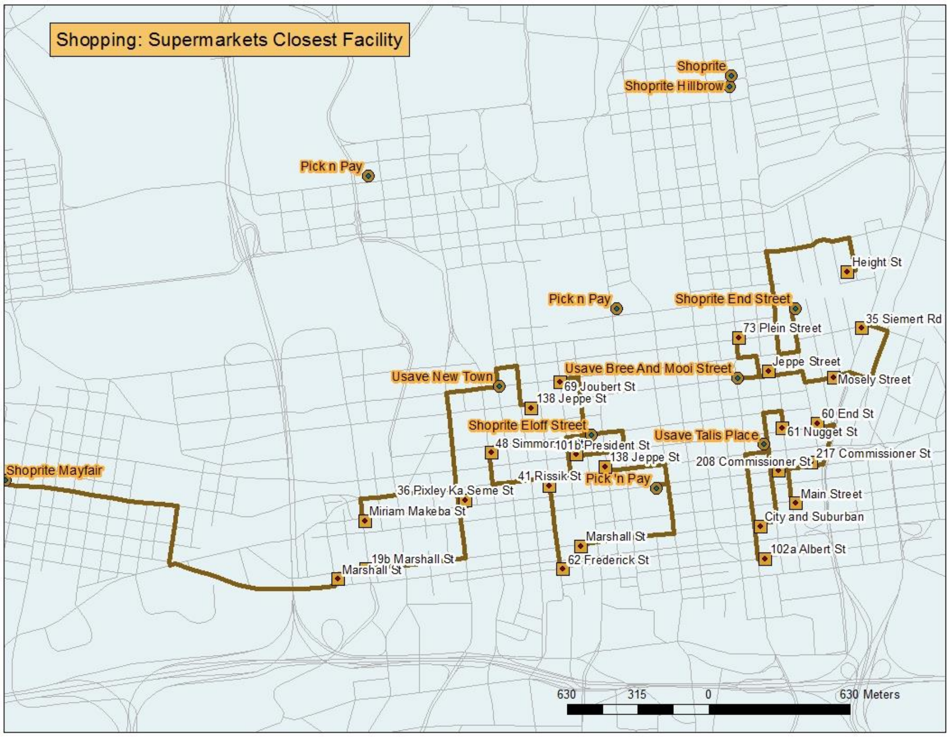


Table 14 Closest Facility: Supermarkets - Distance

FID	ID	MAP	ADDRESS	SUPERMARKET_FID	SUPERMARKET_NAME	SUPERMARKET_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	111	Usave Talis Place	634.054338
1	221	Dilapidated/ abandoned	60 End St	111	Usave Talis Place	615.751022
2	232	Dilapidated/ abandoned	35 Siemert Rd	113	Usave Bree And Mooi Street	991.9697736
3	278	Dilapidated/ abandoned	208 Commissioner St	111	Usave Talis Place	158.1128516
4	288	Dilapidated/ abandoned	217 Commissioner St	111	Usave Talis Place	305.7328
5	292	Dilapidated/ abandoned	61 Nugget St	111	Usave Talis Place	302.9405058
6	378	Dilapidated/ abandoned	19b Marshall St	112	Usave New Town	1422.031741
7	394	Dilapidated/ abandoned	41 Rissik St	78	Shoprite Eloff Street	414.2738476
8	403	Dilapidated/ abandoned	69 Joubert St	78	Shoprite Eloff Street	384.1237824
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	112	Usave New Town	780.8089314
10	421	Dilapidated/ abandoned	124 Marshall St	203	Pick 'n Pay Commissioner	693.9814504
11	424	Dilapidated/ abandoned	62 Frederick St	78	Shoprite Eloff Street	800.5906109
12	398	Dilapidated/ abandoned	143 Jeppe St	203	Pick 'n Pay Commissioner	416.7075656
13	455	Dilapidated/ abandoned	48 Simmonds St	78	Shoprite Eloff Street	770.3858213
14	461	Dilapidated/ abandoned	101b President St	78	Shoprite Eloff Street	436.4499232
15	462	Dilapidated/ abandoned	138 Jeppe St	112	Usave New Town	398.4561668
16	778	Dilapidated/ abandoned	Marshall St	85	Shoprite Mayfair	1813.552689
17	325	Dilapidated/ abandoned	73 Plein Street	113	Usave Bree And Mooi Street	366.930186
18	326	Dilapidated/ abandoned	Jeppe Street	113	Usave Bree And Mooi Street	139.4908107
19	228	Dilapidated/ abandoned	Mosely Street	113	Usave Bree And Mooi Street	468.6515317
20	384	Dilapidated/ abandoned	Miriam Makeba St	112	Usave New Town	1193.27255
21	210	Dilapidated/ abandoned	204 Main Street	111	Usave Talis Place	361.4432545
22	384	Dilapidated/ abandoned	City and Suburban	111	Usave Talis Place	417.7843354
23	239	Dilapidated/ abandoned	33 Height St	75	Shoprite End Street	1265.854998
					Avg.	648.05631193163

Figure 22 Closest Facility: Spaza Shops

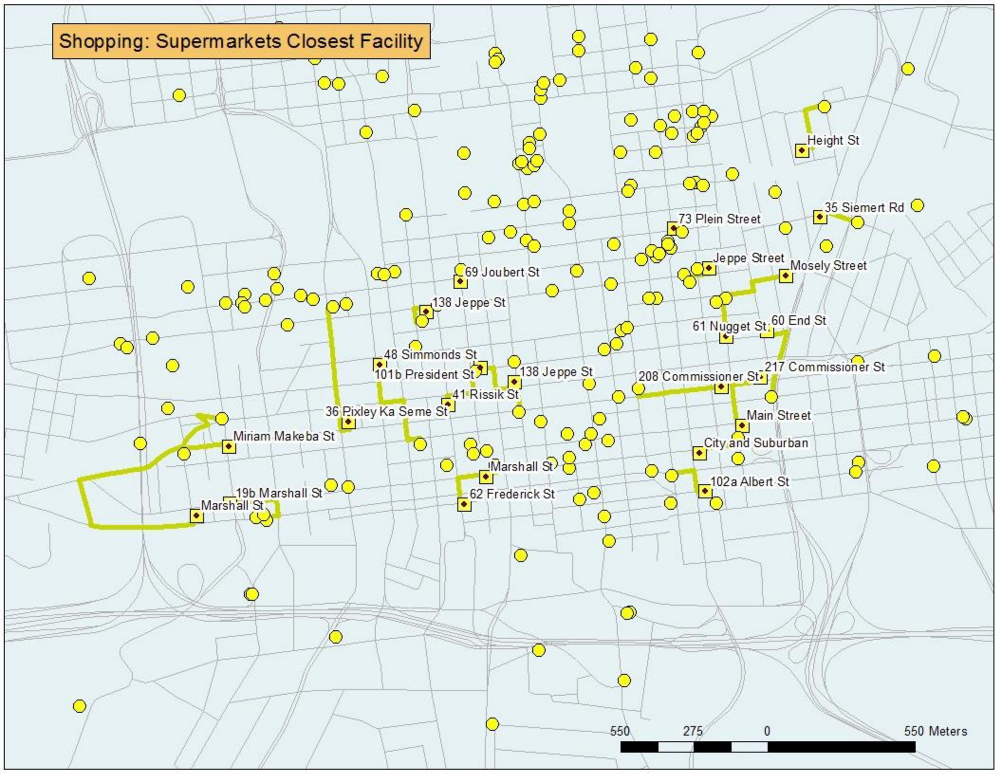


Table 15 Closest Facility: Spaza Shops - Distance

FID	ID	MAP	ADDRESS	SPAZA_FID	SPAZA_NAME	SPAZA_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	2884	LEGGAE SPORTS BAR	199.7308761
1	221	Dilapidated/ abandoned	60 End St	1010	RAYLTON TAVERN	330.9530436
2	232	Dilapidated/ abandoned	35 Siemert Rd	1100	MAC BURGER	152.5711704
3	278	Dilapidated/ abandoned	208 Commissioner St	5120	J C RESTAURANT	338.4861843
4	288	Dilapidated/ abandoned	217 Commissioner St	976	NEW NUGGET HOTEL	309.2612892
5	292	Dilapidated/ abandoned	61 Nugget St	3219	NHT FUNCTIONS EXPERIENCE	167.6056858
6	378	Dilapidated/ abandoned	19b Marshall St	3113	NEW SOUTH AFRICA LIQUOR STOF	277.682746
7	394	Dilapidated/ abandoned	41 Rissik St	2389	MERITING VENUE	229.3429305
8	403	Dilapidated/ abandoned	69 Joubert St	1462	SPRINGBOK HOTEL	43.23108648
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	2196	TRUST ME TAVERN	489.0660234
10	421	Dilapidated/ abandoned	124 Marshall St	5290	KOSPOTONG BAR LOUNG GHANDI	41.38416312
11	424	Dilapidated/ abandoned	62 Frederick St	5290	KOSPOTONG BAR LOUNG GHANDI	254.4802299
12	398	Dilapidated/ abandoned	143 Jeppe St	3817	ESPELONG	115.0773133
13	455	Dilapidated/ abandoned	48 Simmonds St	1219	RAND CLUB	416.8712427
14	461	Dilapidated/ abandoned	101b President St	3817	ESPELONG	309.0640727
15	462	Dilapidated/ abandoned	138 Jeppe St	1151	CLUB 22	99.60017003
16	778	Dilapidated/ abandoned	Marshall St	313	OPTIMUM TAVERN	1282.218196
17	325	Dilapidated/ abandoned	73 Plein Street	2449	HOME BOY	30.47293279
18	326	Dilapidated/ abandoned	Jeppe Street	5221	ARISE AND SHINE RESTAURANT	72.72288792
19	228	Dilapidated/ abandoned	Mosely Street	3219	NHT FUNCTIONS EXPERIENCE	271.657269
20	384	Dilapidated/ abandoned	Miriam Makeba St	1190	LITTLE SWALLOW INN RESTAURAN	199.6824412
21	210	Dilapidated/ abandoned	204 Main Street	976	NEW NUGGET HOTEL	77.52332824
22	384	Dilapidated/ abandoned	City and Suburban	976	NEW NUGGET HOTEL	174.0904724
23	239	Dilapidated/ abandoned	33 Height St	3166	THE DANCE PALACE ENTERTAINMI	232.9927495
					Avg.	254.82368767143

3.4.6 ARIA Calculation: Education

Figure 23 Closest Facility: Primary Schools

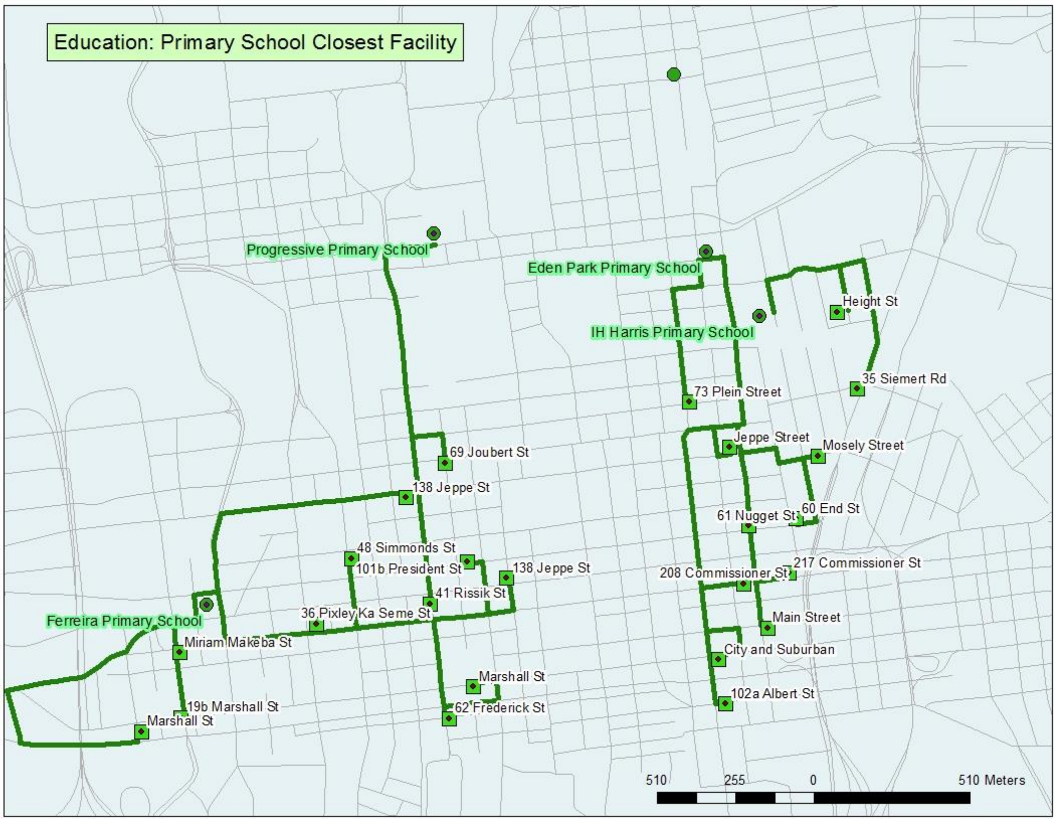


Table 16 Closest Facility: Primary Schools - Distance

FID	ID	MAP	ADDRESS	PRIMARYSCHOOL_FID	PRIMARYSCHOOL_NAME	PRIMARYSCHOOL_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	146	Eden Park Primary School	1713.166335
1	221	Dilapidated/ abandoned	60 End St	146	Eden Park Primary School	1227.973014
2	232	Dilapidated/ abandoned	35 Siemert Rd	374	IH Harris Primary School	869.2495113
3	278	Dilapidated/ abandoned	208 Commissioner St	146	Eden Park Primary School	1440.649122
4	288	Dilapidated/ abandoned	217 Commissioner St	146	Eden Park Primary School	1238.258262
5	292	Dilapidated/ abandoned	61 Nugget St	146	Eden Park Primary School	947.3584133
6	378	Dilapidated/ abandoned	19b Marshall St	362	Ferreira Primary School	524.2352911
7	394	Dilapidated/ abandoned	41 Rissik St	77	Progressive Primary School	1334.322564
8	403	Dilapidated/ abandoned	69 Joubert St	77	Progressive Primary School	985.5473186
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	362	Ferreira Primary School	505.7574052
10	421	Dilapidated/ abandoned	124 Marshall St	362	Ferreira Primary School	1490.788343
11	424	Dilapidated/ abandoned	62 Frederick St	362	Ferreira Primary School	1220.294953
12	398	Dilapidated/ abandoned	143 Jeppe St	362	Ferreira Primary School	1254.488302
13	455	Dilapidated/ abandoned	48 Simmonds St	362	Ferreira Primary School	858.4699535
14	461	Dilapidated/ abandoned	101b President St	362	Ferreira Primary School	1285.785509
15	462	Dilapidated/ abandoned	138 Jeppe St	362	Ferreira Primary School	898.5571489
16	778	Dilapidated/ abandoned	Marshall St	362	Ferreira Primary School	1400.757268
17	325	Dilapidated/ abandoned	73 Plein Street	146	Eden Park Primary School	601.2895415
18	326	Dilapidated/ abandoned	Jeppe Street	146	Eden Park Primary School	834.8788315
19	228	Dilapidated/ abandoned	Mosely Street	146	Eden Park Primary School	1002.608447
20	384	Dilapidated/ abandoned	Miriam Makeba St	362	Ferreira Primary School	302.1995826
21	210	Dilapidated/ abandoned	204 Main Street	146	Eden Park Primary School	1293.968716
22	384	Dilapidated/ abandoned	City and Suburban	146	Eden Park Primary School	1700.877546
23	239	Dilapidated/ abandoned	33 Height St	374	IH Harris Primary School	501.8659294
					Avg.	1059.72280453963

Figure 24 Closest Facility: High Schools

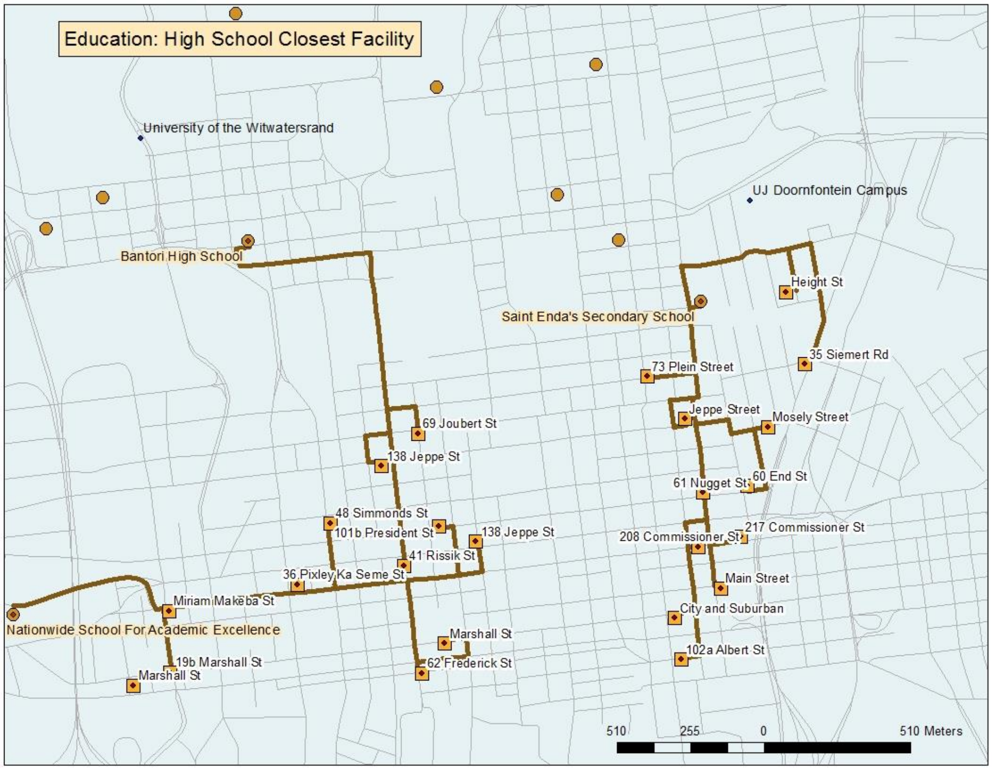


Table 17 Closest Facility: High Schools - Distance

FID	ID	MAP	ADDRESS	HIGHSCHOOL_FID	HIGHSCHOOL_NAME	HIGHSCHOOL_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	120	Saint Enda'S Secondary School	1400.19807
1	221	Dilapidated/ abandoned	60 End St	120	Saint Enda'S Secondary School	977.3982324
2	232	Dilapidated/ abandoned	35 Siemert Rd	120	Saint Enda'S Secondary School	1086.72833
3	278	Dilapidated/ abandoned	208 Commissioner St	120	Saint Enda'S Secondary School	993.2243856
4	288	Dilapidated/ abandoned	217 Commissioner St	120	Saint Enda'S Secondary School	988.0376976
5	292	Dilapidated/ abandoned	61 Nugget St	120	Saint Enda'S Secondary School	696.9594234
6	378	Dilapidated/ abandoned	19b Marshall St	251	Nationwide School For Academic Excellence	831.8010456
7	394	Dilapidated/ abandoned	41 Rissik St	138	Bantori High School	1659.739324
8	403	Dilapidated/ abandoned	69 Joubert St	138	Bantori High School	1310.925408
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	251	Nationwide School For Academic Excellence	1070.027664
10	421	Dilapidated/ abandoned	124 Marshall St	251	Nationwide School For Academic Excellence	2055.143624
11	424	Dilapidated/ abandoned	62 Frederick St	251	Nationwide School For Academic Excellence	1784.695644
12	398	Dilapidated/ abandoned	143 Jeppe St	251	Nationwide School For Academic Excellence	1818.747559
13	455	Dilapidated/ abandoned	48 Simmonds St	251	Nationwide School For Academic Excellence	1422.578716
14	461	Dilapidated/ abandoned	101b President St	251	Nationwide School For Academic Excellence	1850.354036
15	462	Dilapidated/ abandoned	138 Jeppe St	138	Bantori High School	1419.096164
16	778	Dilapidated/ abandoned	Marshall St	251	Nationwide School For Academic Excellence	955.8010456
17	325	Dilapidated/ abandoned	73 Plein Street	120	Saint Enda'S Secondary School	430.3875032
18	326	Dilapidated/ abandoned	Jeppe Street	120	Saint Enda'S Secondary School	584.7115872
19	228	Dilapidated/ abandoned	Mosely Street	120	Saint Enda'S Secondary School	751.8834148
20	384	Dilapidated/ abandoned	Miriam Makeba St	251	Nationwide School For Academic Excellence	618.1699211
21	210	Dilapidated/ abandoned	204 Main Street	120	Saint Enda'S Secondary School	1043.488366
22	384	Dilapidated/ abandoned	City and Suburban	120	Saint Enda'S Secondary School	1252.756699
23	239	Dilapidated/ abandoned	33 Height St	120	Saint Enda'S Secondary School	714.5595165
					Avg.	1154.89222408625

Figure 25 Closest Facility: FET Colleges

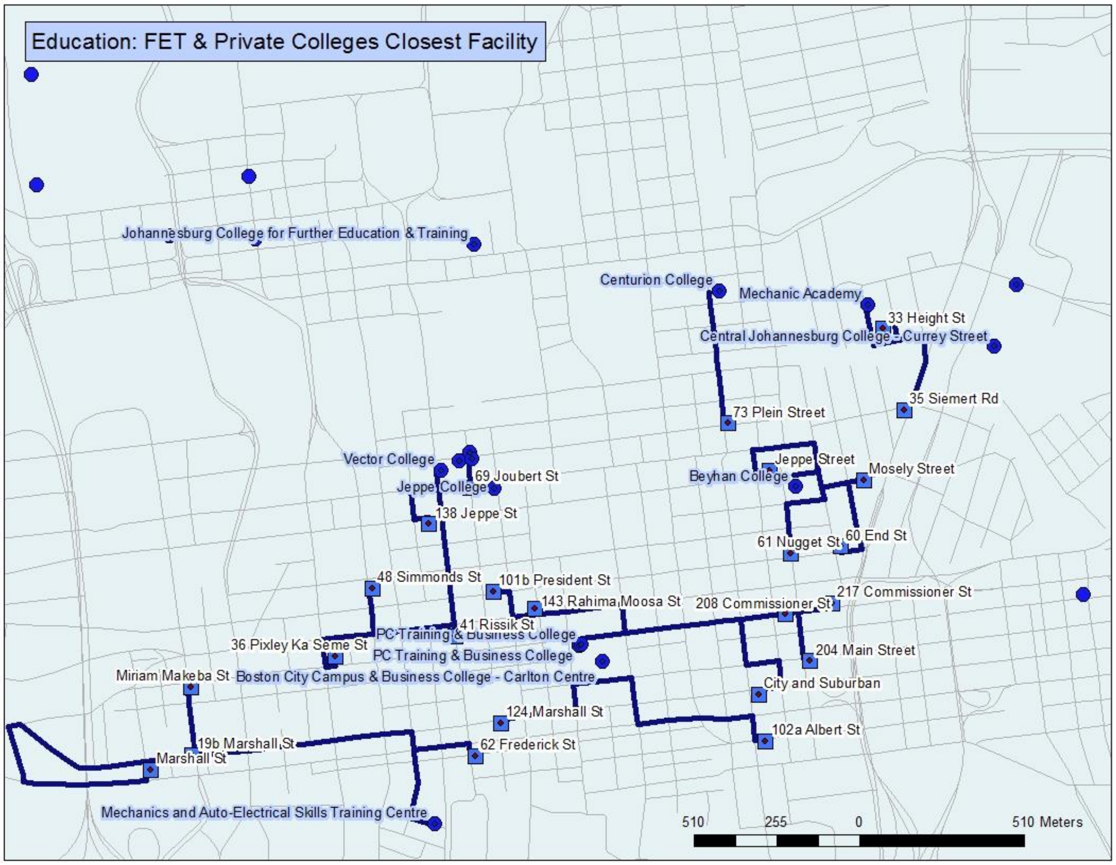


Table 18 Closest Facility: FET Colleges - Distance

FID	ID	MAP	ADDRESS	FET COLLEGE_	FET COLLEGE_NAME	FET COLLEGE_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	134	Boston City Campus & Business College - Carlton Centre	1713.166335
1	221	Dilapidated/ abandoned	60 End St	40	Beyhan College	1227.973014
2	232	Dilapidated/ abandoned	35 Siemert Rd	19	Mechanic Academy	869.2495113
3	278	Dilapidated/ abandoned	208 Commissioner St	157	PC Training & Business College	1440.649122
4	288	Dilapidated/ abandoned	217 Commissioner St	157	PC Training & Business College	1238.258262
5	292	Dilapidated/ abandoned	61 Nugget St	40	Beyhan College	947.3584133
6	378	Dilapidated/ abandoned	19b Marshall St	68	Mechanics and Auto-Electrical Skills Training Centre	524.2352911
7	394	Dilapidated/ abandoned	41 Rissik St	30	Vector College	1334.322564
8	403	Dilapidated/ abandoned	69 Joubert St	37	Johannesburg Polytech Institute	985.5473186
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	30	Vector College	505.7574052
10	421	Dilapidated/ abandoned	124 Marshall St	134	Boston City Campus & Business College - Carlton Centre	1490.788343
11	424	Dilapidated/ abandoned	62 Frederick St	68	Mechanics and Auto-Electrical Skills Training Centre	1220.294953
12	398	Dilapidated/ abandoned	143 Jeppe St	157	PC Training & Business College	1254.488302
13	455	Dilapidated/ abandoned	48 Simmonds St	30	Vector College	858.4699535
14	461	Dilapidated/ abandoned	101b President St	157	PC Training & Business College	1285.785509
15	462	Dilapidated/ abandoned	138 Jeppe St	30	Vector College	898.5571489
16	778	Dilapidated/ abandoned	Marshall St	68	Mechanics and Auto-Electrical Skills Training Centre	1400.757268
17	325	Dilapidated/ abandoned	73 Plein Street	50	Centurion College	601.2895415
18	326	Dilapidated/ abandoned	Jeppe Street	40	Beyhan College	834.8788315
19	228	Dilapidated/ abandoned	Mosely Street	40	Beyhan College	1002.608447
20	384	Dilapidated/ abandoned	Miriam Makeba St	68	Mechanics and Auto-Electrical Skills Training Centre	302.1995826
21	210	Dilapidated/ abandoned	204 Main Street	157	PC Training & Business College	1293.968716
22	384	Dilapidated/ abandoned	City and Suburban	157	PC Training & Business College	1700.877546
23	239	Dilapidated/ abandoned	33 Height St	19	Mechanic Academy	501.8659294
					Avg.	1059.72280453963

Figure 26 Closest Facility: Universities

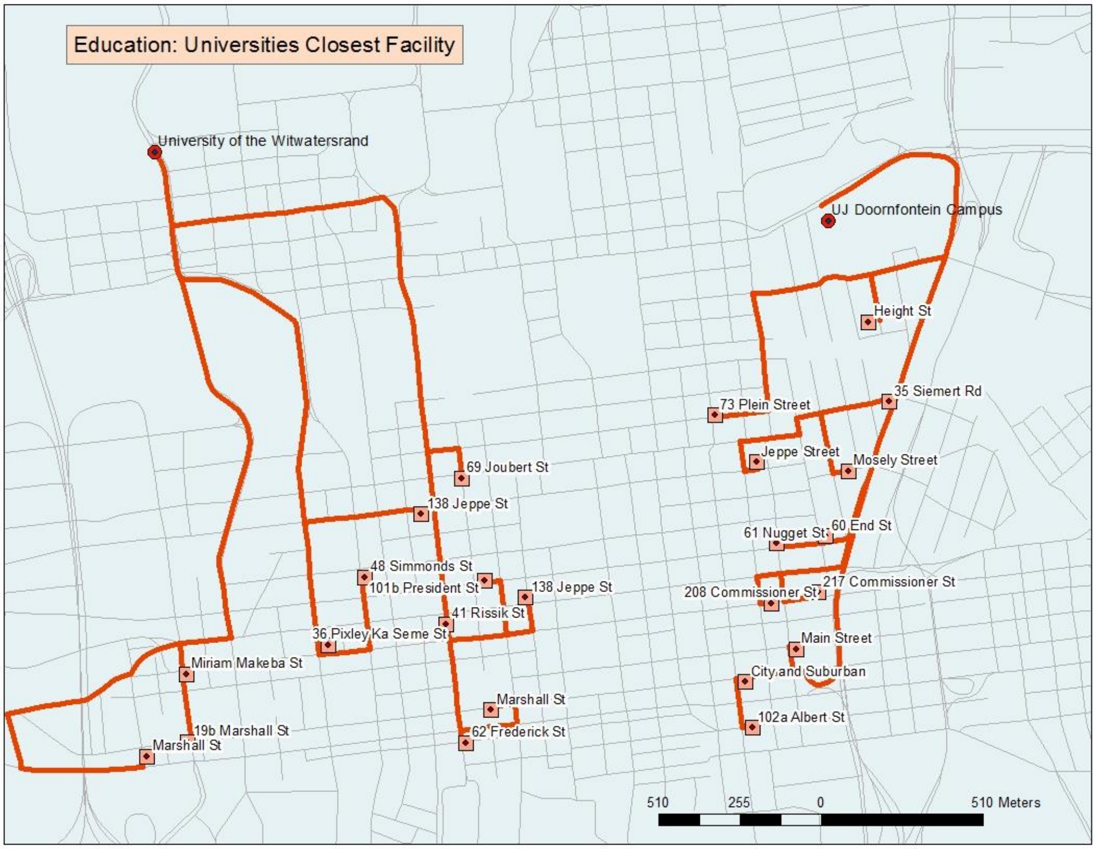
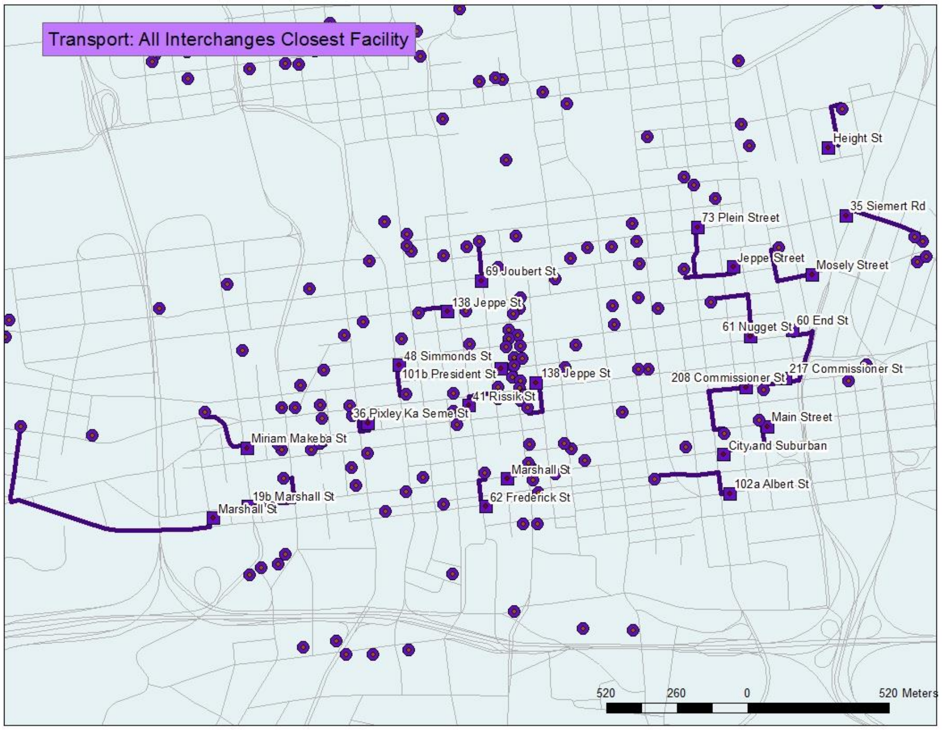


Table 19 Closest Facility: Universities - Distance

FID	ID	MAP	ADDRESS	UNIVERSITY_FID	UNIVERSITY_NAME	UNIVERSITY_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	2	UJ Doornfontein Campus	2665.164239
1	221	Dilapidated/ abandoned	60 End St	2	UJ Doornfontein Campus	1772.621284
2	232	Dilapidated/ abandoned	35 Siemert Rd	2	UJ Doornfontein Campus	1253.413593
3	278	Dilapidated/ abandoned	208 Commissioner St	2	UJ Doornfontein Campus	2186.052825
4	288	Dilapidated/ abandoned	217 Commissioner St	2	UJ Doornfontein Campus	2180.689967
5	292	Dilapidated/ abandoned	61 Nugget St	2	UJ Doornfontein Campus	1938.692374
6	378	Dilapidated/ abandoned	19b Marshall St	4	University of the Witwatersrand	2101.372419
7	394	Dilapidated/ abandoned	41 Rissik St	4	University of the Witwatersrand	2277.610832
8	403	Dilapidated/ abandoned	69 Joubert St	4	University of the Witwatersrand	1928.835587
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	4	University of the Witwatersrand	1888.107723
10	421	Dilapidated/ abandoned	124 Marshall St	4	University of the Witwatersrand	2934.420986
11	424	Dilapidated/ abandoned	62 Frederick St	4	University of the Witwatersrand	2663.927596
12	398	Dilapidated/ abandoned	143 Jeppe St	4	University of the Witwatersrand	2698.120945
13	455	Dilapidated/ abandoned	48 Simmonds St	4	University of the Witwatersrand	2240.820271
14	461	Dilapidated/ abandoned	101b President St	4	University of the Witwatersrand	2729.418152
15	462	Dilapidated/ abandoned	138 Jeppe St	4	University of the Witwatersrand	1804.84188
16	778	Dilapidated/ abandoned	Marshall St	4	University of the Witwatersrand	2977.894397
17	325	Dilapidated/ abandoned	73 Plein Street	2	UJ Doornfontein Campus	1926.532586
18	326	Dilapidated/ abandoned	Jeppe Street	2	UJ Doornfontein Campus	1925.51375
19	228	Dilapidated/ abandoned	Mosely Street	2	UJ Doornfontein Campus	1713.97595
20	384	Dilapidated/ abandoned	Miriam Makeba St	4	University of the Witwatersrand	1879.336711
21	210	Dilapidated/ abandoned	204 Main Street	2	UJ Doornfontein Campus	2395.786626
22	384	Dilapidated/ abandoned	City and Suburban	2	UJ Doornfontein Campus	2450.273521
23	239	Dilapidated/ abandoned	33 Height St	2	UJ Doornfontein Campus	1151.213294
					Avg.	2153.52656281625

3.4.7 ARIA Calculation: Transport

Figure 27 Closest Facility: All Transport Interchange Types

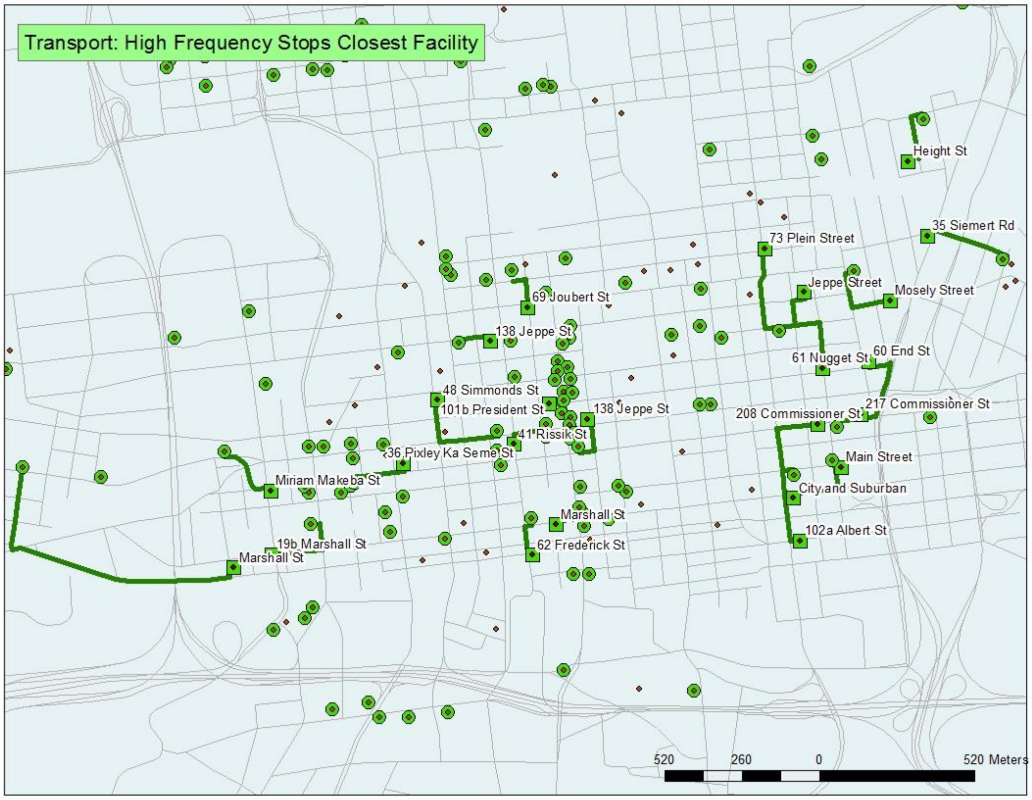


Includes all bus and mini-bus taxes stops and interchanges, as well as those of the main metro service and bus-rapid transit service. Stops are numerous and frequently occurring. Some are informal, therefore they are not named.

Table 20 Closest Facility: All Interchanges - Distance

FID	ID	MAP	ADDRESS	ALL INETRCHANGES_FID	ALL INTERCHANGES_NAME	ALL INTERCHANGES_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	24	Anderson 1	347.4557185
1	221	Dilapidated/ abandoned	60 End St	8	Nugget & Commissioner	394.7676357
2	232	Dilapidated/ abandoned	35 Siemert Rd	167	Location 109	302.2144661
3	278	Dilapidated/ abandoned	208 Commissioner St	127	Location 69	320.4613176
4	288	Dilapidated/ abandoned	217 Commissioner St	8	Nugget & Commissioner	84.74941368
5	292	Dilapidated/ abandoned	61 Nugget St	4	Kerk & Mooi	290.0562894
6	378	Dilapidated/ abandoned	19b Marshall St	84	Location 26	264.3503493
7	394	Dilapidated/ abandoned	41 Rissik St	118	Location 60	148.1835504
8	403	Dilapidated/ abandoned	69 Joubert St	31	De Villiers	145.6513161
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	48	Sauer 1	93.36687211
10	421	Dilapidated/ abandoned	124 Marshall St	77	Location 19	97.37397208
11	424	Dilapidated/ abandoned	62 Frederick St	80	Location 22	133.4850252
12	398	Dilapidated/ abandoned	143 Jeppe St	122	Location 64	157.3265273
13	455	Dilapidated/ abandoned	48 Simmonds St	49	Simmonds 1	109.5582158
14	461	Dilapidated/ abandoned	101b President St	115	Location 57	82.45828987
15	462	Dilapidated/ abandoned	138 Jeppe St	5	Jeppe & Rissik	105.3175151
16	778	Dilapidated/ abandoned	Marshall St	60	Location 2	1046.867563
17	325	Dilapidated/ abandoned	73 Plein Street	26	Jeppe & Mooi	228.1115074
18	326	Dilapidated/ abandoned	Jeppe Street	26	Jeppe & Mooi	180.0723009
19	228	Dilapidated/ abandoned	Mosely Street	133	Location 75	246.0294231
20	384	Dilapidated/ abandoned	Miriam Makeba St	92	Location 34	221.3043847
21	210	Dilapidated/ abandoned	204 Main Street	128	Location 70	35.44017934
22	384	Dilapidated/ abandoned	City and Suburban	128	Location 70	246.8627245
23	239	Dilapidated/ abandoned	33 Height St	144	Location 86	186.2256608
					Avg.	227.82042574890

Figure 28 Closest Facility: High-Frequency Stops

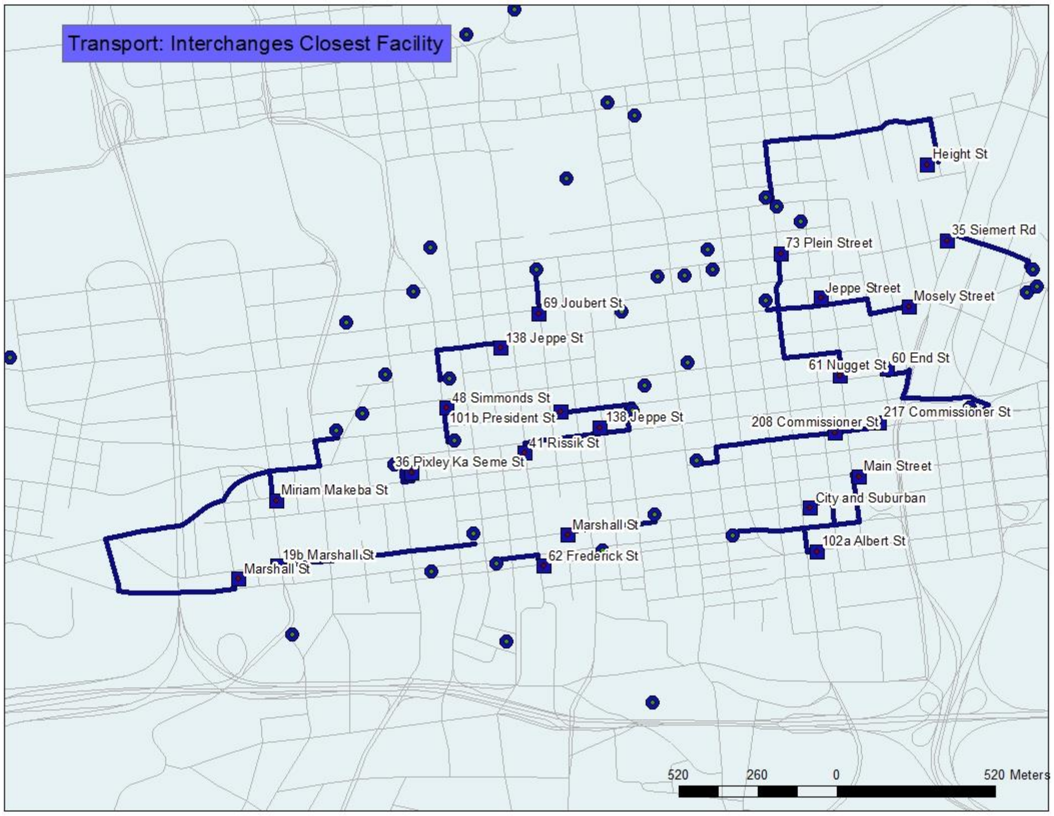


High Frequency Stops were selected as Metro Bus service and bus-rapid transit (BRT) service stops only.

Table 21 Closest Facility: High Frequency Stops - Distance

FID	ID	MAP	ADDRESS	HIGH_FREQUENCEY_ID	HIGH FREQUENCY STOP_NAME	HFS_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	87	Location 69	308.203755
1	221	Dilapidated/ abandoned	60 End St	8	Nugget & Commissioner	394.767636
2	232	Dilapidated/ abandoned	35 Siemert Rd	127	Location 109	302.214466
3	278	Dilapidated/ abandoned	208 Commissioner St	87	Location 69	320.461318
4	288	Dilapidated/ abandoned	217 Commissioner St	8	Nugget & Commissioner	84.749414
5	292	Dilapidated/ abandoned	61 Nugget St	4	Kerk & Mooi	290.056289
6	378	Dilapidated/ abandoned	19b Marshall St	44	Location 26	264.350349
7	394	Dilapidated/ abandoned	41 Rissik St	78	Location 60	148.183550
8	403	Dilapidated/ abandoned	69 Joubert St	60	Location 42	138.413489
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	49	Location 31	167.950973
10	421	Dilapidated/ abandoned	124 Marshall St	37	Location 19	97.373972
11	424	Dilapidated/ abandoned	62 Frederick St	40	Location 22	133.485025
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	82	Location 64	157.326527
13	455	Dilapidated/ abandoned	48 Simmonds St	6	Rissik & Market	337.501034
14	461	Dilapidated/ abandoned	101b President St	75	Location 57	82.458290
15	462	Dilapidated/ abandoned	138 Jeppe St	5	Jeppe & Rissik	105.317515
16	778	Dilapidated/ abandoned	Marshall St	20	Location 2	1046.867563
17	325	Dilapidated/ abandoned	73 Plein Street	4	Kerk & Mooi	327.491830
18	326	Dilapidated/ abandoned	Jeppe Street	4	Kerk & Mooi	180.473477
19	228	Dilapidated/ abandoned	Mosely Street	93	Location 75	246.029423
20	384	Dilapidated/ abandoned	Miriam Makeba St	52	Location 34	221.304385
21	210	Dilapidated/ abandoned	204 Main Street	88	Location 70	35.440179
22	384	Dilapidated/ abandoned	City and Suburban	88	Location 70	246.862724
23	239	Dilapidated/ abandoned	33 Height St	104	Location 86	186.225661
					Avg.	242.646202

Figure 29 Closest Facility: Interchanges



Normal interchanges were selected as Minibus taxi and Gautrain (commuter rail) stops only.

Table 22 Closest Facility: Interchanges - Distance

FID	ID	MAP	ADDRESS	INTERCHANGE_FID	INTERCHANGE_NAME	INTERCHANGE_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	9	Anderson 1	347.455718
1	221	Dilapidated/ abandoned	60 End St	27	Berea Road	525.208592
2	232	Dilapidated/ abandoned	35 Siemert Rd	20	Jeppe Taxi Rank 1	306.815240
3	278	Dilapidated/ abandoned	208 Commissioner St	26	Von Weilligh & Fox	510.179059
4	288	Dilapidated/ abandoned	217 Commissioner St	26	Von Weilligh & Fox	657.799007
5	292	Dilapidated/ abandoned	61 Nugget St	11	Jeppe & Mooi	459.705765
6	378	Dilapidated/ abandoned	19b Marshall St	35	Marshall 1	657.387449
7	394	Dilapidated/ abandoned	41 Rissik St	6	Kruis & President	483.902241
8	403	Dilapidated/ abandoned	69 Joubert St	16	De Villiers	145.651316
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	30	Sauer 1	93.366872
10	421	Dilapidated/ abandoned	124 Marshall St	29	Marshall 2	291.601006
11	424	Dilapidated/ abandoned	62 Frederick St	36	Frederick 2	185.612697
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	6	Kruis & President	205.858685
13	455	Dilapidated/ abandoned	48 Simmonds St	31	Simmonds 1	109.558216
14	461	Dilapidated/ abandoned	101b President St	6	Kruis & President	236.133893
15	462	Dilapidated/ abandoned	138 Jeppe St	32	Simmonds 2	307.958692
16	778	Dilapidated/ abandoned	Marshall St	3	President & Diagonal	1521.607051
17	325	Dilapidated/ abandoned	73 Plein Street	11	Jeppe & Mooi	228.111507
18	326	Dilapidated/ abandoned	Jeppe Street	11	Jeppe & Mooi	180.072301
19	228	Dilapidated/ abandoned	Mosely Street	11	Jeppe & Mooi	509.233022
20	384	Dilapidated/ abandoned	Miriam Makeba St	3	President & Diagonal	423.049365
21	210	Dilapidated/ abandoned	204 Main Street	9	Anderson 1	595.467323
22	384	Dilapidated/ abandoned	City and Suburban	9	Anderson 1	487.107259
23	239	Dilapidated/ abandoned	33 Height St	45	Claim & Noord 1	926.446521
					Avg.	433.137033

3.4.8 ARIA Calculation: Financial

Figure 30 Closest Facility: Banks

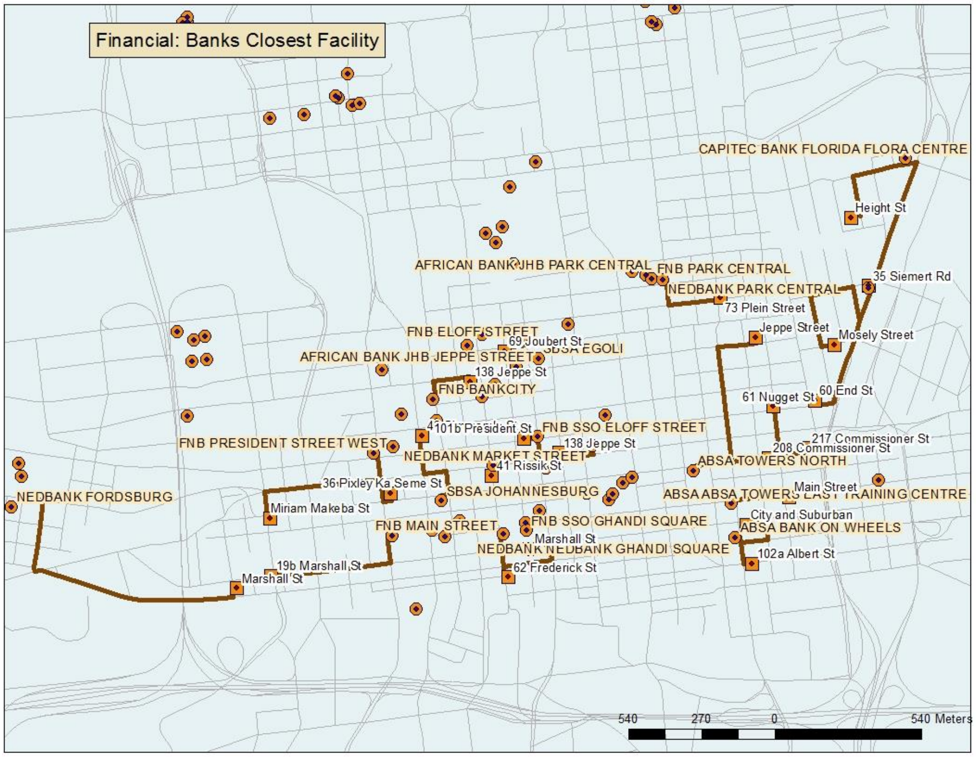


Table 23 Closest Facility: Banks - Distance

FID	ID	MAP	ADDRESS	BANKS_FID	BANKS_NAME	BANKS_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	490	ABSA BANK ON WHEELS	131.7587907
1	221	Dilapidated/ abandoned	60 End St	784	NEDBANK SIEMERT ROAD, JOHANN	510.2300729
2	232	Dilapidated/ abandoned	35 Siemert Rd	824	SBSA ELLIS PARK	527.7312719
3	278	Dilapidated/ abandoned	208 Commissioner St	500	ABSA TOWERS NORTH	280.1634804
4	288	Dilapidated/ abandoned	217 Commissioner St	500	ABSA TOWERS NORTH	427.7834288
5	292	Dilapidated/ abandoned	61 Nugget St	500	ABSA TOWERS NORTH	502.4645153
6	378	Dilapidated/ abandoned	19b Marshall St	659	FNB MAIN STREET	542.1372175
7	394	Dilapidated/ abandoned	41 Rissik St	740	NEDBANK MARKET STREET	42.77714264
8	403	Dilapidated/ abandoned	69 Joubert St	683	FNB ELOFF STREET	107.4482926
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	655	FNB PRESIDENT STREET WEST	212.863157
10	421	Dilapidated/ abandoned	124 Marshall St	797	NEDBANK NEDBANK GHANDI SQUA	438.2042947
11	424	Dilapidated/ abandoned	62 Frederick St	797	NEDBANK NEDBANK GHANDI SQUA	167.7109041
12	398	Dilapidated/ abandoned	143 Jeppe St	594	CAPITEC BANK JOHANNESBURG MA	134.3918584
13	455	Dilapidated/ abandoned	48 Simmonds St	832	SBSA JOHANNESBURG	334.4862635
14	461	Dilapidated/ abandoned	101b President St	589	CAPITEC BANK JOHANNESBURG EL(	163.6002949
15	462	Dilapidated/ abandoned	138 Jeppe St	657	FNB BANKCITY	200.3755891
16	778	Dilapidated/ abandoned	Marshall St	815	SBSA PLAZA	1133.402346
17	325	Dilapidated/ abandoned	73 Plein Street	809	NEDBANK PARK CENTRAL	285.8428377
18	326	Dilapidated/ abandoned	Jeppe Street	500	ABSA TOWERS NORTH	711.7996311
19	228	Dilapidated/ abandoned	Mosely Street	784	NEDBANK SIEMERT ROAD, JOHANN	651.2826191
20	384	Dilapidated/ abandoned	Miriam Makeba St	655	FNB PRESIDENT STREET WEST	625.3267751
21	210	Dilapidated/ abandoned	204 Main Street	522	ABSA ABSA TOWERS EAST TRAININ	214.8232622
22	384	Dilapidated/ abandoned	City and Suburban	490	ABSA BANK ON WHEELS	271.4103316
23	239	Dilapidated/ abandoned	33 Height St	824	SBSA ELLIS PARK	349.9430096
					Avg.	373.66489113712

Figure 31 Closest Facility: Post Offices

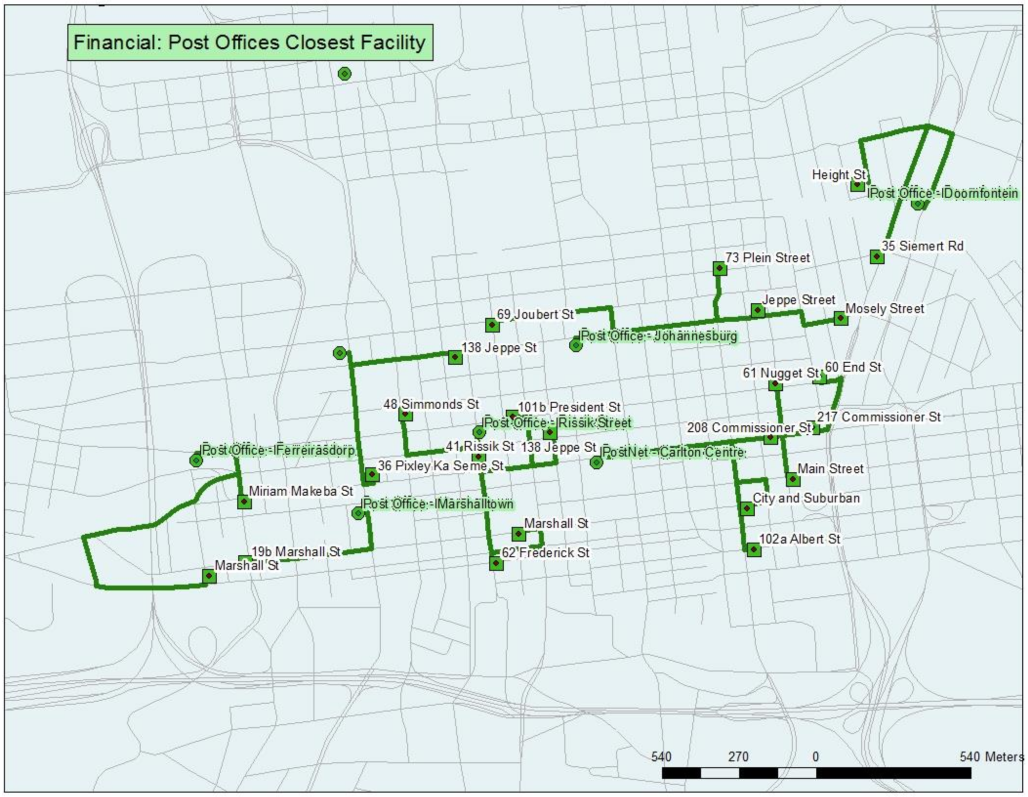


Table 24 Closest Facility: Post Offices - Distance

FID	ID	MAP	ADDRESS	POSTOFFICE_FID	POSTOFFICE_NAME	POSTOFFICE_DIST_m
0	199	Dilapidated/ abandoned	102a Albert St	46	PostNet - Carlton Centre	885.0149685
1	221	Dilapidated/ abandoned	60 End St	46	PostNet - Carlton Centre	1070.135927
2	232	Dilapidated/ abandoned	35 Siemert Rd	164	Post Office - Doornfontein	860.3882418
3	278	Dilapidated/ abandoned	208 Commissioner St	46	PostNet - Carlton Centre	612.4977562
4	288	Dilapidated/ abandoned	217 Commissioner St	46	PostNet - Carlton Centre	760.1177046
5	292	Dilapidated/ abandoned	61 Nugget St	46	PostNet - Carlton Centre	834.7987911
6	378	Dilapidated/ abandoned	19b Marshall St	150	Post Office - Marshalltown	573.190239
7	394	Dilapidated/ abandoned	41 Rissik St	127	Post Office - Rissik Street	81.9066077
8	403	Dilapidated/ abandoned	69 Joubert St	24	Post Office - Johannesburg	656.171236
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	159	Post Office - Newtown	493.325912
10	421	Dilapidated/ abandoned	124 Marshall St	127	Post Office - Rissik Street	738.7167616
11	424	Dilapidated/ abandoned	62 Frederick St	127	Post Office - Rissik Street	468.2233711
12	398	Dilapidated/ abandoned	143 Jeppe St	127	Post Office - Rissik Street	502.4167203
13	455	Dilapidated/ abandoned	48 Simmonds St	127	Post Office - Rissik Street	438.0185814
14	461	Dilapidated/ abandoned	101b President St	127	Post Office - Rissik Street	533.7139273
15	462	Dilapidated/ abandoned	138 Jeppe St	159	Post Office - Newtown	410.0600696
16	778	Dilapidated/ abandoned	Marshall St	110	Post Office - Ferreirasdorp	1414.836993
17	325	Dilapidated/ abandoned	73 Plein Street	24	Post Office - Johannesburg	691.4163732
18	326	Dilapidated/ abandoned	Jeppe Street	24	Post Office - Johannesburg	643.3771667
19	228	Dilapidated/ abandoned	Mosely Street	24	Post Office - Johannesburg	972.5378876
20	384	Dilapidated/ abandoned	Miriam Makeba St	110	Post Office - Ferreirasdorp	316.2793067
21	210	Dilapidated/ abandoned	204 Main Street	46	PostNet - Carlton Centre	815.8281591
22	384	Dilapidated/ abandoned	City and Suburban	46	PostNet - Carlton Centre	872.7261802
23	239	Dilapidated/ abandoned	33 Height St	164	Post Office - Doornfontein	758.1879432
					Avg.	683.49528432934

3.4.9 ARIA Calculation: Metro ARIA (Final)

The following results tables reflect the ARIA calculation for each individual service type. In running the Jenks' (K-means) clustering, the iterations were based on the threshold scores i.e. the first run was for the service types with score-ranges 0-2, the next for score ranges 0-3 and the last for the final ARIA score. Low scores (better accessibility) are highlighted red:

Table 25 Health ARIA Results

FID	ID	MAP	ADDRESS	MAJOR HOSPITAL ARIA	HOSPITAL ARIA	HEALTH ARIA
0	199	Dilapidated/ abandoned	102a Albert St	1.006724	0.891559	0.632761
1	221	Dilapidated/ abandoned	60 End St	1.045667	1.097929	0.714532
2	232	Dilapidated/ abandoned	35 Siemert Rd	0.962251	1.864109	0.942120
3	278	Dilapidated/ abandoned	208 Commissioner St	1.149465	0.587762	0.579076
4	288	Dilapidated/ abandoned	217 Commissioner St	1.213432	0.752326	0.655253
5	292	Dilapidated/ abandoned	61 Nugget St	0.924070	0.835579	0.586550
6	378	Dilapidated/ abandoned	19b Marshall St	1.073298	1.755172	0.942823
7	394	Dilapidated/ abandoned	41 Rissik St	0.909425	0.488688	0.466038
8	403	Dilapidated/ abandoned	69 Joubert St	1.104624	0.453566	0.519397
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	1.067314	1.039581	0.702299
10	421	Dilapidated/ abandoned	124 Marshall St	0.716001	0.749168	0.488390
11	424	Dilapidated/ abandoned	62 Frederick St	0.712894	0.919346	0.544080
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	0.859095	0.372064	0.410386
13	455	Dilapidated/ abandoned	48 Simmonds St	1.007489	0.885674	0.631055
14	461	Dilapidated/ abandoned	101b President St	0.873001	0.588317	0.487106
15	462	Dilapidated/ abandoned	138 Jeppe St	1.114018	0.411555	0.508524
16	778	Dilapidated/ abandoned	Marshall St	1.551624	2.034047	1.195224
17	325	Dilapidated/ abandoned	73 Plein Street	0.742623	1.122495	0.621706
18	326	Dilapidated/ abandoned	Jeppe Street	0.875330	1.068942	0.648091
19	228	Dilapidated/ abandoned	Mosely Street	0.948011	1.435884	0.794632
20	384	Dilapidated/ abandoned	Miriam Makeba St	1.159155	1.499388	0.886181
21	210	Dilapidated/ abandoned	204 Main Street	1.114194	0.814431	0.642875
22	384	Dilapidated/ abandoned	City and Suburban	1.067239	0.877860	0.648366
23	239	Dilapidated/ abandoned	33 Height St	0.803054	1.454557	0.752537

A capped maximum value of 0-3 is applied to the Health ARIA, 0-2 to the Shopping ARIA. To be added to the FINAL ARIA score (range 0-12, 12 being the least accessible).

In this run, scores were capped at the maximum level for these sites:

- 19b Marshall: supermarket
- Marshall Street: supermarket
- Marshall Street: Spaza Shop.

Table 26 Shopping ARIA Results

FID	ID	MAP	ADDRESS	SHOPPING_CENTRE_ARIA	SUPERMARKET_ARIA	SPAZA_ARIA	SHOPPING ARIA
0	199	Dilapidated/ abandoned	102a Albert St	0.533884	0.978394	0.783800	0.382680
1	221	Dilapidated/ abandoned	60 End St	0.649419	0.950150	1.298753	0.483054
2	232	Dilapidated/ abandoned	35 Siemert Rd	0.470852	1.530685	0.598732	0.433378
3	278	Dilapidated/ abandoned	208 Commissioner St	0.363804	0.243980	1.328315	0.322683
4	288	Dilapidated/ abandoned	217 Commissioner St	0.455935	0.471769	1.213628	0.356889
5	292	Dilapidated/ abandoned	61 Nugget St	0.502543	0.467460	0.657732	0.271289
6	378	Dilapidated/ abandoned	19b Marshall St	0.626293	1.999999	1.089705	0.619333
7	394	Dilapidated/ abandoned	41 Rissik St	0.146555	0.639256	0.900006	0.280969
8	403	Dilapidated/ abandoned	69 Joubert St	0.360846	0.592732	0.169651	0.187205
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	0.454970	1.204847	1.919233	0.596508
10	421	Dilapidated/ abandoned	124 Marshall St	0.454166	1.070866	0.162403	0.281239
11	424	Dilapidated/ abandoned	62 Frederick St	0.387657	1.235372	0.998652	0.436947
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	0.281118	0.643011	0.451596	0.229288
13	455	Dilapidated/ abandoned	48 Simmonds St	0.368806	1.188764	1.635920	0.532248
14	461	Dilapidated/ abandoned	101b President St	0.402186	0.673475	1.212855	0.381419
15	462	Dilapidated/ abandoned	138 Jeppe St	0.203527	0.614848	0.390859	0.201539
16	778	Dilapidated/ abandoned	Marshall St	0.817943	1.999999	1.999999	0.802990
17	325	Dilapidated/ abandoned	73 Plein Street	0.224857	0.566201	0.119584	0.151774
18	326	Dilapidated/ abandoned	Jeppe Street	0.418523	0.215245	0.285385	0.153192
19	228	Dilapidated/ abandoned	Mosely Street	0.623954	0.723165	1.066060	0.402196
20	384	Dilapidated/ abandoned	Miriam Makeba St	0.487719	1.841310	0.783610	0.518773
21	210	Dilapidated/ abandoned	204 Main Street	0.490704	0.557734	0.304223	0.225444
22	384	Dilapidated/ abandoned	City and Suburban	0.526214	0.644673	0.683180	0.309011
23	239	Dilapidated/ abandoned	33 Height St	0.407069	1.953310	0.914329	0.545785

Table 28 Education ARIA Results

FID	ID	MAP	ADDRESS	PRIMARYSCHOOL ARIA	HIGHSCHOOL_ARIA	COLLEGE_ARIA	UNIVERSITY_ARIA	EDUCATION ARIA
0	199	Dilapidated/ abandoned	102a Albert St	1.616617	1.212406	1.616617	1.237581	1.894407
1	221	Dilapidated/ abandoned	60 End St	1.158768	0.846311	1.158768	0.823125	1.328991
2	232	Dilapidated/ abandoned	35 Siemert Rd	0.820261	0.940978	0.820261	0.582028	1.054510
3	278	Dilapidated/ abandoned	208 Commissioner St	1.359458	0.860015	1.359458	1.015104	1.531345
4	288	Dilapidated/ abandoned	217 Commissioner St	1.168474	0.855524	1.168474	1.012613	1.401695
5	292	Dilapidated/ abandoned	61 Nugget St	0.893968	0.603484	0.893968	0.900241	1.097220
6	378	Dilapidated/ abandoned	19b Marshall St	0.494691	0.720241	0.494691	0.975782	0.895135
7	394	Dilapidated/ abandoned	41 Rissik St	1.259124	1.437138	1.259124	1.057619	1.671002
8	403	Dilapidated/ abandoned	69 Joubert St	0.930005	1.135106	0.930005	0.895664	1.296927
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	0.477254	0.926517	0.477254	0.876752	0.919259
10	421	Dilapidated/ abandoned	124 Marshall St	1.406772	1.779511	1.406772	1.362612	1.985222
11	424	Dilapidated/ abandoned	62 Frederick St	1.151523	1.545335	1.151523	1.237007	1.695129
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	1.183789	1.574820	1.183789	1.252885	1.731761
13	455	Dilapidated/ abandoned	48 Simmonds St	0.810089	1.231785	0.810089	1.040535	1.297499
14	461	Dilapidated/ abandoned	101b President St	1.213322	1.602188	1.213322	1.267418	1.765417
15	462	Dilapidated/ abandoned	138 Jeppe St	0.847917	1.228769	0.847917	0.838087	1.254230
16	778	Dilapidated/ abandoned	Marshall St	1.321815	0.827611	1.321815	1.382799	1.618013
17	325	Dilapidated/ abandoned	73 Plein Street	0.567403	0.372665	0.567403	0.894594	0.800688
18	326	Dilapidated/ abandoned	Jeppe Street	0.787828	0.506291	0.787828	0.894121	0.992022
19	228	Dilapidated/ abandoned	Mosely Street	0.946104	0.651042	0.946104	0.795893	1.113048
20	384	Dilapidated/ abandoned	Miriam Makeba St	0.285169	0.535262	0.285169	0.872679	0.659426
21	210	Dilapidated/ abandoned	204 Main Street	1.221045	0.903537	1.221045	1.112495	1.486040
22	384	Dilapidated/ abandoned	City and Suburban	1.605021	1.084739	1.605021	1.137796	1.810859
23	239	Dilapidated/ abandoned	33 Height St	0.473582	0.618724	0.473582	0.534571	0.700153

Table 27 Transport ARIA analysis

FID	ID	MAP	ADDRESS	ALL_INTERCHANGES ARIA	INTERCHANGE_ARIA	HFS_ARIA	TRANSPORT ARIA
0	199	Dilapidated/ abandoned	102a Albert St	1.525130	0.802184	1.270178	0.799443
1	221	Dilapidated/ abandoned	60 End St	1.732802	1.212569	1.626927	1.016066
2	232	Dilapidated/ abandoned	35 Siemert Rd	1.326547	0.708356	1.245494	0.728977
3	278	Dilapidated/ abandoned	208 Commissioner St	1.406640	1.177870	1.320694	0.867823
4	288	Dilapidated/ abandoned	217 Commissioner St	0.372001	1.518686	0.349272	0.497768
5	292	Dilapidated/ abandoned	61 Nugget St	1.273179	1.061340	1.195388	0.784424
6	378	Dilapidated/ abandoned	19b Marshall St	1.160345	1.517735	1.089448	0.837229
7	394	Dilapidated/ abandoned	41 Rissik St	0.650440	1.117204	0.610698	0.528520
8	403	Dilapidated/ abandoned	69 Joubert St	0.639325	0.336271	0.570433	0.343562
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	0.409827	0.215560	0.692164	0.292789
10	421	Dilapidated/ abandoned	124 Marshall St	0.427415	0.673230	0.401300	0.333766
11	424	Dilapidated/ abandoned	62 Frederick St	0.585922	0.428531	0.550122	0.347683
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	0.690573	0.475274	0.648378	0.403161
13	455	Dilapidated/ abandoned	48 Simmonds St	0.480897	0.252941	1.390918	0.472168
14	461	Dilapidated/ abandoned	101b President St	0.361944	0.545171	0.339829	0.277099
15	462	Dilapidated/ abandoned	138 Jeppe St	0.462283	0.710996	0.434037	0.357181
16	778	Dilapidated/ abandoned	Marshall St	1.999999	1.999999	1.999999	1.333333
17	325	Dilapidated/ abandoned	73 Plein Street	1.001278	0.526650	1.349668	0.639466
18	326	Dilapidated/ abandoned	Jeppe Street	0.790413	0.415740	0.743772	0.433317
19	228	Dilapidated/ abandoned	Mosely Street	1.079927	1.175686	1.013943	0.726568
20	384	Dilapidated/ abandoned	Miriam Makeba St	0.971398	0.976710	0.912046	0.635590
21	210	Dilapidated/ abandoned	204 Main Street	0.155562	1.374778	0.146057	0.372533
22	384	Dilapidated/ abandoned	City and Suburban	1.083585	1.124603	1.017377	0.716792
23	239	Dilapidated/ abandoned	33 Height St	0.817423	1.999999	0.767478	0.796644

A capped maximum value of 0-3 is applied to the Education ARIA, 0-2 to the Transport ARIA. To be added to the FINAL ARIA score (range 0-12, 12 being least accessible).

In this run, scores were capped at the maximum level for these sites:

- Marshall Street: all interchanges, normal interchanges and high-frequency interchanges.
- 33 Height Street: normal interchanges.

Table 30 Financial ARIA Results

FID	ID	MAP	ADDRESS	BANKS ARIA	POSTOFFICE ARIA	FINANCIAL ARIA
0	199	Dilapidated/ abandoned	102a Albert St	0.352612	1.294837	0.549150
1	221	Dilapidated/ abandoned	60 End St	1.365475	1.565682	0.977052
2	232	Dilapidated/ abandoned	35 Siemert Rd	1.412312	1.258806	0.890373
3	278	Dilapidated/ abandoned	208 Commissioner St	0.749772	0.896126	0.548633
4	288	Dilapidated/ abandoned	217 Commissioner St	1.144832	1.112104	0.752312
5	292	Dilapidated/ abandoned	61 Nugget St	1.344693	1.221367	0.855353
6	378	Dilapidated/ abandoned	19b Marshall St	1.450865	0.838616	0.763160
7	394	Dilapidated/ abandoned	41 Rissik St	0.114480	0.119835	0.078105
8	403	Dilapidated/ abandoned	69 Joubert St	0.287553	0.960023	0.415859
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	0.569663	0.721769	0.430478
10	421	Dilapidated/ abandoned	124 Marshall St	1.172720	1.080793	0.751171
11	424	Dilapidated/ abandoned	62 Frederick St	0.448827	0.685043	0.377957
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	0.359659	0.735070	0.364910
13	455	Dilapidated/ abandoned	48 Simmonds St	0.895150	0.640851	0.512000
14	461	Dilapidated/ abandoned	101b President St	0.437826	0.780860	0.406229
15	462	Dilapidated/ abandoned	138 Jeppe St	0.536244	0.599946	0.378730
16	778	Dilapidated/ abandoned	Marshall St	3.033205	2.070003	1.701069
17	325	Dilapidated/ abandoned	73 Plein Street	0.764971	1.011589	0.592187
18	326	Dilapidated/ abandoned	Jeppe Street	1.904914	0.941304	0.948740
19	228	Dilapidated/ abandoned	Mosely Street	1.742959	1.422889	1.055283
20	384	Dilapidated/ abandoned	Miriam Makeba St	1.673496	0.462738	0.712078
21	210	Dilapidated/ abandoned	204 Main Street	0.574909	1.193612	0.589507
22	384	Dilapidated/ abandoned	City and Suburban	0.726347	1.276858	0.667735
23	239	Dilapidated/ abandoned	33 Height St	0.936516	1.109280	0.681932

A capped maximum value of, 0-3 is applied to the Financial ARIA. To be added to the FINAL ARIA score (range 0-12, 12 being least accessible).

In this run, scores were capped at the maximum level for these sites:

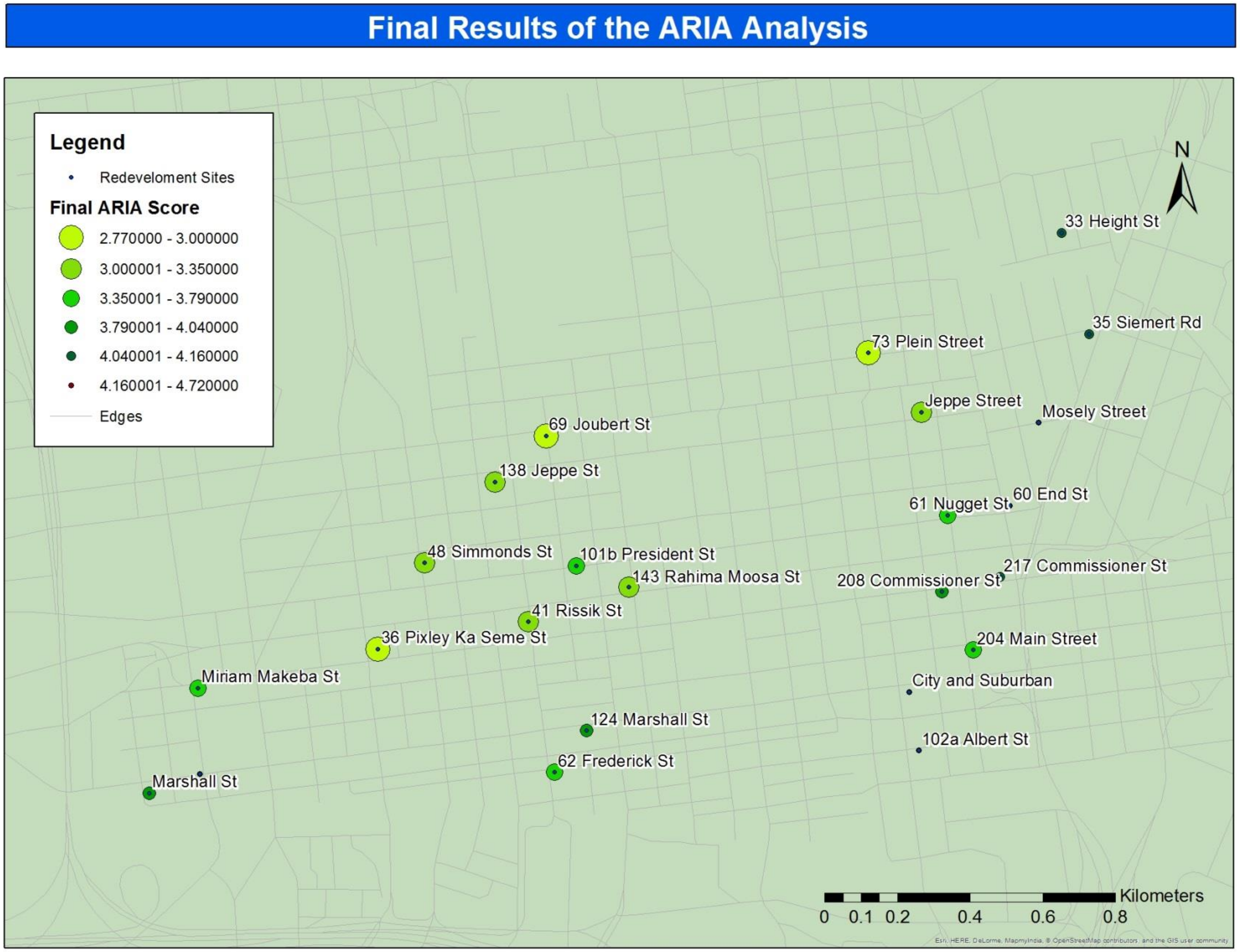
- Marshall Street: banks and post-offices

The results of the service type calculations are compiled into a single table, final ARIA score ordered and ranked:

Table 29 Results of ARIA analysis

FID	ID	ADDRESS	HEALTH ARIA	SHOPPING ARIA	EDUCATION ARIA	TRANSPORT ARIA	FINANCIAL ARIA	FINAL ARIA	RANK
15	462	138 Jeppe St	0.508524	0.201539	1.254230	0.357181	0.378730	2.700205	1
8	403	69 Joubert St	0.519397	0.187205	1.296927	0.343562	0.415859	2.762949	2
17	325	73 Plein Street	0.621706	0.151774	0.800688	0.639466	0.592187	2.805820	3
9	406	36 Pixley Ka Seme St	0.702299	0.596508	0.919259	0.292789	0.430478	2.941333	4
7	394	41 Rissik St	0.466038	0.280969	1.671002	0.528520	0.078105	3.024634	5
12	398	143 Rahima Moosa St	0.410386	0.229288	1.731761	0.403161	0.364910	3.139506	6
18	326	Jeppe Street	0.648091	0.153192	0.992022	0.433317	0.948740	3.175362	7
21	210	204 Main Street	0.642875	0.225444	1.486040	0.372533	0.589507	3.316399	8
14	461	101b President St	0.487106	0.381419	1.765417	0.277099	0.406229	3.317270	9
11	424	62 Frederick St	0.544080	0.436947	1.695129	0.347683	0.377957	3.401796	10
20	384	Miriam Makeba St	0.886181	0.518773	0.659426	0.635590	0.712078	3.412048	11
13	455	48 Simmonds St	0.631055	0.532248	1.297499	0.472168	0.512000	3.444971	12
23	239	33 Height St	0.752537	0.545785	0.700153	0.796644	0.681932	3.477051	13
5	292	61 Nugget St	0.586550	0.271289	1.097220	0.784424	0.855353	3.594837	14
4	288	217 Commissioner St	0.655253	0.356889	1.401695	0.497768	0.752312	3.663917	15
10	421	124 Marshall St	0.488390	0.281239	1.985222	0.333766	0.751171	3.839788	16
3	278	208 Commissioner St	0.579076	0.322683	1.531345	0.867823	0.548633	3.849560	17
2	232	35 Siemert Rd	0.942120	0.433378	1.054510	0.728977	0.890373	4.049357	18
6	378	19b Marshall St	0.942823	0.619333	0.895135	0.837229	0.763160	4.057680	19
19	228	Mosely Street	0.794632	0.402196	1.113048	0.726568	1.055283	4.091727	20
22	384	City and Suburban	0.648366	0.309011	1.810859	0.716792	0.667735	4.152764	21
0	199	102a Albert St	0.632761	0.382680	1.894407	0.799443	0.549150	4.258440	22
1	221	60 End St	0.714532	0.483054	1.328991	1.016066	0.977052	4.519695	23
16	778	Marshall St	1.195224	0.802990	1.618013	1.333333	1.701069	6.650629	24

Figure 32 Mapped Results of ARIA Analysis



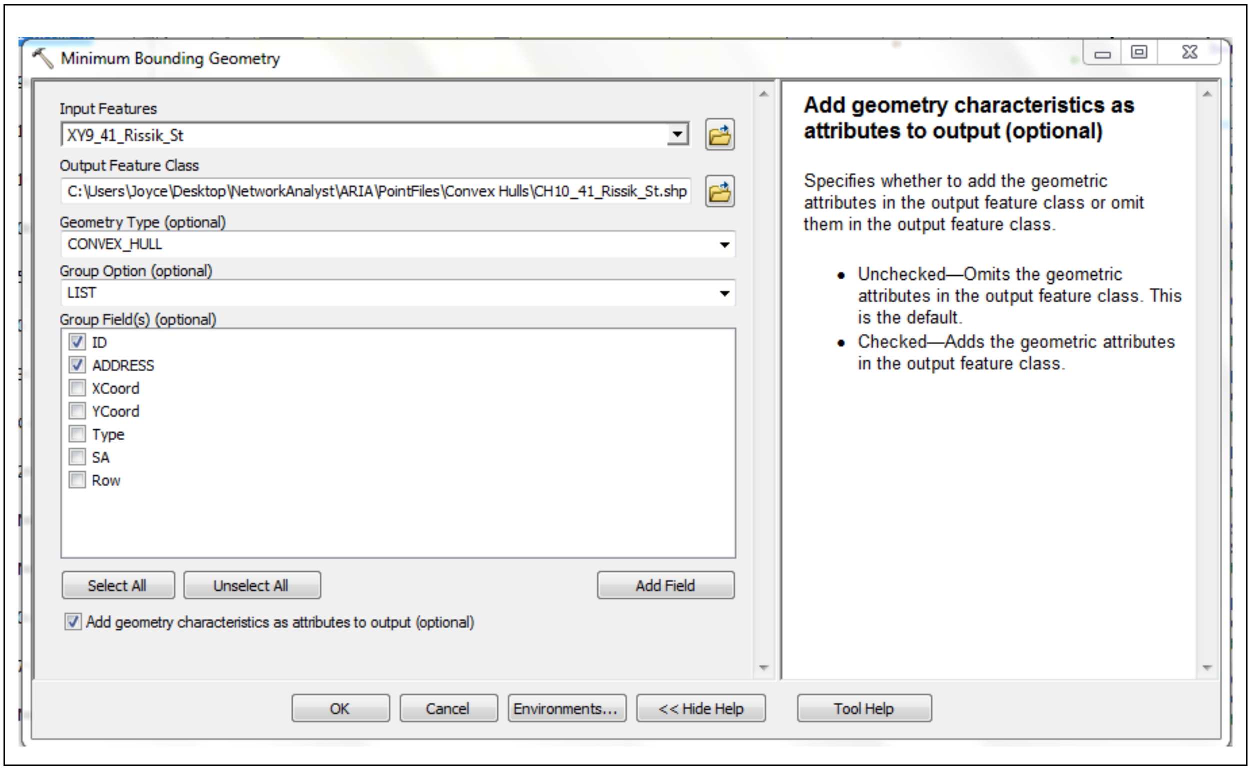
3.4.10 Service Area Size and Shape Calculations

Service area *size* analysis can give further insight into time and distance costs of access. In a study of catchment areas around stops at high-quality public transport systems in Denmark, Landex, Hansen, & Andersen (2006) demonstrate the stark contrast. Not just between Euclidean and service area buffers, but also *amongst* the latter. In drawing 600m buffers of both types around the stops, the Euclidean buffers had the same[5] area size in square metres, but the service area buffers ranged in size from approximately 400,000m^2 to slightly over 850,000m^2.

In this research, for each of the locations that are identified as being potential re-development sites, a *service area* based on all the closest facility results (i.e. by amenity type) is created. The spatial extent of each service area is represented by the bounding area of these points, known as the convex hulls. The spatial extent of each service area is then calculated, and the most compact (smallest size) ones are identified. These are then potentially the most efficient in terms of travel costs.

ESRI ArcGIS Minimum Bounding Geometry tool was used to generate the convex hulls:

Figure 33 Creation of Convex Hulls for Service Area Size Analysis



[5] With two exceptions which were not explained.

Figure 34 Mapped Results of Service Area (Convex Hull) Size Analysis

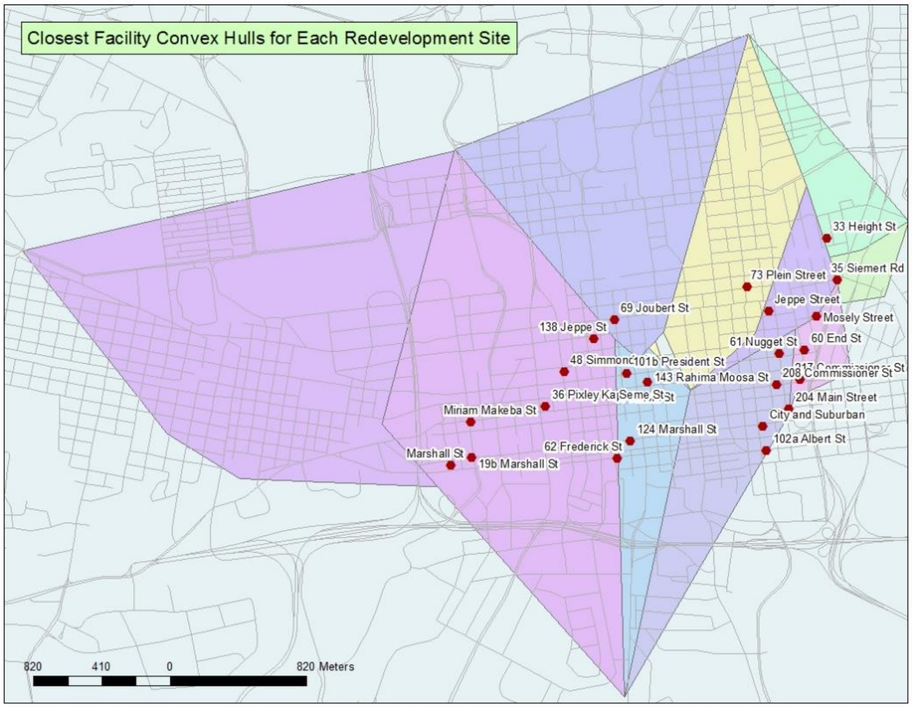


Table 31 Results of the Service Area Analysis

FID	ID	Map	Address	Districts	Area - SQM	Rank
18	325	Dilapidated/ abandoned	73 Plein Street	Station District	884 653	1
6	292	Dilapidated/ abandoned	61 Nugget St	Commercial district	916 346	2
19	326	Dilapidated/ abandoned	Jeppe Street	Commercial district	1 012 300	3
24	239	Dilapidated/ abandoned	33 Height St	Doornfontein	1 031 230	4
4	278	Dilapidated/ abandoned	208 Commissioner St	Commercial district	1 060 130	5
20	228	Dilapidated/ abandoned	Mosely Street	Commercial district	1 134 110	6
1	199	Dilapidated/ abandoned	102a Albert St	Commercial district	1 150 380	7
23	384	Dilapidated/ abandoned	City and Suburban	Commercial district	1 262 110	8
22	210	Dilapidated/ abandoned	204 Main Street	Commercial district	1 267 420	9
2	221	Dilapidated/ abandoned	60 End St	Commercial district	1 280 680	10
5	288	Dilapidated/ abandoned	217 Commissioner St	Commercial district	1 304 860	11
3	232	Dilapidated/ abandoned	35 Siemert Rd	Doornfontein	1 374 710	12
16	462	Dilapidated/ abandoned	138 Jeppe St	Exchange District	1 507 730	13
9	403	Dilapidated/ abandoned	69 Joubert St	Station District	1 609 470	14
8	394	Dilapidated/ abandoned	41 Rissik St	Mid-Town District	1 850 620	15
7	378	Dilapidated/ abandoned	19b Marshall St	Mid-Town District	2 564 580	16
21	384	Dilapidated/ abandoned	Miriam Makeba St	Financial District	2 564 580	16
10	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	Financial District	2 600 290	18
12	424	Dilapidated/ abandoned	62 Frederick St	Mid-Town District	2 752 760	19
14	455	Dilapidated/ abandoned	48 Simmonds St	Exchange District	2 758 150	20
11	421	Dilapidated/ abandoned	124 Marshall St	Financial District	3 167 170	21
13	398	Dilapidated/ abandoned	143 Rahima Moosa St	Mid-Town District	3 167 170	21
15	461	Dilapidated/ abandoned	101b President St	Mid-Town District	3 167 170	21
17	778	Dilapidated/ abandoned	Marshall St	Financial District	4 457 090	24

The biggest limitation of this method is that it assumes people will select the nearest service point to frequent, whereas in reality the trade-off location choices and are influenced by network constraints (e.g. capability, coupling and legal constraints Acheampong & Silva, 2015).

The idea of service area compactness is further analysed using unweighted ***standard distance,*** a widely used indicator to estimate the dispersion of points around a geographic centroid. A single representative value that comes from measuring the compactness of a distribution can explain the dispersion of features around the center. The resulting value is a **distance measure** of compactness (*How Standard Distance works*, n.d.). Standard Distance Deviation is similar to standard deviation (SD) in conventional statistics (Flores et al., 2013; Levine, 1996). The standard distance is a popular measure to estimate the dispersion of points around a mean center or geographic centroid. It is obtained by calculating the standard deviation (SD) of the distances between the distribution points (Myint, 2008; Lee and Wong, 2001; Ebdon, 1982 in Flores et al., 2013). The radius of the resulting is a circular polygon is the standard deviation of the distance of points from the centroid; any outliers do not end up within the SD representation (Ebdon, 1982 in Flores et al., 2013). A smaller standard distance means greater clustering of service points and potentially better travel cost value.

The method is as follows:

- Esri ArcGIS Standard Distance tool was used; it is based on Euclidean distance. Run for 2 Standard Deviations. According to the empirical rule, more data is covered (up to 95%) with 2 standard deviations, if the data is normally distributed. (*The Empirical Rule,* N.D)
- Each potential re-development site location was selected and saved as a separate file;
- The service points (amenities) within a walkable 600m radius around each site were drawn;
- The point dispersion around each site was measured using SD;
- The variety of service points within each radius investigated;
- The final results are compiled into a single table;
- A **model** was created to generate the results (see appendix 5).

Figure 35 SD Results Model

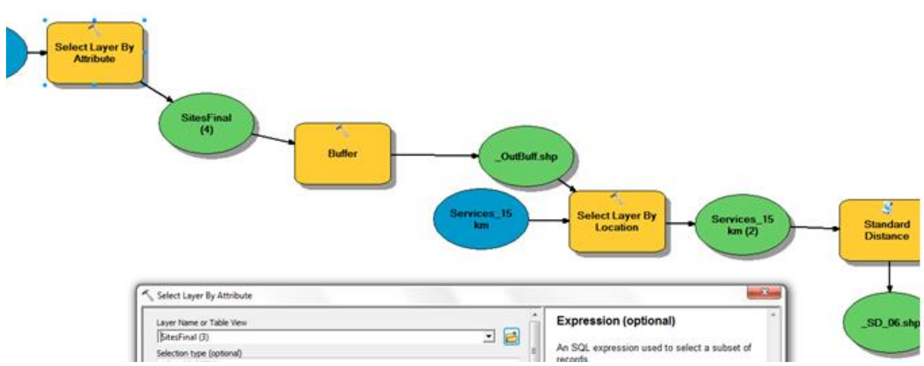
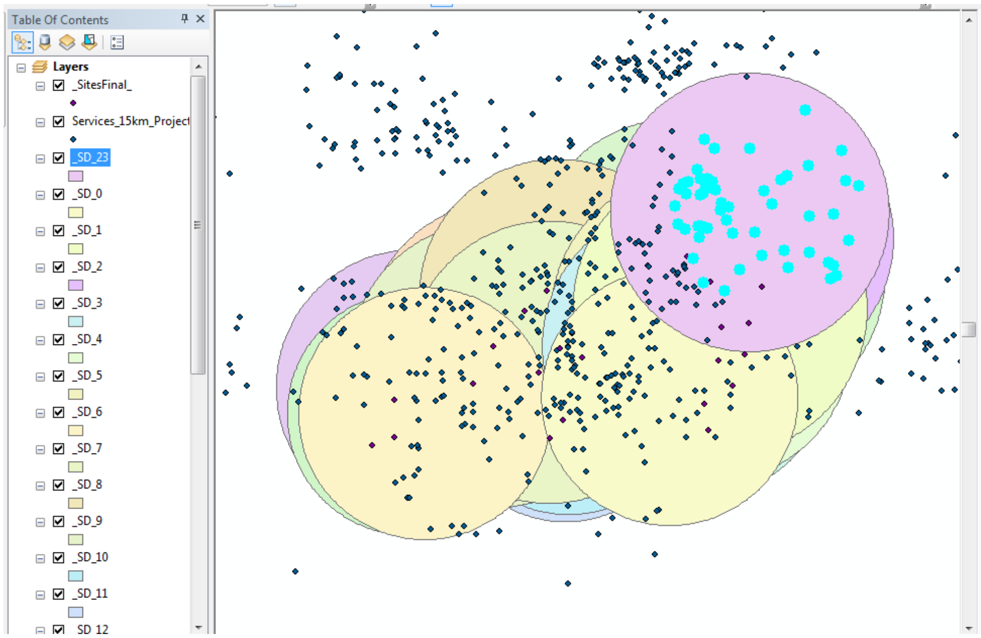


Figure 36 Process of Generating Standard Distance Results



Once the model to generate the results was created, it was run for each site sequentially.

Table 32 Results of the Standard Distance Analysis

ID	Map	Address	Districts	X	Y	StdDist	StdDist (Metres)	Rank
778	Dilapidated/ abandoned	Marshall St	Financial District	28.03276420000	-26.20885420000	0.18411	687	1
424	Dilapidated/ abandoned	62 Frederick St	Mid-Town District	28.04277800000	-26.20839100000	0.17813	699	2
421	Dilapidated/ abandoned	124 Marshall St	Financial District	28.04355700000	-26.20746500000	0.17766	705	3
378	Dilapidated/ abandoned	19b Marshall St	Mid-Town District	28.03401900000	-26.20843100000	0.18312	713	4
199	Dilapidated/ abandoned	102a Albert St	Commercial district	28.05176200000	-26.20790500000	0.17215	725	5
384	Dilapidated/ abandoned	City and Suburban	Commercial district	28.05152190000	-26.20660528000	0.17227	732	6
325	Dilapidated/ abandoned	73 Plein Street	Station District	28.05051200000	-26.19905100000	0.17236	745	7
210	Dilapidated/ abandoned	204 Main Street	Commercial district	28.05311090000	-26.20566581000	0.17121	749	8
398	Dilapidated/ abandoned	143 Rahima Moosa St	Mid-Town District	28.04460000000	-26.20426800000	0.17745	750	9
384	Dilapidated/ abandoned	Miriam Makeba St	Financial District	28.03396900000	-26.20652000000	0.18346	777	10
403	Dilapidated/ abandoned	69 Joubert St	Station District	28.04256400000	-26.20089900000	0.17782	782	11
461	Dilapidated/ abandoned	101b President St	Mid-Town District	28.04331000000	-26.20379400000	0.17793	783	12
239	Dilapidated/ abandoned	33 Height St	Doornfontein	28.05528933000	-26.19638267000	0.17158	788	13
326	Dilapidated/ abandoned	Jeppe Street	Commercial district	28.05182400000	-26.20036800000	0.17158	790	14
462	Dilapidated/ abandoned	138 Jeppe St	Exchange District	28.04130000000	-26.20192900000	0.17890	792	15
288	Dilapidated/ abandoned	217 Commissioner St	Commercial district	28.05377800000	-26.20404400000	0.17050	795	16
394	Dilapidated/ abandoned	41 Rissik St	Mid-Town District	28.04212600000	-26.20504000000	0.17846	798	17
278	Dilapidated/ abandoned	208 Commissioner St	Commercial district	28.05233200000	-26.20436900000	0.17149	801	18
232	Dilapidated/ abandoned	35 Siemert Rd	Doornfontein	28.05597300000	-26.19863200000	0.16949	805	19
406	Dilapidated/ abandoned	36 Pixley Ka Seme St	Financial District	28.03841800000	-26.20564300000	0.18115	810	20
292	Dilapidated/ abandoned	61 Nugget St	Commercial district	28.05247900000	-26.20266700000	0.17139	810	21
455	Dilapidated/ abandoned	48 Simmonds St	Exchange District	28.03955700000	-26.20372800000	0.18007	817	22
228	Dilapidated/ abandoned	Mosely Street	Commercial district	28.05472200000	-26.20060400000	0.17008	827	23
221	Dilapidated/ abandoned	60 End St	Commercial district	28.05401100000	-26.20245600000	0.17043	832	24

The ESRI ArcMap Standard Distance tool was used to measure the dispersion of service points around each site. A smaller standard distance means greater clustering of service points and potentially better travel cost value. Moreover, the service area with the greatest number and most variety of services will further entrench (re-development) location attractiveness. The next section takes this analysis further, checking for 'hot-spots' of services using Kernel Density Estimation (KDE).

3.5 Application: Goods and Services Clustering Using KDE

In the previous section, the idea of service area size or compactness was explored, with the understanding that the smallest or most compact are potentially the most efficient in terms of travel costs. In this section, the application of the KDE method for assessing service clustering in the Johannesburg CBD, and the proximity of chosen potential redevelopment sites to them is presented. The section begins with a justification and description for the use of this method in this research. Finally, the basic units of application are put forward and the limitations of the method are highlighted.

3.5.1 Method Justification

As stated in previous sections, the CBD provides a platform for economic theories of agglomeration and scale, where firms realize certain operational cost-saving advantages by co-locating (Flores et al., 2013). Such clusters hold particular advantages for the urban poor because a 'cluster' means a multiplicity of services, which potentially means value and efficiency rendered for the cost of travel and better accessibility. Space-time research, of which this research is a part, encapsulates models that posit that peoples' travel choices are a function of travel cost and distance (Acheampong & Silva, 2015). In the context of accessibility to services and amenities for the urban poor, this is a significant element of investigation because of the financial implication. Research in South Africa shows that low-income households spend as a much as 11% to 12% of their budget on transport, and 29% to 34% on food (Ismail et al. 2016).

Accessibility is the key concept that links land-use with transportation: Land-use incorporates a number of activity locations: primarily residential, employment, and adjunct activities e.g. shopping, schools, and recreation (Acheampong & Silva, 2015). Mossleson (2017b) in his detailed ethnographic study of the inhabitants of the Johannesburg inner-city indicated that some respondents explicitly stated that they had come to live in the CBD to be closer to employment opportunities, however many of the respondents also pointed to the ease of proximity to other amenities such as shops. Battersby & Peyton (2014) indicate that the more food insecure a household is, the more they are likely to depend on informal means of securing food. In the South African context, such informal means are shops are known as "Spaza shops", popular with the poor for their flexible credit account arrangements.

The KDE method of assessing spatial clustering has been chosen as the method to analyse the services identified in the Metro ARIA (3.3.1) Section.

KDE will be used to analyse whether or not the selected potential redevelopment sites are located within or near a 'hot-spot' of services, to identify and rank best sites.

Point Pattern Analysis (PPA) is an approach that can be used to reveal density distribution patterns in different places, especially with lesser or greater distance from the point(s) of interest. There are various tools and methods that are conventionally used to assess point patterns or spatial clustering. The most commonly used are (Yu et al., 2015):

- Quadrat (and its close peer, Nearest Neighbour) analysis
- Voronoi Analysis and
- Kernel Density Estimation

Quadrat Analysis is considered to be the most straightforward of the methods: a sample of equally-sized quadrats are created to cover the study area, in order to count the number of points or locations that fall inside them. The frequency of occurrences in each cell is recorded and statistical methods of analysis are applied. While this method has been applied to CBD analysis before (e.g. Matti 1972, Holm 1997 in Borruso, 2003) limitations exist. (Borruso, 2003):

- The choice of sampling unit directly affects the results but the selection of the shape or size of the quadrat is arbitrary;
- Strictly it is not a measure of clustering, but of density, as it is not able to determine how close or far apart points are from each other (De Smith et al.,2015);
- It is only concerned with the number of points per quadrat and does not investigate the distribution pattern per quadrat; for this reason Quadrat analysis and Nearest Neighbour analysis are often accompanied by Ripley's K function to assess local fluctuations in distribution.

Nearest Neighbour analysis calculates the value of R, a measure of randomness, dispersion or clustering in the distribution pattern of points (Flores et al., 2013). Accompanied by Ripley's K-function, it is able to measure local fluctuations in the pattern over different spatial scales. A key limitation of this method is that it can suffer from 'edge effects' although software such as SpatSTAT automatically corrects for border effects in the study area (Garrocho & Lobato, 2010).

Voronoi analysis follows a relatively a similar, as it is based on the construction of cells around points based on the closest location to each point. Borders are drawn around each cell on this basis thus creating a catchment area or natural sphere of influence around each cell, resulting in a contiguous surface. Then the regional influence of each activity is obtained by calculating the reciprocal of sub-regional area as the density value (Yan and Weibel, 2008 in (Yu et al., 2015). This method suffers from similar limitations to quadrat analysis (Yu et al., 2015).

Quadrat and Voronoi analysis are excluded because of their technical limitations, Nearest Neighbour is nuanced in terms of aiming to describe the point pattern over various distances, which is not the aim of this research, and therefore it is also excluded.

KDE is considered to be the best method of the three because it considers the impact of distance decay based on Tobler's First Law of Geography (Tobler, 1979; Silverman, 1986; Bailey and Gatrell, 1995 in Yu et al., 2015b). In this way, the intensity of clustering can be estimated, and visualized (Borruso, 2003).

KDE is a 'smoothing method' that uses a weight function (called kernel function) to estimate the intensity of point distributions in a cell, relating distributions to the intensity in Neighbouring cells (Yu et al., 2015). This is done by placing a grid over the study area and measuring the distance from each grid cell to each data point. The resulting z-score represents incident density for each grid cell (Levine, 1996). This creates a smoothed surface that varies with intensity further away from the 'kernel'. The elements of the method are:

- Kernel: the *type* of density function that is used to analyse the points. There are different types: normal, uniform, quartic (spherical), triangular (conical), and negative exponential (peaked). All but the first involve cut-off distances. The quartic type is the most popular.
- Bandwidth: the size of the cell in which point estimations are made. The bandwidth of the Kernel function can be fixed.
- Distances are commonly defined as straight line or Euclidean.

The resulting resurface can be used (De Smith et al., 2015):

- For generating a probability surface that can be used to predict the likelihood of events;
- To visualize and analyse temporal patterns; how the occurrence of events changes over time;
- To compare cases with controls. The effect on cases when controls are manipulated;
- May also be used for hot-spot and cool-spot identification and analysis.

The results can be 1) probabilities 2) relative densities 3) absolute densities of the point pattern.

KDE avoids the vagaries of the Grid-based (quadrat) and Voronoi analyses in that it removes the arbitrariness of grid-size and shape (Borruso, 2003).

Selecting a bandwidth size is the most crucial aspect of running KDE analysis, is it is the one element that makes the most significant impact on the results (Zambom & Dias, 2012). Selecting a too wide bandwidth can result in over-generalization, whereas if it is too small, the result may be too nuanced to be meaningful. It also influences that visualization of the results. Smooth or grainy. It is possible to selectively select a bandwidth by observing the densities produced by various bandwidth sizes.

Finally, researchers point to the advantages of network (road) KDE over Euclidean KDE (Borruso, 2003; Flores et al., 2013; Yu et al., 2015a). Simply because the movement of people and goods is constrained by a street network. It is indicated that Euclidean methods tend to overstate the results.

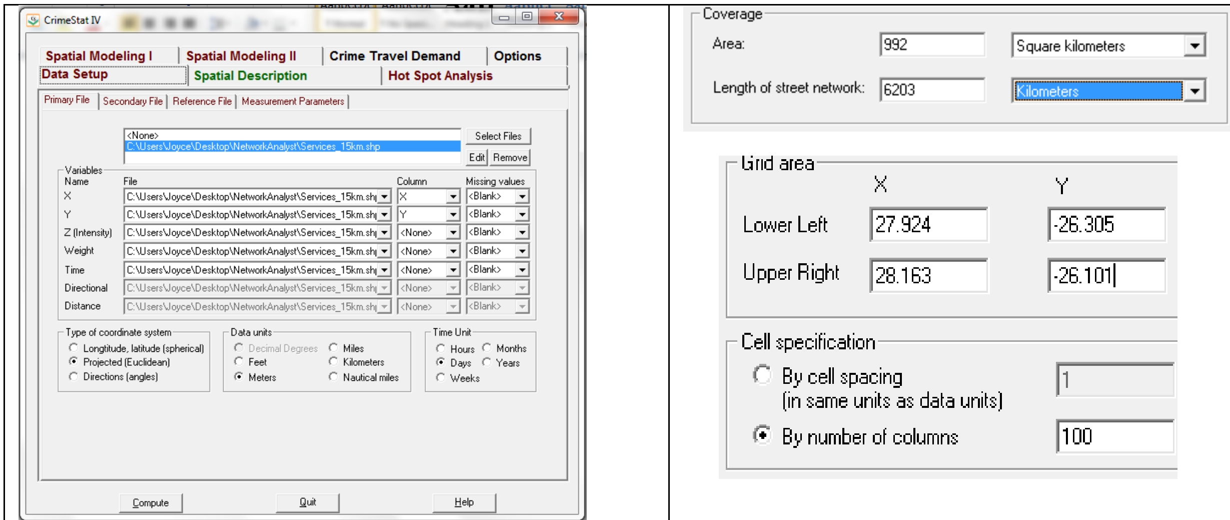
The next section presents the application of the method.

3.5.2 Data Preparation and Method Application

The following parameters were chosen to run the analysis:

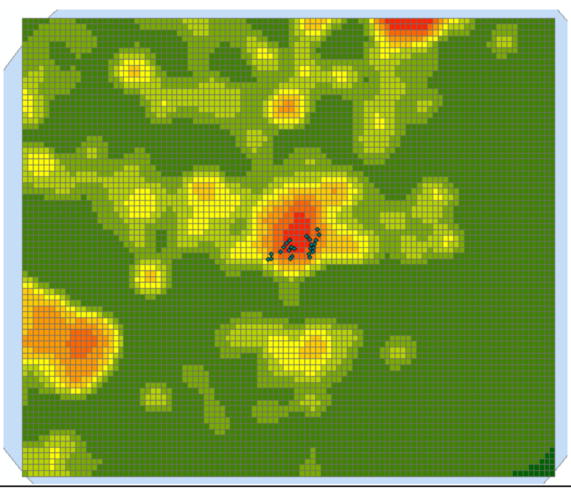
- Used for hot-spot and cool-spot identification and analysis;
- Absolute densities of the point pattern;
- Quartic (spherical) kernel type was chosen as it aligns better with planar (Euclidean) distances; it is a generally kernel type selection (Yu et al., 2015)
- The bandwidth was made adaptable to the clustering: that is, the algorithm detected the amount of clustering and automatically adjusted the bandwidth accordingly. This would mitigate against overgeneralizing or over-emphasizing local variation (Yu et al., 2015)
- KDE normally runs on Euclidean distance although plug-ins such as SANET can be used to run network KDE (the latest version 10.2 was incompatible with ESRI ArcMap 10.3 and so could not be used in this instance). The Euclidean method is used in this research, as the scale of the study is large enough to not suffer greatly from the vagaries of network distance greatly. Furthermore, the street network grid is distributed fairly evenly throughout the study area.
- CrimeStat IV is the application that was used to run the analysis, with mapping done in ESRI ArcMap 10.3.

Figure 37 Parameters of the KDE Run



Selecting the data preparation parameters. The area, street network and grid refer to the 15km extent of the area of interest mentioned before. A hundred columns were randomly selected for the grid.

Figure 38 Results of the KDE Run - High Level



The run statistics are included in appendix

Limitations: According to Yu et al. (2015) most KDE methods assume that the real world is represented as a flat, homogeneous and isotropic space, as such, they use a certain type of kernel estimator that measures Euclidean distance. Researchers point to the inadequacy of this approach (Miller 1994 in Yu et al. (2015), Borruso 2003, Flores et al., 2013). It

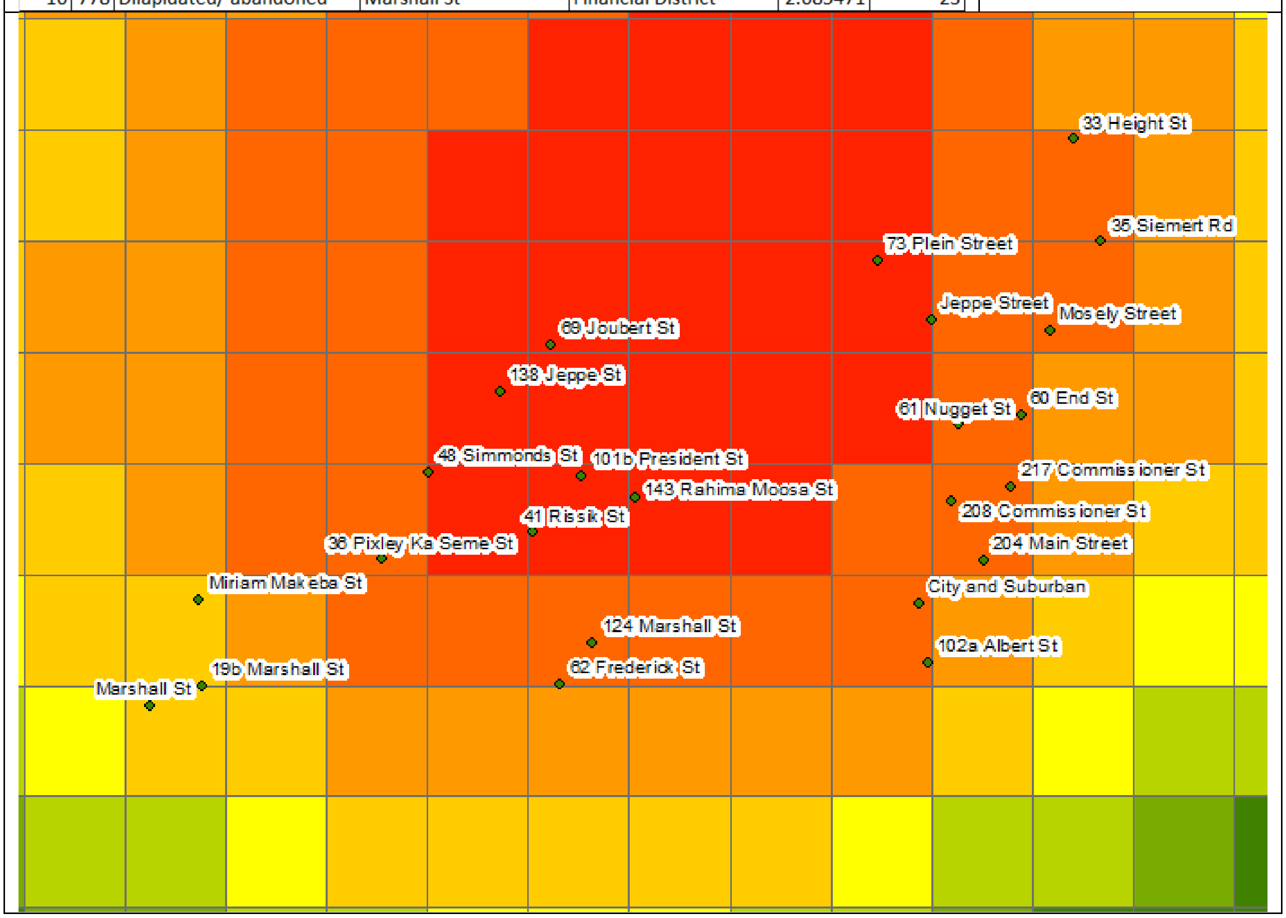
They conclude that the planar method has a tendency to overestimate the clustering tendency of network phenomenon, therefore it is preferable to use It is the network rather than Euclidean distance when observing social and economic phenomena in urban space (Lu and Chen, 2007; Steenberghen et al., 2010; Okabe and Sugihara, 2012 in Yu et al. 2015).

Table 33 Results of the KDE Run - Low Level

FID	ID	Type	Address	Districts	Z_values	Rank
8	403	Dilapidated/ abandoned	69 Joubert St	Station District	7.841520	1
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	Mid-Town District	7.214683	2
7	394	Dilapidated/ abandoned	41 Rissik St	Mid-Town District	7.089068	3
14	461	Dilapidated/ abandoned	101b President St	Mid-Town District	7.089068	3
15	462	Dilapidated/ abandoned	138 Jeppe St	Exchange District	6.975465	5
17	325	Dilapidated/ abandoned	73 Plein Street	Station District	6.954494	6
18	326	Dilapidated/ abandoned	Jeppe Street	Commercial district	6.954494	6
13	455	Dilapidated/ abandoned	48 Simmonds St	Exchange District	6.395264	8
10	421	Dilapidated/ abandoned	124 Marshall St	Financial District	5.743255	9
11	424	Dilapidated/ abandoned	62 Frederick St	Mid-Town District	5.743255	9
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	Financial District	5.420941	11
1	221	Dilapidated/ abandoned	60 End St	Commercial district	5.132836	12
5	292	Dilapidated/ abandoned	61 Nugget St	Commercial district	5.132836	12
23	239	Dilapidated/ abandoned	33 Height St	Doornfontein	4.414795	14
0	199	Dilapidated/ abandoned	102a Albert St	Commercial district	4.371919	15
22	384	Dilapidated/ abandoned	City and Suburban	Commercial district	4.371919	15
3	278	Dilapidated/ abandoned	208 Commissioner St	Commercial district	4.337578	17
4	288	Dilapidated/ abandoned	217 Commissioner St	Commercial district	4.337578	17
21	210	Dilapidated/ abandoned	204 Main Street	Commercial district	4.337578	17
2	232	Dilapidated/ abandoned	35 Siemert Rd	Doornfontein	4.324417	20
19	228	Dilapidated/ abandoned	Mosely Street	Commercial district	4.324417	20
20	384	Dilapidated/ abandoned	Miriam Makeba St	Financial District	2.933264	22
6	378	Dilapidated/ abandoned	19b Marshall St	Mid-Town District	2.085471	23
16	778	Dilapidated/ abandoned	Marshall St	Financial District	2.085471	23

KFinal_KDE
Z
0.000000
0.000001 - 0.535994
0.535995 - 0.902086
0.902087 - 1.350909
1.350910 - 2.016783
2.016784 - 2.944342
2.944343 - 4.193775
4.193776 - 6.125125
6.125126 - 9.722416

Once mapped, the Z-scores were transferred to each potential site, as a measure of proximity to service clustering. A 5-class Jenks natural break is applied to class the scores. The top class is highlighted. Final ranking is on the z-values.



3.6 Conclusion

In this chapter, the technical application of the methods described in the previous chapter, namely: 1) Metro ARIA 2) Service area size and Standard Distance and 3) Kernel Density Estimation of the service points in the study area was made. In the Metro ARIA analysis, the aim was to understand the accessibility of the different service types, highlighting those that mean the most for low-income households (food and transport). Service Area Size and compactness were analyzed to shed light on travel efficiency of each redevelopment location: large service areas being less efficient to traverse, in contrast to small ones.

The biggest limitation of these methods is that it assumes people will select the nearest service point to frequent, whereas in reality the trade-off location choices and are influenced by network constraints (e.g. capability, coupling and legal constraints Acheampong & Silva, 2015).

KDE was used to analyze whether or not the selected sites are located within or near a 'hot-spot' of services. For this research, CrimeStat IV which runs Euclidean distance, is the application that was used to run the KDE analysis, with mapping done in ESRI ArcMap 10.3. The key limitation is that planar, and not network KDE was used, which tends to overestimate the clustering tendencies of entities. Plug-ins such as SANET can be used to run network KDE (the latest version 10.2 was incompatible with ESRI ArcMap 10.3 and so could not be used in this research).

Ultimately the results of all these tests are used to rank the sites in order to identify the top-ranking sites in the next chapter. The methods selected for this research are intended to complement and triangulate each other. It can be argued that all methods serve the same end. They are run parallel with each other in order to observe the extent to which they confirm (or not) each other's results. In this chapter, the technical application of the method was presented. In the next chapter, the results are interpreted.

4. Results Analysis

4.1 Introduction

The previous chapter presented a description of how the methodology was applied. In this chapter, the results are analysed within the framework of identifying where the best potential brownfield sites for re-development for social housing in the Johannesburg CBD located, which was the aim of this research. In this introductory section, the motivation for this research, the statement of the research problem and the research question are revisited. A brief review of the main points from the literature review is presented. The subsequent section addresses the results from the perspective of both what the literature said, and the results expected prior to the commencement of this research. In the course of the discussion, gaps, anomalies and trends will be highlighted. The conclusion juxtaposes the expected results with the final results, and states the most viable sites for brownfield development.

The motivation for this research is drawn from efforts to address the housing backlog of 2.1 million units (Tomlinson, 2015) which South Africa has been battling, specifically within the social/affordable housing sphere (income earners of between R3500 and R7000 per month). The housing backlog in Johannesburg stands at 158 000 units, with 80 000 units in the inner city alone (Private Sector sign MoU to Revive Inner City, July 30 2017). Those below the R7000pm threshold qualify for a government-subsidized (RDP) house, but yet research has shown how such housing is typically found in peripheral, inaccessible areas, where transport costs (which make up about of low-income households' budgets) start to become expensive (NASHO 2012, HDA Report, 2013). This research intends to highlight the utility of the CBD from firstly a social housing perspective, and secondly an accessibility perspective. To this end, the statement of the problem was presented as:

> *The costs of housing location for low-income populations*: that social housing projects so far, have tended to favor suburban or urban-peripheral locations which are far removed from basic amenities and services that are needed by low-income populations.

And the research question was posed thus:

> *"Where are the best potential sites for re-development for social housing in the Johannesburg CBD located?"*

In response to the question, the trajectory of this research was firstly, to render a description of the study area and its demarcation, as having followed the classic urban evolutionary patterns of growth, congestion, decay and regeneration. This was done with an analysis of the change in the value of CBD buildings as represented by the change in commercial office rentals and stock. Together with a temporal analysis of mortgage bond values by block in the study area, the context of the fieldwork was set. Lastly, the technical application of: 1) Metro ARIA, a distance cost measure which provides insight into the ease of access to each site to the amenities needed by low-income households; 2) Service area size around each potential redevelopment site, and its Standard Distance, which represent the *spatial extent* expressed as size or compactness, as a follow-on analysis of the ease of access to amenities; 3) Kernel Density Estimation which was used to assess the level of spatial density of the service points or amenities around each potential redevelopment site. This was all in order to identify the best-located redevelopment site(s) for social housing within the Johannesburg CBD.

The literature review raised the following key points in this respect:

- Brownfielding or the re-development of existing urban land, with its **emphasis on region-wide impacts,** is a **viable** option for CBD regeneration and social housing**;**
- The evolution of Johannesburg and its CBD has followed the classic urban **morphological cycles** of urbanization, growth, decline and (now) regeneration;
- The regeneration of the Johannesburg CBD is an important aspect of **social housing policies**;
- The **CBD is naturally a highly accessible location**; it is the best location for social housing;
- Metro ARIA. The **lowest scores** reflect the **greatest accessibility**;
- Size of the Service area. A **small size/compact shape** means better access;
- Kernel Density Estimation (KDE). Isolates **clusters and hotspots of service delivery**:

Prior to the research, the following results were expected:

- *There will be clusters of varying density of service provision (e.g transport hubs, shops etc.) in varying locations and by type of service zone.*
- *I expect CBD building decay to be fairly heterogeneously spread out, but some 'zones' within the CBD are to be more conducive for redevelopment to social housing than others, because of the nearness, multiplicity and density of amenities.*
- *The research should point to specific locations and properties that can be further investigated by the city.*

Other expectations were:

- To use information on the *value* of buildings, rather than sales. That is, the municipal valuation;

- The limitation of using deeds data as opposed to building valuation data became clear during the course of the fieldwork. It became evident that of the buildings that did not emerge in the purchases and sales data over the decades. Many of them were still occupied and were being maintained. But on the other hand, some buildings that did appear in the purchases and sales data emerged as aging/un-maintained, dilapidated or even abandoned.

This introductory section revisited the reason for this research, expected results prior to the research and highlights from the literature review. The next sections analyse the results from these perspectives. In the coming sub-sections: the results of the Metro ARIA calculations are analysed, that is, how easily accessible are different amenities from each identified potential redevelopment site.

4.2 Measures of Accessibility Results Analysis

4.2.1 Analysis of Results: ARIA Measure of Network Distance

Measurements were taken from each potential redevelopment site to the nearest (1) Hospital (2) shopping Centre (3) education (schools) (4) public transport hubs and (5) financial and postal services. These categories are further broken down into sub-types, for which GIS layers were obtained, and the network distance to each potential redevelopment site calculated. In effect, the closest hospital, shopping centre etc, was actually the ARIA score calculated from the sub-types. The final ARIA score was then derived from the main service-type categories:

Table 8 Application of Remoteness Index for this Research

Service type	Service facilities and weighting	Score range
Health (Health ARIA)	(Major Hospital + All Hospital + GP)/3	0–3
Shopping (Shopping-ARIA)	(Spasa + Major Shopping Centre + Supermarket)/6	0–3
Education (Education-ARIA)	Primary School + High School + FET + University)/3	0–2
Public transport (Public Transport ARIA)	(All transit stops + Go Zone (high frequency) stop + Interchange)/4.5	0–2
Financial and postal (Finance-ARIA)	(Bank + Post Office)/3	0–2
Metro-ARIA = Health-ARIA + Shopping-ARIA + Education-ARIA + Public Transport-ARIA + Finance ARIA		0–12

Source: Somenahalli et al., 2016, p 15

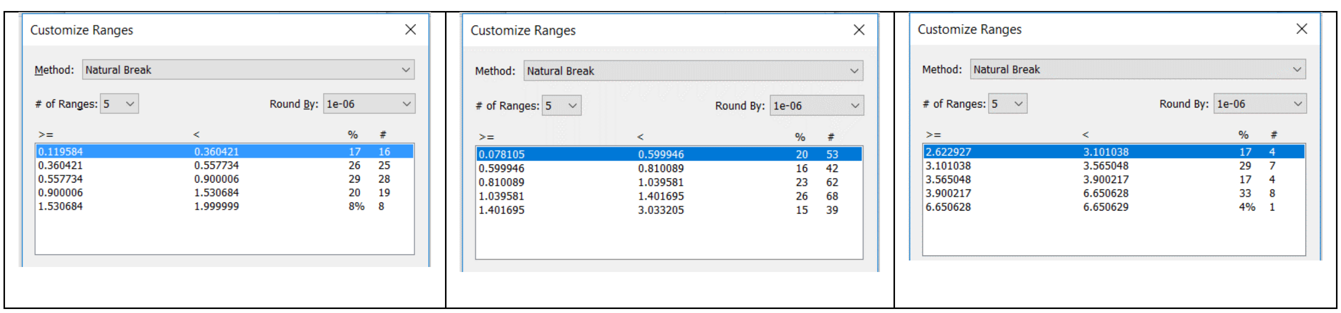
A capped, weighted score was assigned to each category of services and an overall ARIA is derived for each potential redevelopment site. Once scores were derived, they were standardized to a ratio by dividing by the weighted mean for that service, because ARIA distance values are strongly skewed. A capped maximum value is applied to each service type (0-2 or 0-3), and they are summed to get an overall measure of accessibility, which is a score out of 12; 12 being least accessible. Even with standardization, results of some of the categories still overwhelm the index, and for this reason, a cap or threshold (score range) is applied. The rationale behind the 0-2/0-3 threshold is that it cannot be set too low, if the aim is to distinguish the least from the more accessible locations. *All locations exceeding the threshold are given a value equal to the threshold*. The threshold is expressed as an integral multiple of the sum of the mean distances for each category or service type, meaning smaller 'desired travel' distances for less in-demand services. It reflects the principle that people are willing to travel longer distances for higher order or high demand services (Taylor et al., 1999), (GISCA & University of Adelaide, 2008).

Because of the particular interest with services that are most significant for urban poor households in this research (low-income households (R0-R86,000 per annum) tend to spend most of their income on transport and food costs (Ismail et al., 2016)) food and transport were given the highest weights, and their score ranges swapped. In effect, shopping score range became 0-2.

The 5-class Jenks' natural break method of classifying the data was applied, to arrive at the following descriptions for access to each service type from each of the 24 sites:

1) Highly accessible
2) Accessible
3) Moderately accessible
4) Far
5) Very Far

The classification was run in three iterations: the first run was for the service types with score-ranges 0-2, the next for score ranges 0-3 and the last for the final ARIA score, resulting in differing class breaks:



This section summarizes the ARIA scores presented in section 3.4.9. An Exploratory Data Analysis approach is taken, in order to summarize and describe the data.

The summary statistics to describe the measures of central tendency, and the spread of the values are as follows:

Table 34 Exploratory Data Analysis Results

	HEALTH ARIA	SHOPPING ARIA	EDUCATION ARIA	TRANSPORT ARIA	FINANCIAL ARIA	FINAL ARIA
N	24	24	24	24	24	24
Min	0.410	0.152	0.659	0.277	0.078	2.700
Max	1.195	0.803	1.985	1.333	1.701	6.651
Sum	16	9.105	31.998	14.543	15.999	87.649
Mean	0.667	0.379	1.333	0.606	0.667	3.652
Std. error	0.037	0.034	0.080	0.054	0.065	0.166
Variance	0.033	0.027	0.153	0.070	0.103	0.660
Stand. dev	0.182	0.165	0.391	0.264	0.320	0.812
Median	0.638	0.369	1.313	0.583	0.630	3.461
25 prcntil	0.525	0.240	1.008	0.361	0.420	3.149
75 prcntil	0.744	0.510	1.689	0.794	0.832	4.056
Skewness	1.235	0.687	-0.100	0.877	1.303	2.217
Kurtosis	1.835	0.230	-1.092	0.793	3.753	7.490
Geom. mean	0.646	0.345	1.274	0.554	0.587	3.581
Coeff. var	27.245	43.620	29.325	43.615	48.067	22.244

The statistics above describe the accessibility of the 24 sites to the various service types, *together*. The mean is the balance point of the data, it is only applicable when there are no outliers or extreme (minimum or maximum) values in the data, that is, when there is little variability in the data. In this case, except for the transport variable, the mean and median are close together meaning either statistic is appropriate for describing the average ARIA for each service type. However, because of the skewness of the data, it is more cautious to use the median. In conclusion, the average accessibility is as follows:

Table 35 Summary of Accessibility Findings by Summary Type

TYPE	ITERATION	MEDIAN ARIA	DESCRIPTION	SCORE RANGE
HEALTH	2	0.638	Accessible	0-3
SHOPPING	1	0.369	Accessible	0-2
EDUCATION	2	1.313	Far	0-3
TRANSPORT	1	0.583	Moderately accessible	0-2
FINANCIAL	2	0.630	Accessible	0-2
FINAL	3	3.461	Accessible	0-12

Overall accessibility is good for health and shopping service location, which bodes well for the food security issues of the urban (CBD-based) poor, although not so well for transport. Overall, the study area can be described as “accessible”.

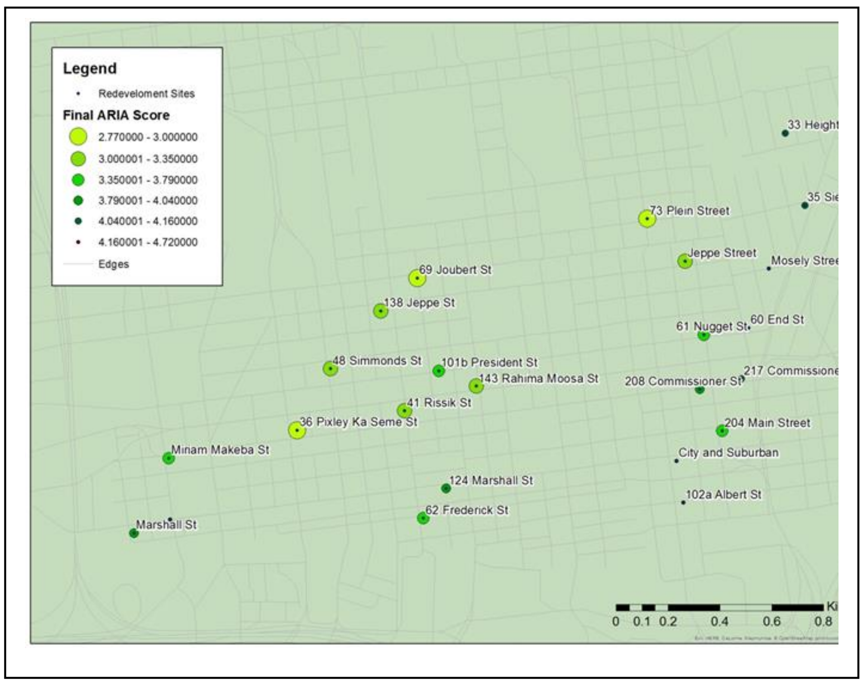
- Variance is the mean of the squared deviations from the mean; the closer to zero the variance is, the smaller the difference in the data values, which is the case here. Ultimately, it is expected that overall accessibility should be relatively equitable for all service types, that is, good overall accessibility which is typical for a CBD.

- Coefficient of variation is the standard deviation divided by the mean. It describes the dispersion of the data when different measurement values are used, as is the case here. In effect, it allows for checking the dispersion of the data, across the service-types. In conclusion, there is a greater spread of data values with financial, transport and shopping centre locations. Which means for some sites, these services are quite far, but fairly close by for others.

The 24 potential redevelopment sites are classed by CBD district (see figure 8). For expediency, an additional "district" of Doornfontein is included, as those sites do not fall into any of the districts established in section 3.2:

Table 36 Potential Redevelopment Site by CBD District

DISTRICT	ADDRESS
Commercial district	204 Main Street
	208 Commissioner St
	Jeppe Street
	61 Nugget St
	102a Albert St
	City and Suburban
	Mosely Street
	217 Commissioner St
	60 End St
Doornfontein	33 Height St
	35 Siemert Rd
Exchange District	138 Jeppe St
	48 Simmonds St
Financial District	36 Pixley Ka Seme St
	Miriam Makeba St
	124 Marshall St
	Marshall St
Mid-Town District	41 Rissik St
	143 Rahima Moosa St
	101b President St
	62 Frederick St
	19b Marshall St
Station District	69 Joubert St
	73 Plein Street



Nineteen redevelopment sites had **high accessibility** to 50 service or amenity locations. The top sites had high accessibility to 4 or 5 locations across the service sub-types. These were: 73 Plein Street, 69 Joubert Street, 41 Rissik, 204 Main Street, Miriam Makeba Street and 36 Pixley Ka Seme Street. No Major hospitals are highly accessible, they are only built for larger population sizes, and are expected to have a larger catchment area.

Twenty-one redevelopment sites had **good to high accessibility** to 107 service points. The top sites had good accessibility to 7-8 locations across the service sub-types. These were: 73 Plein Street, 36 Pixley Ka Seme Street, 101b President Street, 138 Jeppe Street and Jeppe Street.

All 24 sites had some service or amenity locations to which they had **moderate to high accessibility**. The top sites had good accessibility to 10-12 locations across the service types. These were: 69 Joubert Street, 73 Plein Street, Rahima Moosa Street,138 Jeppe Street and Jeppe Street. Turning to the services that had the best accessibility: shopping and education had the most sites moderately to highly accessible with 49 and 52 locations each. Transport had only 37 sites moderately to highly accessible.

There is a clear indication that generally, the same redevelopment sites emerge when moderate to high accessibility is measured. Tables 25 to 28 in chapter 3 show the disaggregated ARIA scores by service type for each redevelopment sites. At this low level, some sites that are not in the top sites mentioned above scored well (i.e. had low ARIA scores), but for very specific services. Examples include 33 Height Street and 204 Main Street. But for the most part, even at the disaggregated level, the same top sites generally emerged. Turning to the final score, 4 of the sites mentioned above: 69 Joubert Street, 73 Plein Street, 138 Jeppe Street, and 36 Pixley Ka Seme Street emerge as the choice redevelopment sites, with 138 Jeppe Street outranking them:

Table 29 (p.83) Results of ARIA analysis

FID	ID	ADDRESS	HEALTH ARIA	SHOPPING ARIA	EDUCATION ARIA	TRANSPORT ARIA	FINANCIAL ARIA	FINAL ARIA	RANK
15	462	138 Jeppe St	0.508524	0.201539	1.254230	0.357181	0.378730	2.700205	1
8	403	69 Joubert St	0.519397	0.187205	1.296927	0.343562	0.415859	2.762949	2
17	325	73 Plein Street	0.621706	0.151774	0.800688	0.639466	0.592187	2.805820	3
9	406	36 Pixley Ka Seme St	0.702299	0.596508	0.919259	0.292789	0.430478	2.941333	4
7	394	41 Rissik St	0.466038	0.280969	1.671002	0.528520	0.078105	3.024634	5
12	398	143 Rahima Moosa St	0.410386	0.229288	1.731761	0.403161	0.364910	3.139506	6
18	326	Jeppe Street	0.648091	0.153192	0.992022	0.433317	0.948740	3.175362	7
21	210	204 Main Street	0.642875	0.225444	1.486040	0.372533	0.589507	3.316399	8
14	461	101b President St	0.487106	0.381419	1.765417	0.277099	0.406229	3.317270	9
11	424	62 Frederick St	0.544080	0.436947	1.695129	0.347683	0.377957	3.401796	10
20	384	Miriam Makeba St	0.886181	0.518773	0.659426	0.635590	0.712078	3.412048	11
13	455	48 Simmonds St	0.631055	0.532248	1.297499	0.472168	0.512000	3.444971	12
23	239	33 Height St	0.752537	0.545785	0.700153	0.796644	0.681932	3.477051	13
5	292	61 Nugget St	0.586550	0.271289	1.097220	0.784424	0.855353	3.594837	14
4	288	217 Commissioner St	0.655253	0.356889	1.401695	0.497768	0.752312	3.663917	15
10	421	124 Marshall St	0.488390	0.281239	1.985222	0.333766	0.751171	3.839788	16
3	278	208 Commissioner St	0.579076	0.322683	1.531345	0.867823	0.548633	3.849560	17
2	232	35 Siemert Rd	0.942120	0.433378	1.054510	0.728977	0.890373	4.049357	18
6	378	19b Marshall St	0.942823	0.619333	0.895135	0.837229	0.763160	4.057680	19
19	228	Mosely Street	0.794632	0.402196	1.113048	0.726568	1.055283	4.091727	20
22	384	City and Suburban	0.648366	0.309011	1.810859	0.716792	0.667735	4.152764	21
0	199	102a Albert St	0.632761	0.382680	1.894407	0.799443	0.549150	4.258440	22
1	221	60 End St	0.714532	0.483054	1.328991	1.016066	0.977052	4.519695	23
16	778	Marshall St	1.195224	0.802990	1.618013	1.333333	1.701069	6.650629	24

Table 37 Highest Ranking ARIA Sites - Highly Accessible Sites

ADDRESS	HOSPITAL ARIA	SHOPPING_CENTRE_ARIA	SPAZA_ARIA	SUPERMARKET_ARIA	COLLEGE_ARIA	PRIMARYSCHOOL ARIA	HIGHSCHOOL_ARIA	UNIVERSITY_ARIA	HFS_ARIA	INTERCHANGE_ARIA	ALL_ARIA	BANKS ARIA	POSTOFFICE ARIA	
73 Plein Street		1	1		1	1	1							5
41 Rissik St	1	1										1	1	4
69 Joubert St	1		1							1		1		4
204 Main Street			1						1		1	1		4
36 Pixley Ka Seme St					1	1				1		1		4
Miriam Makeba St					1	1	1						1	4
138 Jeppe St	1	1										1		3
143 Rahima Moosa St	1	1										1		3
Jeppe Street			1	1			1							3
101b President St	1								1			1		3
33 Height St					1	1		1						3
208 Commissioner St	1			1										2
19b Marshall St					1	1								2
217 Commissioner St									1					1
48 Simmonds St										1				1
124 Marshall St			1											1
35 Siemert Rd								1						1
102a Albert St												1		1
62 Frederick St												1		1
Grand Total	**6**	**4**	**5**	**2**	**5**	**5**	**3**	**2**	**3**	**3**	**1**	**9**	**2**	**50**

Highly Accessible and Accessible Sites

ADDRESS	HOSPITAL ARIA	MAJOR HOSPITAL ARIA	SHOPPING_CENTRE_ARIA	SPAZA_ARIA	SUPERMARKET_ARIA	COLLEGE_ARIA	PRIMARYSCHOOL ARIA	HIGHSCHOOL_ARIA	UNIVERSITY_ARIA	HFS_ARIA	INTERCHANGE_ARIA	ALL_ARIA	BANKS ARIA	POSTOFFICE ARIA	
73 Plein Street		1	1	1		1	1	1			1		1		8
36 Pixley Ka Seme St			1			1	1				1	1	1	1	7
Jeppe Street			1	1	1	1	1	1			1				7
138 Jeppe St	1		1	1						1		1	1	1	7
101b President St	1		1							1	1	1	1	1	7
62 Frederick St		1	1							1	1		1	1	6
124 Marshall St	1	1	1	1						1		1			6
143 Rahima Moosa St	1		1	1							1		1	1	6
204 Main Street			1	1	1					1		1	1		6
33 Height St		1	1			1	1	1	1						6
69 Joubert St	1		1	1							1		1		5
Miriam Makeba St			1			1	1	1						1	5
217 Commissioner St	1		1		1					1		1			5
208 Commissioner St	1		1		1								1		4
48 Simmonds St			1								1	1		1	4
41 Rissik St	1		1										1	1	4
61 Nugget St			1		1			1							3
19b Marshall St						1	1	1							3
Mosely Street								1	1						2
102a Albert St			1										1		2
City and Suburban			1										1		2
35 Siemert Rd			1						1						2
Grand Total	**8**	**4**	**20**	**7**	**5**	**6**	**6**	**7**	**3**	**6**	**8**	**7**	**12**	**8**	**107**

Highly Accessible, Accessible and Moderately Accessible Sites

ADDRESS	HOSPITAL ARIA	MAJOR HOSPITAL ARIA	SHOPPING_CENTRE_ARIA	SPAZA_ARIA	SUPERMARKET_ARIA	COLLEGE_ARIA	PRIMARYSCHOOL ARIA	HIGHSCHOOL_ARIA	UNIVERSITY_ARIA	HFS_ARIA	INTERCHANGE_ARIA	ALL_ARIA	BANKS ARIA	POSTOFFICE ARIA	
69 Joubert St	1		1	1	1	1	1		1	1	1	1	1	1	12
73 Plein Street		1	1	1	1	1	1	1	1	1	1		1	1	12
138 Jeppe St	1		1	1	1	1	1		1	1	1	1	1	1	12
Jeppe Street		1	1	1	1	1	1	1	1	1	1	1		1	12
48 Simmonds St	1	1	1			1	1			1	1	1	1	1	10
143 Rahima Moosa St	1	1	1	1	1					1	1	1	1	1	10
36 Pixley Ka Seme St			1			1	1	1	1	1	1	1	1	1	10
35 Siemert Rd		1	1	1		1	1	1	1	1	1				9
101b President St	1	1	1		1					1	1	1	1	1	9
61 Nugget St	1	1	1	1	1	1	1	1	1						9
33 Height St		1	1			1	1	1	1			1	1		8
62 Frederick St	1	1	1							1	1	1	1	1	8
41 Rissik St	1	1	1		1							1	1	1	7
Miriam Makeba St			1	1		1	1	1	1					1	7
204 Main Street	1		1	1	1			1				1	1		7
102a Albert St	1	1	1	1						1	1		1		7
Mosely Street		1	1		1	1	1	1	1						7
208 Commissioner St	1		1		1			1	1				1	1	7
124 Marshall St	1	1	1	1						1	1	1			7
19b Marshall St			1			1	1	1	1					1	6
217 Commissioner St	1		1		1			1	1			1			6
City and Suburban	1		1	1	1								1		5
60 End St			1					1	1						3
Marshall St			1					1							2
Grand Total	**14**	**13**	**24**	**12**	**13**	**12**	**12**	**14**	**14**	**12**	**12**	**13**	**14**	**13**	**192**

It is at this stage that the Australian ARIA score classification is applied. It is necessary to highlight, however, that this classification was based on a sample of Australian data, with natural breaks in the 0-12 continuous variable applied to generate the 5 classes below. Naturally, due to the uniqueness of the underlying structure and pattern of data, the natural breaks in the data differ from data sample to data sample. Furthermore, the data sample needs to be large enough to render a distribution that will provide a clear 0-12 classification.

What has emerged in this research is that since the sample is fairly small, the Jenks natural break classification does not score up to the 12th value: the maximum value is 6.65. This research identifies a need for a standard and stable classification of scores, that is not dependent on sample size or the changing position of natural breaks in the data. A properly calibrated classification that suits the local situation, and is stable (which falls outside the scope of this research). However, for demonstration purposes, the Australian classification is applied to this research:

Table 6 (p.40) Explanation of ARIA Scores

1. **Highly Accessible** (ARIA score 0 - 1.84) - relatively unrestricted accessibility to a wide range of goods and services and opportunities for social interaction
2. **Accessible** (ARIA score >1.84 - 3.51) - some restrictions to accessibility of some goods, services and opportunities for social interaction
3. **Moderately Accessible** (ARIA score >3.51 -5.80) - significantly restricted accessibility of goods, services and opportunities for social interaction
4. **Remote** (ARIA score >5.80 - 9.08) - very restricted accessibility of goods, services and opportunities for social interaction
5. **Very Remote** (ARIA score >9.08 - 12) - very little accessibility of goods, services and opportunities for social interaction

Source: DHAC 2001, p.3

Please note that with the last 2 categories, the word 'remote' is done away with and replaced with the word 'far', as the word 'remote' reflects more a rural situation:

Table 39 Final ARIA Scores Classified for Accessibility

FID	ID	ADDRESS	FINAL ARIA	RANK	Access Description
17	325	73 Plein Street	2.622927	1	Accessible
8	403	69 Joubert St	2.710913	2	Accessible
15	462	138 Jeppe St	2.761751	3	Accessible
9	406	36 Pixley Ka Seme St	2.835421	4	Accessible
12	398	143 Rahima Moosa St	3.101038	5	Accessible
18	326	Jeppe Street	3.102466	6	Accessible
7	394	41 Rissik St	3.137191	7	Accessible
13	455	48 Simmonds St	3.192087	8	Accessible
14	461	101b President St	3.362901	9	Accessible
11	424	62 Frederick St	3.374776	10	Accessible
20	384	Miriam Makeba St	3.426418	11	Accessible
5	292	61 Nugget St	3.565048	12	Moderately Accessible
21	210	204 Main Street	3.589448	13	Moderately Accessible
23	239	33 Height St	3.750945	14	Moderately Accessible
3	278	208 Commissioner St	3.817821	15	Moderately Accessible
10	421	124 Marshall St	3.900217	16	Moderately Accessible
4	288	217 Commissioner St	3.923786	17	Moderately Accessible
2	232	35 Siemert Rd	3.929993	18	Moderately Accessible
19	228	Mosely Street	4.127670	19	Moderately Accessible
0	199	102a Albert St	4.154442	21	Moderately Accessible
22	384	City and Suburban	4.176592	22	Moderately Accessible
6	378	19b Marshall St	4.152855	20	Moderately Accessible
1	221	60 End St	4.427615	23	Moderately Accessible
16	778	Marshall St	6.650629	24	Far

According to this classification, 50% of the sites have good (not 'high') accessibility, and the remaining have moderate accessibility, with a single site classified as 'far' from amenities. These results are consistent with the findings of the 2013 HDA report. The methodology was a simple 1,5-km buffer drawn around each Affordable Housing project, to calculate how many amenities were in close proximity, by urban zone. The CBD emerged as having the most amenities in the vicinity:

Spatial type	SAPS	Post office	Private hospital	Public hospital	Medical clinic	Total medical facilities	Secondary school	Primary school	Combined schools	Total schools
Suburban Outer	1 Less than one per project	3 Less than one per project	0	0	0	0	3 Less than one per project	11 About 3 per project	1 Less than one per project	15 About 4 per project
Suburban Inner	3 Less than one per project	6 About one per project	5 One per project	4 Less than one per project	3 Less than one per project	12 **About 2,5 per project**	8 About one per project	27 About 5,5 per project	6 About one per project	41 **About 8 per project**
CBD	6 Less than one per project	20 2 per project	36 About 3,5 per project	5 Less than one per project	6 Less than one per project	47 **About 5 per project**	46 About 4,5 per project	62 About 6 per project	20 About 2 per project	128 **About 13 per project**
Greyzone	0	0	0	0	0	0	0	0	0	0

Source: HDA Report, 2013 p.26

Spatial type	Taxi rank	Railway station	Bus stop	Total transport facilites
Suburban Outer	1	2	0	3 **Less than 1 per project**
Suburban Inner	0	3	0	3 **Less than one per project**
CBD	70	18	146	234 **About 23 per project**
Greyzone	2	0	3	55 **Around 1 project**

Source: HDA Report, 2013 p.27

Furthermore, the results show that there could be room for more and better service provision within the CBD, to attain the high accessibility classification. This concludes the analysis of the finding of the Metro ARIA calculation. Next is the analysis of the size and shape of the service areas around the sites.

4.2.2 Analysis of Results: Service Area Size and Shape

There is a stark contrast, not just between Euclidean and network service area buffers, but *amongst* network service buffers themselves. While Euclidean buffers naturally have the same area size in square metres, but network service area buffers can range in size (see Andersen, 2002).

In this research, for each of the locations that were identified as being potential re-development sites, a service area based on all the closest facility results (i.e. by amenity type) was created. The spatial extent of each service area represented by the bounding area of these points (the convex hulls) determines the network *service area*. The spatial extent of each service area is then calculated, and the most compact (smallest size) ones are identified. These are then potentially the most efficient in terms of travel costs, for all service types.

When the pattern and structure of the data were investigated, it showed quite large spread of the data: the standard deviation is double the mean, the range of the data is wide judging from the minimum and maximum values. The median and mean are dissimilar, meaning there is a level of skewness in the data, although not large since both the kurtosis and skewness are close to zero. Indeed, from the graphic below, the data is positively skewed meaning a large number of small or 'compact' SAs, which has the effect of pulling up the mean (Wegner, 2005):

Table 40 Summary Statistics – Service Area Size

	SA Area
N	24
Min	884 653
Max	4 457 090
Sum	45 845 710
Mean	1 910 238
Std. error	198 031
Variance	941 189 200 000
Stand. dev	970 149
Median	1 441 220
25 prcntil	1 138 178
75 prcntil	2 714 643
Skewness	0.95
Kurtosis	0.17
Geom. mean	1 703 207
Coeff. var	50.79

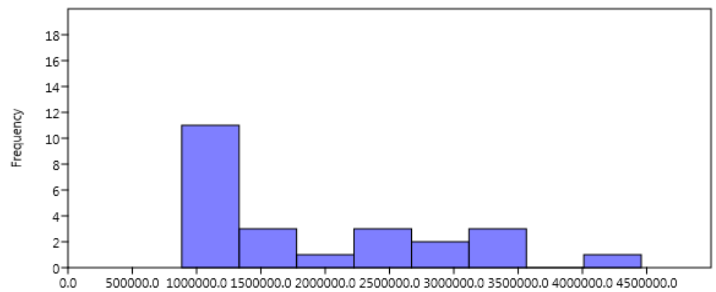


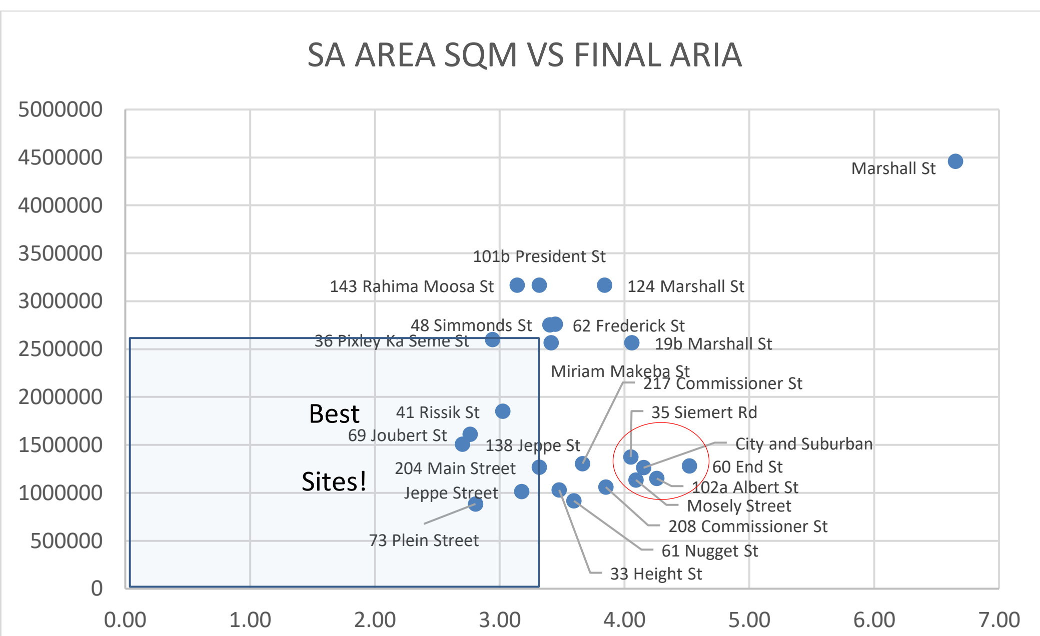
Table 31 (p.86) Results of The Service Area Size Analysis

FID	ID	Map	Address	Districts	Area - SQM	Rank
18	325	Dilapidated/ abandoned	73 Plein Street	Station District	884 653	1
6	292	Dilapidated/ abandoned	61 Nugget St	Commercial district	916 346	2
19	326	Dilapidated/ abandoned	Jeppe Street	Commercial district	1 012 300	3
24	239	Dilapidated/ abandoned	33 Height St	Doornfontein	1 031 230	4
4	278	Dilapidated/ abandoned	208 Commissioner St	Commercial district	1 060 130	5
20	228	Dilapidated/ abandoned	Mosely Street	Commercial district	1 134 110	6
1	199	Dilapidated/ abandoned	102a Albert St	Commercial district	1 150 380	7
23	384	Dilapidated/ abandoned	City and Suburban	Commercial district	1 262 110	8
22	210	Dilapidated/ abandoned	204 Main Street	Commercial district	1 267 420	9
2	221	Dilapidated/ abandoned	60 End St	Commercial district	1 280 680	10
5	288	Dilapidated/ abandoned	217 Commissioner St	Commercial district	1 304 860	11
3	232	Dilapidated/ abandoned	35 Siemert Rd	Doornfontein	1 374 710	12
16	462	Dilapidated/ abandoned	138 Jeppe St	Exchange District	1 507 730	13
9	403	Dilapidated/ abandoned	69 Joubert St	Station District	1 609 470	14
8	394	Dilapidated/ abandoned	41 Rissik St	Mid-Town District	1 850 620	15
7	378	Dilapidated/ abandoned	19b Marshall St	Mid-Town District	2 564 580	16
21	384	Dilapidated/ abandoned	Miriam Makeba St	Financial District	2 564 580	16
10	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	Financial District	2 600 290	18
12	424	Dilapidated/ abandoned	62 Frederick St	Mid-Town District	2 752 760	19
14	455	Dilapidated/ abandoned	48 Simmonds St	Exchange District	2 758 150	20
11	421	Dilapidated/ abandoned	124 Marshall St	Financial District	3 167 170	21
13	398	Dilapidated/ abandoned	143 Rahima Moosa St	Mid-Town District	3 167 170	21
15	461	Dilapidated/ abandoned	101b President St	Mid-Town District	3 167 170	21
17	778	Dilapidated/ abandoned	Marshall St	Financial District	4 457 090	24

A 5-class natural break indicates that the most compact SAs are 1,130,000m² in size or less. 73 Plein Street and 61 Nugget clearly distinguish themselves from the rest of the group, having the smallest, most compact service area. The efficiency of getting to the closest facility of each service type is best from these sites. Anomalies are 33 Height street, which ranked in the middle of the field (13th) for the ARIA calculation, and 208 Commissioner Street which ranked 17th. This brings back the assertion, at the beginning of this research: although all these methods are applied for **measuring accessibility** to services and amenities by poor urban households, albeit from different approaches, the methods are intended to complement and triangulate each other. They are run parallel with each other in order to observe the extent to which they confirm each other's results.

The result is therefore confirmed for Jeppe Street and 73 Plein street and Jeppe Street which ranked amongst the most accessible locations according to the final ARIA score. However, 61 Nugget ranked in the middle of the table for final ARIA, and 69 Joubert which drew the second best final ARIA score ranks in the middle of this (service area and shape) table. Looking at the scatterplot below, although there is no correlation between SA size and Final ARIA (coefficient of 0.33), the graphic helps to illustrate and confirm previous results, as well as to highlight the anomaly: Marshall Street. It can be confirmed at this stage, that Marshall Street would not adequately serve the location needs of the urban poor, should it be selected as a brownfield site for housing development. The good accessibility, compact service area sites can be seen at the bottom left of the graph:

Figure 39 Scatterplot: Final ARIA vs Service Area Size



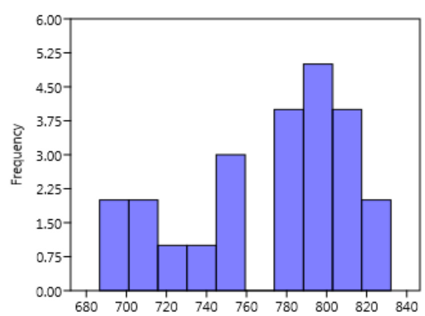
The cluster of sites in the red circle, closely located together by ARIA score and SA size mostly belong in the Commercial District of the CBD, confirming the theory that entities that are closer together tend to share similar qualities (Tobler, 1979 in Yu et al., 2015b).

The idea of service area compactness was further analysed using ***standard distance***, a widely used indicator to estimate the dispersion of points around a geographic centroid (Myint, 2008; Lee and Wong, 2001; Ebdon, 1982) in (Flores et al., 2013). Standard Distance measures the degree to which services are concentrated or dispersed around the sites. It was anticipated at the start of the research, that the variation in point density will not be equal in all directions. The method was to simply extract the service points (amenities) within a walkable distance of 600m -around each potential redevelopment site, and calculate the point dispersion.

When the structure and pattern of the data are explored, it appeared that there was not much variation in the standard distance data. The range of the data is small, the standard deviation was 42m, which is just 5% of the mean. The mean and the median are close together, meaning the skewness of the data is not large. What skewness there is, is negative (pulling down the mean), meaning most sites have a greater point density or more service points around them (Wegner, 2005):

Table 41 Summary Statistics - Standard Distance

	StdDist
N	24
Min	686.67
Max	832.04
Sum	18509.12
Mean	771.21
Std. error	8.73
Variance	1829.18
Stand. dev	42.77
Median	785.34
25 prcntil	735.66
75 prcntil	803.83
Skewness	-0.58
Kurtosis	-0.84
Geom. mean	770.05
Coeff. var	5.55

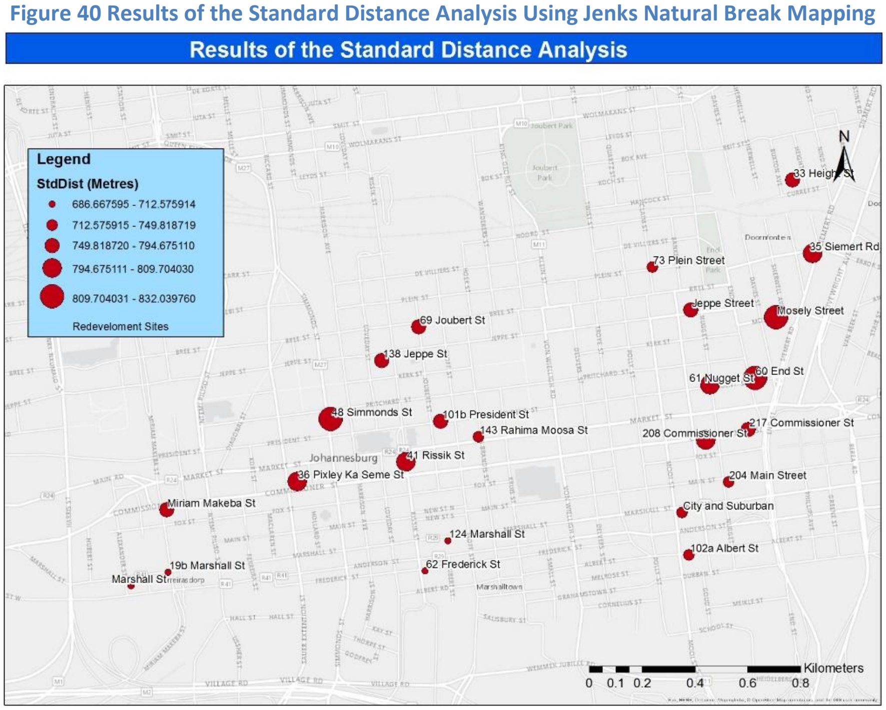


Interestingly, the sites that scored worst in the ARIA calculation and the calculation of service area size are the ones showing the lowest (and best) dispersion or distribution of services around the site. A smaller standard distance means that services are closer to the potential redevelopment sites, and that travel costs should be lower to access those amenities. The results showed that:

Table 32 (p.88) Results of the Standard Distance Analysis

FID_	ID	Map	Address	StdDist (Metres)	Rank
16	778	Dilapidated/ abandoned	Marshall St	687	1
11	424	Dilapidated/ abandoned	62 Frederick St	699	2
10	421	Dilapidated/ abandoned	124 Marshall St	705	3
6	378	Dilapidated/ abandoned	19b Marshall St	713	4
0	199	Dilapidated/ abandoned	102a Albert St	725	5
22	384	Dilapidated/ abandoned	City and Suburban	732	6
17	325	Dilapidated/ abandoned	73 Plein Street	745	7
21	210	Dilapidated/ abandoned	204 Main Street	749	8
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	750	9
20	384	Dilapidated/ abandoned	Miriam Makeba St	777	10
8	403	Dilapidated/ abandoned	69 Joubert St	782	11
14	461	Dilapidated/ abandoned	101b President St	783	12
23	239	Dilapidated/ abandoned	33 Height St	788	13
18	326	Dilapidated/ abandoned	Jeppe Street	790	14
15	462	Dilapidated/ abandoned	138 Jeppe St	792	15
4	288	Dilapidated/ abandoned	217 Commissioner St	795	16
7	394	Dilapidated/ abandoned	41 Rissik St	798	17
3	278	Dilapidated/ abandoned	208 Commissioner St	801	18
2	232	Dilapidated/ abandoned	35 Siemert Rd	805	19
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	810	20
5	292	Dilapidated/ abandoned	61 Nugget St	810	21
13	455	Dilapidated/ abandoned	48 Simmonds St	817	22
19	228	Dilapidated/ abandoned	Mosely Street	827	23
1	221	Dilapidated/ abandoned	60 End St	832	24

Figure 40 Results of the Standard Distance Analysis Using Jenks Natural Break Mapping

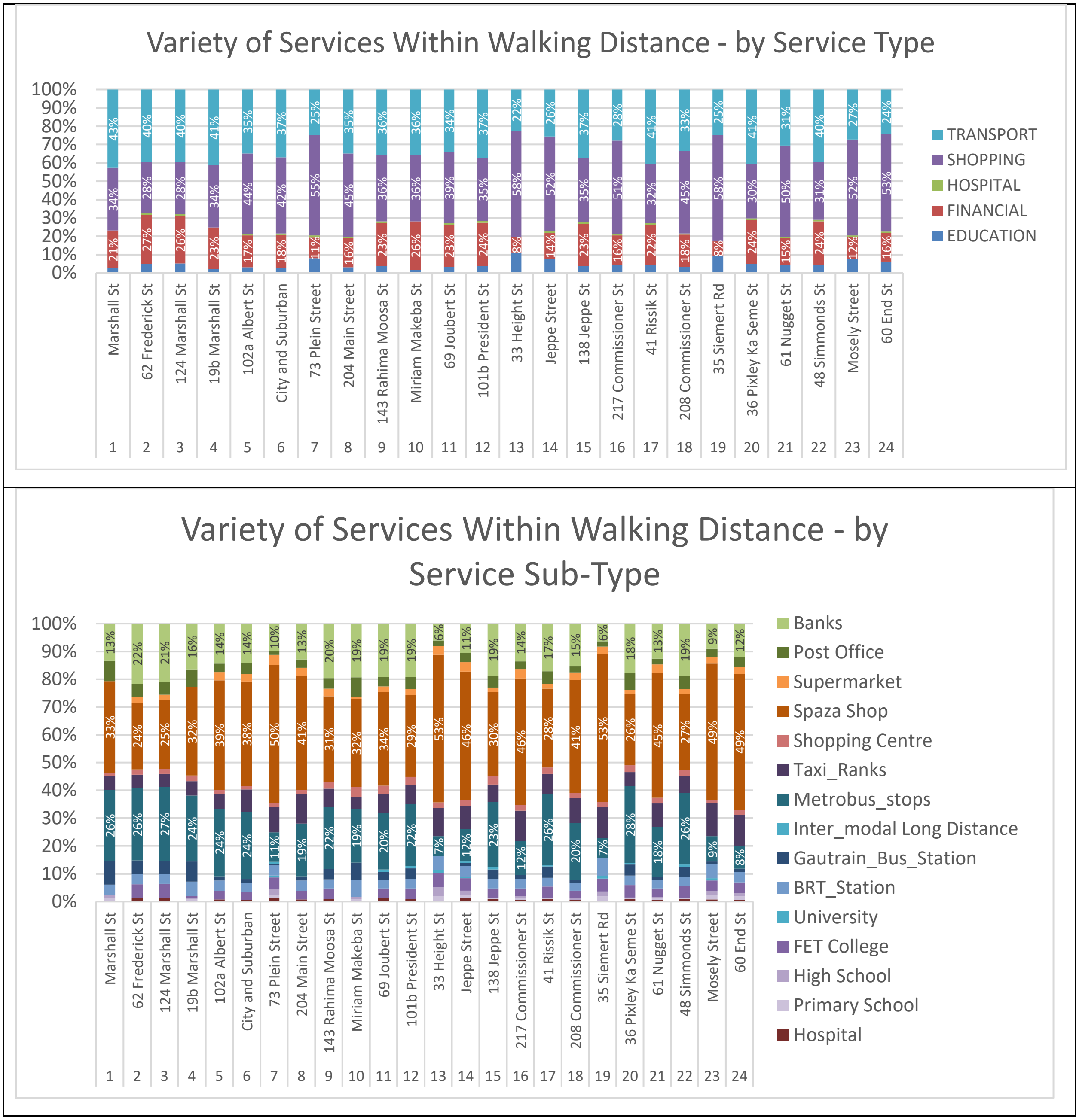


This map shows the standard distance (SD) of the service point dispersion around each potential redevelopment site within a 15 km radius.

The smaller the SD, the greater the clustering of services around the site and potentially the greater the accessibility as a result of lower travel cost.

This incongruity of the results of this method with the previous two measures of accessibility could potentially mean that the distribution of the services around these sites is of a homogenous service type, hence, the decision to also consider the variety of service points around each site:

Figure 41 Variety of Services Around the Redevelopment Sites



Nevertheless, it turned out from the results presented above, that the variety of the distribution of service types around each potential redevelopment site is by and large, quite similar. This concludes this investigation, with the understanding that further analysis into the reasons for the seemingly contrary standard distance results is required.

The final section compares these results with the KDE hot-spots analysis.

4.3 Analysis of Results: Goods and Services Clustering Using KDE

In this section, the aim was to understand the extent to which each site is a hot-spot or falls within a hot-spot, with regards to proximity to services using the method Kernel Density Estimation (KDE). Each site was assessed for 1) whether or not it falls within a 'hot-spot' of services and 2) where more than 1 site is within a 'hot-spot', the extent to which they overlap the highest part of the scale.

Point Pattern Analysis (PPA) is an approach that can be used to reveal density distribution patterns in different places, especially with lesser or greater distance from the point(s) of interest. There are various tools and methods that are conventionally used to assess point patterns or spatial (Yu et al. 2015, Borruso 2003). Kernel Density Estimation (KDE) is one such approach that is commonly used because it considers the decay impact of services based on Tobler's First Law of Geography (Tobler, 1979 in Yu et al., 2015b). Using this method, not only is the dispersion of service amenities around the sites considered, but also the *intensity* of clustering is estimated, and visualized over the study area.

Used for hot-spot and cool-spot identification and analysis, the Quartic (spherical) kernel type was chosen as it better aligns better with planar (Euclidean) distances; it is a common kernel type selection (Yu et al., 2015). CrimeStat IV is the application that was used to run the analysis, with mapping done in ESRI ArcMap 10.3. The Euclidean method is used in this research, as the scale of the study is large enough to not suffer greatly the vagaries of network distance greatly. Furthermore, the street network grid is distributed fairly evenly throughout the study area. The analysis covered the 15km extent of the area of interest.

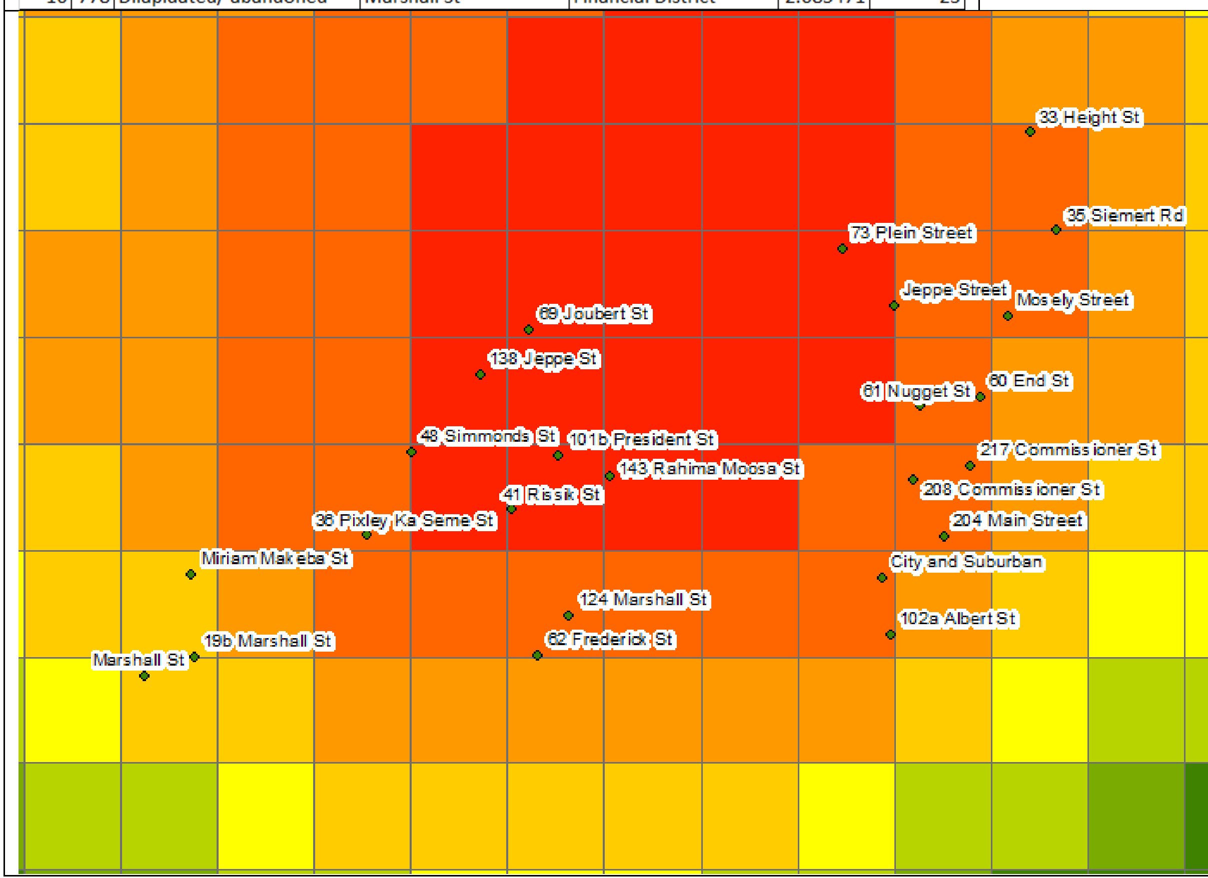
The results this time were very consistent with the first two measures of accessibility: Metro ARIA and Service Area Size. The results mean that the highlighted sites in Table 33, which are largely the same sites that emerged at the top with the other two methods, lie in the hotspot of services (regardless of the service type). It is expected the limitations that plague Euclidean KDE, are not as pronounced in this research, given the smallness of the study area. The inadequacy of this approach (Miller 1994 in Yu et al. 2015, Borruso 2003, Flores et al., 2013) is mainly that the planar method has a tendency to overestimate the clustering tendency of network phenomenon.

Table 42 Results of the KDE Run - Low Level

FID	ID	Type	Address	Districts	Z_values	Rank
8	403	Dilapidated/ abandoned	69 Joubert St	Station District	7.841520	1
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	Mid-Town District	7.214683	2
7	394	Dilapidated/ abandoned	41 Rissik St	Mid-Town District	7.089068	3
14	461	Dilapidated/ abandoned	101b President St	Mid-Town District	7.089068	3
15	462	Dilapidated/ abandoned	138 Jeppe St	Exchange District	6.975465	5
17	325	Dilapidated/ abandoned	73 Plein Street	Station District	6.954494	6
18	326	Dilapidated/ abandoned	Jeppe Street	Commercial district	6.954494	6
13	455	Dilapidated/ abandoned	48 Simmonds St	Exchange District	6.395264	8
10	421	Dilapidated/ abandoned	124 Marshall St	Financial District	5.743255	9
11	424	Dilapidated/ abandoned	62 Frederick St	Mid-Town District	5.743255	9
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	Financial District	5.420941	11
1	221	Dilapidated/ abandoned	60 End St	Commercial district	5.132836	12
5	292	Dilapidated/ abandoned	61 Nugget St	Commercial district	5.132836	12
23	239	Dilapidated/ abandoned	33 Height St	Doornfontein	4.414795	14
0	199	Dilapidated/ abandoned	102a Albert St	Commercial district	4.371919	15
22	384	Dilapidated/ abandoned	City and Suburban	Commercial district	4.371919	15
3	278	Dilapidated/ abandoned	208 Commissioner St	Commercial district	4.337578	17
4	288	Dilapidated/ abandoned	217 Commissioner St	Commercial district	4.337578	17
21	210	Dilapidated/ abandoned	204 Main Street	Commercial district	4.337578	17
2	232	Dilapidated/ abandoned	35 Siemert Rd	Doornfontein	4.324417	20
19	228	Dilapidated/ abandoned	Mosely Street	Commercial district	4.324417	20
20	384	Dilapidated/ abandoned	Miriam Makeba St	Financial District	2.933264	22
6	378	Dilapidated/ abandoned	19b Marshall St	Mid-Town District	2.085471	23
16	778	Dilapidated/ abandoned	Marshall St	Financial District	2.085471	23

KFinal_KDE
Z
0.000000
0.000001 - 0.535994
0.535995 - 0.902086
0.902087 - 1.350909
1.350910 - 2.016783
2.016784 - 2.944342
2.944343 - 4.193775
4.193776 - 6.125125
6.125126 - 9.722416

Once mapped, the Z-scores were transferred to each potential site, as a measure of proximity to service clustering. A 5-class Jenks natural break is applied to class the scores. The top class is highlighted. Final ranking is on the z values.



In the conclusion in the next section, the final ranking of the sites is given, and the most suitable sites for social housing redevelopments are identified.

4.4 Conclusion

As Chapter 4 is concluded, the motivation for this research, its objectives and what has been achieved is reviewed.

The impetus for this research was found in the massive housing backlog of 2.1 million units, which lies in the low-income population bracket and efforts to breach it in the way of programs and strategies emanating from the Republic of South Africa's Social Housing Act No. 16 of 2008. Much of the current programs have failed to address the burgeoning question of accessibility for poor households. A very topical issue of modern South Africa. The literature pointed to a misalignment between these objectives and resultant projects on the ground, with a preference for projects on the urban fringe where land is cheaper. Far from amenities for the very target group the legislation is intended to benefit (HDA Report, 2013).

Moreover, the literature points to brownfield development or refurbishing and repurposing of existing buildings as one method of arresting urban degeneration, especially for housing (Meyer, 1998).

Anticipation for similar results were elicited from the findings of the HAD 2012 survey, which found that more services were found to be in the CBD, than in any other urban zone. It was clear that the CBD is a choice location in the drive for poverty alleviation, yet space-time research approaches and the nuanced approaches of ABA (agent-based approach) can shed deeper insights for cherry-picking brownfielding sites, notwithstanding legal, cost and other potential vagaries that emerge in the course of site acquisition.

As such the research question and objectives of the research were as follows:

> *"Where are the best potential sites for re-development for social housing in the Johannesburg CBD located?"*

And

- To determine which properties have not been on the market in the last 3 decades and the current condition of such properties;
- To identify potential buildings and sites for redevelopment to social housing from such sites;
- To assess how far each potential site is, from amenities and services or service clusters, that are required most by low-income populations;

- To identify the sites which are closest to most amenities as the best sites for re-development to social housing.

The first objective was attained by the temporal analysis and extraction of transfer and sales information to isolate potential sites, in spite of the limitations with the data. Indeed, potential redevelopment sites have been identified and the distances of these sites from services and service clusters (specifically those of particular importance to poor households) elicited. And in this last section, the sites which are closest to most amenities as the best sites for re-development to social housing are identified:

Table 43 Final Selection of the Best Potential Sites for Brownfield Development for Social Housing

FID	ID	ADDRESS	Districts	Final ARIA Rank	SA Size Rank	StdDist Rank	KDE RANK	SUM RANK	FINAL RANK
17	325	73 Plein Street	Station District	3	1	7	6	17	1
8	403	69 Joubert St	Station District	2	15	11	1	29	2
18	326	Jeppe Street	Commercial district	7	3	14	6	30	3
15	462	138 Jeppe St	Exchange District	1	14	15	5	35	4
12	398	143 Rahima Moosa St	Mid-Town District	6	22	9	2	39	5
7	394	41 Rissik St	Mid-Town District	5	16	17	3	41	6
11	424	62 Frederick St	Mid-Town District	10	20	2	9	41	6
21	210	204 Main Street	Commercial district	8	9	8	17	42	8
23	239	33 Height St	Doornfontein	13	4	13	14	44	9
14	461	101b President St	Mid-Town District	9	22	12	3	46	10
0	199	102a Albert St	Commercial district	23	7	5	15	50	11
10	421	124 Marshall St	Financial District	16	22	3	9	50	11
5	292	61 Nugget St	Commercial district	14	2	22	12	50	11
22	384	City and Suburban	Commercial district	22	8	6	15	51	14
9	406	36 Pixley Ka Seme St	Financial District	4	19	21	11	55	15
3	278	208 Commissioner St	Commercial district	17	5	18	17	57	16
4	288	217 Commissioner St	Commercial district	15	11	16	17	59	17
20	384	Miriam Makeba St	Financial District	11	17	10	22	60	18
6	378	19b Marshall St	Mid-Town District	20	17	4	23	64	19
13	455	48 Simmonds St	Exchange District	12	21	23	8	64	19
2	232	35 Siemert Rd	Doornfontein	18	12	19	20	69	21
2	232	35 Siemert Rd	Doornfontein	18	12	19	20	69	21
1	221	60 End St	Commercial district	24	10	25	12	71	23
19	228	Mosely Street	Commercial district	21	6	24	20	71	23
16	778	Marshall St	Financial District	25	25	1	23	74	25

It is worthwhile to note that at the beginning of this research, it was highlighted that the accessibility measures employed here, though seemingly serve the same end, are deliberately selected to complement and triangulate each other, in order to observe the extent to which they confirm each other's results. This as well has been successfully achieved. The top 4 sites listed in table 43 consistently emerged in the top of 1) the Metro ARIA calculation, 2) the Service Area size calculation and 3) the KDE analysis. The contradiction emerged with the Standard Distance analysis, which seemingly reversed the trend.

Much of the thinking of this research is not novel, except perhaps the application of the Metro ARIA method to the South Africa situation, which it has been pointed out in this research, requires further customization to suit the local conditions. Government is already making in-roads, if perhaps only verbal as at this stage, into making more CBD locations available for affordable housing (see: *Affordable Housing Project Gets Green Light,* n.d., and *Building affordable housing in Johannesburg*, n.d., *Joburg frees up land for pro-poor developments*, 31 July 2018).

The significance of this research lies in its timeliness regarding the current drive by COJ to refurbish buildings in the CBD for social housing. It lends itself to fine-tuning existing site-selection approaches by putting forward a site-selection approach for optimally locating social housing, so contributing to sound fiscal spending through rational decision-making. Furthermore, the research emphatically supports the idea that gentrification should not be allowed to displace poor households from the CBD. In the final chapter concludes the research and puts forward recommendations and suggestion for future work.

5. Conclusion

5.1 Introduction

In the fourth chapter, the results were analysed for identifying where the best potential brownfield sites for re-development for social housing in the Johannesburg CBD located. In this concluding chapter, the findings of the research are summarized and gaps, anomalies and deviations in the data are highlighted. Next, the limitations of the research are addressed and some ideas for future work are presented and placed in the context of the literature. Lastly, the research question, "Where are the best potential sites for re-development for social housing in the Johannesburg CBD located?" is answered, the significance and contribution of this research is addressed. The chapter concludes with some personal reflections.

5.2 Discussion

5.2.1 Summary of Findings

This section begins with a summary of the main findings of the research, gaps and anomalies.

The technical section of the research presented the application of 1) Metro ARIA 2) Service area size and Standard Distance and 3) Kernel Density Estimation of the service points in relation as measures of accessibility to service amenities for low-income households, to identify potential best brownfield redevelopment sites for affordable housing. In the next section, the main findings will be discussed, noticeable and outstanding points highlighted, and gaps, anomalies and deviations noted. The section also draws from the findings of other research in chapter 2. The section concludes with relating how the results and conclusions relate to the research question.

The findings were as follows:

Table 43 (p.114) Final Selection of the Best Potential Sites for Brownfield Development for Social Housing

FID	ID	ADDRESS	Districts	Final ARIA Rank	SA Size Rank	StdDist Rank	KDE Score	SUM RANK	FINAL RANK
17	325	73 Plein Street	Station District	3	1	7	1	12	1
18	326	Jeppe Street	Commercial district	7	3	14	1	25	2
21	210	204 Main Street	Commercial district	8	9	8	2	27	3
8	403	69 Joubert St	Station District	2	15	11	1	29	4
15	462	138 Jeppe St	Exchange District	1	14	15	1	31	5
23	239	33 Height St	Doornfontein	13	4	13	2	32	6
11	424	62 Frederick St	Mid-Town District	10	20	2	2	34	7
0	199	102a Albert St	Commercial district	23	7	5	2	37	8
12	398	143 Rahima Moosa St	Mid-Town District	6	22	9	1	38	9
22	384	City and Suburban	Commercial district	22	8	6	2	38	9
7	394	41 Rissik St	Mid-Town District	5	16	17	1	39	11
5	292	61 Nugget St	Commercial district	14	2	22	2	40	12
20	384	Miriam Makeba St	Financial District	11	17	10	3	41	13
3	278	208 Commissioner St	Commercial district	17	5	18	2	42	14
10	421	124 Marshall St	Financial District	16	22	3	2	43	15
4	288	217 Commissioner St	Commercial district	15	11	16	2	44	16
6	378	19b Marshall St	Mid-Town District	20	17	4	3	44	16
14	461	101b President St	Mid-Town District	9	22	12	1	44	16
9	406	36 Pixley Ka Seme St	Financial District	4	19	21	2	46	19
2	232	35 Siemert Rd	Doornfontein	18	12	19	2	51	20
2	232	35 Siemert Rd	Doornfontein	18	12	19	2	51	20
19	228	Mosely Street	Commercial district	21	6	24	2	53	22
16	778	Marshall St	Financial District	25	25	1	3	54	23
13	455	48 Simmonds St	Exchange District	12	21	23	1	57	24
1	221	60 End St	Commercial district	24	10	25	2	61	25

In revisiting and unpacking the results, there was consistency in the different methodologies regarding the results they yielded. Excluding the results of the Standard Distance analysis which yielded results contrary to the prevailing trend. Of the top 4 sites in table 43, 2 ranked in the top 10 for all 3 measures, and all 4 ranked in the top 20.

<u>Metro ARIA:</u> the graphic below is the disaggregated results of the Metro ARIA calculation. To demonstrate consistency of the trend, the results are ordered according to table 43's rankings:

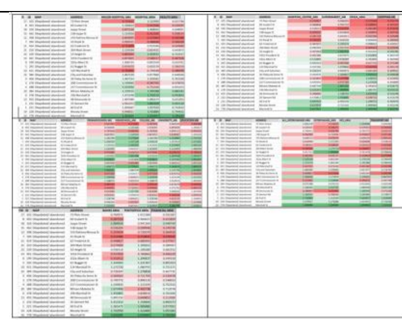
<u>HEALTH</u>

<u>SHOPPING</u>

<u>EDUCATION</u>

<u>TRANSPORT</u>

<u>FINANCIAL</u>



The low (best) ARIA scores were highlighted red. Except for education, even at the disaggregated level, the same sites kept emerging with the lowest (best) ARIA scores.

The 5-class Jenks' natural break method of classifying the data was applied, classifying site from highly accessible to very far. While all the service types were in summary, classified as either 'accessible' or 'moderately accessible' to any of the 24 sites, only education was classified as 'far'. Ultimately the entire study area was classified as "accessible". According to this classification, 50% of the sites have good (not 'high') accessibility, and the remaining have moderate accessibility. These results are consistent with the findings of the 2013 HDA report, whose methodology of a simple 1,5-km buffer drawn around each Affordable Housing project to calculate how many amenities were in close proximity (by urban zone) showed that the CBD had the most amenities in the vicinity (HDA Report, 2013).

Table 36 Potential Redevelopment Site by CBD District

DISTRICT	ADDRESS
Commercial district	204 Main Street
	208 Commissioner St
	Jeppe Street
	61 Nugget St
	102a Albert St
	City and Suburban
	Mosely Street
	217 Commissioner St
	60 End St
Doornfontein	33 Height St
	35 Siemert Rd
Exchange District	138 Jeppe St
	48 Simmonds St
Financial District	36 Pixley Ka Seme St
	Miriam Makeba St
	124 Marshall St
	Marshall St
Mid-Town District	41 Rissik St
	143 Rahima Moosa St
	101b President St
	62 Frederick St
	19b Marshall St
Station District	69 Joubert St
	73 Plein Street

From the results, it was clear that **no one district** held the preponderance of the best sites. Nevertheless, this may be more an indication of the arbitrariness of the demarcation of districts than a failure of Tobler's Law (Tobler, 1979 in Yu et al., 2015b).

Nevertheless, most of the low-ARIA (best access) sites lie to the north of the study area (138 Jeppe, 69 Joubert, Jeppe Street and 73 Plein); and to the west: 36 Pixley-Ka-Seme, 48 Simmonds; 41 Rissik and 143 Rahima Moosa. So, there is clearly a spatial dimension to the distribution of the best sites.

The least accessible sites according to Metro ARIA lie to the south (and south-east) of the study area, close to the highway. Understandably, to the south of the Highway the land-use is predominantly residential, with the suburbs of Booysens, and further south there is Mondeor, Ridgeway, Winchester Hills and others.

It is was at the final stage that the Australian ARIA score classification was applied. The key constraint with this approach was highlighted as being the questionable applicability of the classification or categories of scores from "Highly Accessible" to "Far". The following were noted:

- The Australian index took natural breaks in the 0-12 continuous variable: any sample needs to be large enough to cover that range. In the case of this research the highest score was 6.65;
- This means that due to the uniqueness of the underlying structure and pattern of data, the natural breaks in the data will differ from data sample to data sample, and in this case, the least accessible sites mentioned in the previous point would score as "Very Far";
- Although there is nothing inherently wrong with that approach, it does however, limit the analysis to the single dataset at the time, and renders a very narrow view that will not allow for comparisons across geographies and across time;
- For this reason, the need was identified for a stable scoring mechanism, empirically derived taking into account the local situation relating to accessibility, mobility and social needs.

It is necessary to highlight, however, that this classification was based on a sample of Australian data, with natural breaks in the 0-12 continuous variable applied to generate the 5 classes below. Naturally, due to the uniqueness of the underlying structure and pattern of data, the natural breaks in the data differ from data sample to data sample. Furthermore, the data sample needs to be large enough to render a distribution that will provide a clear 0-12 classification.

Service Area Size and Shape: a "service area" based on all the closest facilities (i.e. by amenity type) to each potential redevelopment site was created. The spatial extent of each service area was then calculated, and the most compact (smallest size) ones are identified. These are then identified as potentially the most efficient in terms of travel costs, for all service types.

From this analysis, it was noted that some results did not align with the Metro ARIA results:

Table 44 Metro ARIA and Service ARIA Size Results Rank Comparison

FID	ID	Map	Address	Rank	ARIA Rank
17	325	Dilapidated/ abandoned	73 Plein Street	1	3
5	292	Dilapidated/ abandoned	61 Nugget St	2	14
18	326	Dilapidated/ abandoned	Jeppe Street	3	7
23	239	Dilapidated/ abandoned	33 Height St	4	13
3	278	Dilapidated/ abandoned	208 Commissioner St	5	17
19	228	Dilapidated/ abandoned	Mosely Street	6	20
0	199	Dilapidated/ abandoned	102a Albert St	7	22
22	384	Dilapidated/ abandoned	City and Suburban	8	21
21	210	Dilapidated/ abandoned	204 Main Street	9	8
1	221	Dilapidated/ abandoned	60 End St	10	23
4	288	Dilapidated/ abandoned	217 Commissioner St	11	15
2	232	Dilapidated/ abandoned	35 Siemert Rd	12	18
15	462	Dilapidated/ abandoned	138 Jeppe St	13	1
8	403	Dilapidated/ abandoned	69 Joubert St	14	2
7	394	Dilapidated/ abandoned	41 Rissik St	15	5
6	378	Dilapidated/ abandoned	19b Marshall St	16	19
20	384	Dilapidated/ abandoned	Miriam Makeba St	16	11
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	18	4
11	424	Dilapidated/ abandoned	62 Frederick St	19	10
13	455	Dilapidated/ abandoned	48 Simmonds St	20	12
10	421	Dilapidated/ abandoned	124 Marshall St	21	16
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	21	6
14	461	Dilapidated/ abandoned	101b President St	21	9
16	778	Dilapidated/ abandoned	Marshall St	24	24

There could be any number of factors responsible for this incongruity, which requires proper investigation. Chief among them, however, should be the fact that while some sites did not rank highly for the total Metro ARIA, there could have been some amenities they were especially close to, and the results of the Service Area Size analysis attests to that. No. 33 Height street is one such example, ranking 13th in terms of accessibility (Metro ARIA), but it is close to shopping services (excluding supermarkets); education facilities (except for university), transport infrastructure and banks (but not post offices. There is a Standard Bank branch is in the same neighbourhood).

Table 45 Demonstrating A Cause for Anomaly Between Metro ARIA and Service Area Size Results

Line	Service Type	33 Height St	208 Commissioner St	61 Nugget St	Average Distance (Study Area)
2	HOSPITAL	1 853.24	2 652.66	2 132.51	2 307.74
3	CLINIC	1 304.79	527.24	749.55	897.04
4	SHOPPING_CENTRE	652.24	582.92	805.22	1 602.29
5	SUPERMARKET	1 265.85	158.11	302.94	648.06
6	SPAZA	232.99	338.49	167.61	254.82
7	PRIMARY SCHOOL	501.87	1 440.65	947.36	1 059.72
8	HIGH SCHOOL	714.56	993.22	696.96	1 154.89
9	FET COLLEGE	501.87	1 440.65	947.36	1 059.72
10	UNIVERSITY	1 151.21	2 186.05	1 938.69	2 153.53
11	ALL INTERCHANGES	186.23	320.46	290.06	227.82
12	NORMAL INTERCHANGE	926.45	510.18	459.71	433.14
13	HIGH FREQUENCY INTERCHANGE	186.23	320.46	290.06	242.65
14	BANKS	349.94	280.16	502.46	373.66
15	POST OFFICE	758.19	612.50	834.80	683.50
Average		**756.12**	**883.13**	**790.38**	**935.61**

*Highlighted distances are below the study area average distance

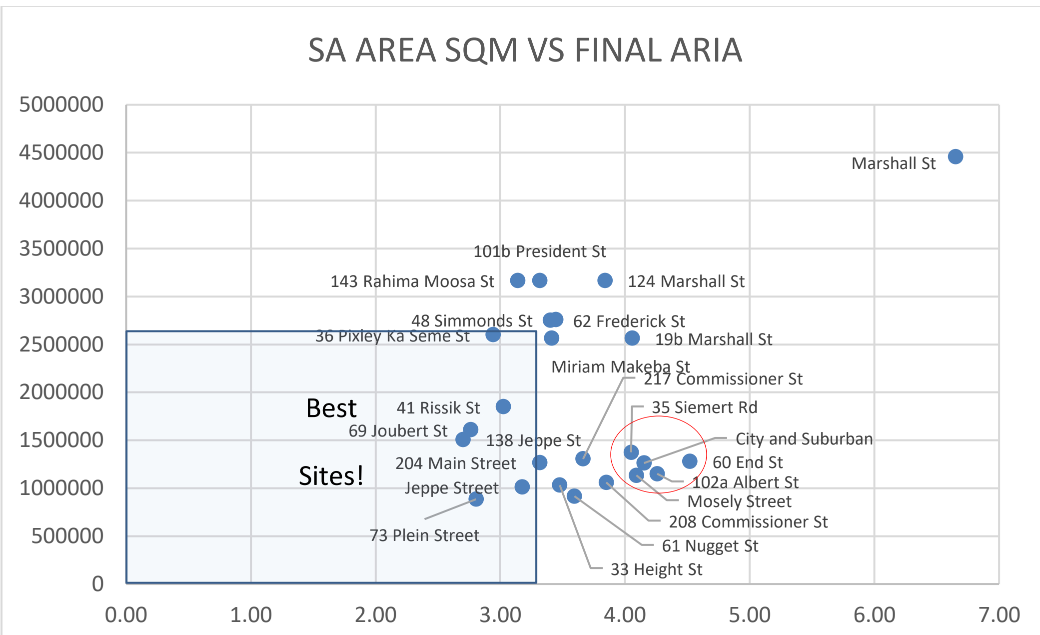
To be highlighted also is the important role that the South African Postal Services are going to play in the payment of social grants going forward. After government terminated the contract of the previous service provider, the South African postal offices were selected as the location from which the old and indigent will receive their grant payments (most of whom do not own a bank account).

This makes postal service locations now particularly sensitive for accessibility, possibly needing to be tested for “walking distance”. The methods presented here can play such a role. “The Post Office has been criticized for its branches not being located in proximity to social grant beneficiaries or within 5km of existing cash pay points” (*Post Office*, 4 June 2018).

<u>Future Work</u>: this approach enables policy-makers to highlight on a micro-scale, sites or areas where there is not equitable access to *particular* basic needs or amenities, and to promote the development of the services that are particularly missing, as in the example of 33 Height Street above.

When the results of the Metro ARIA analysis and the Service Area Size were overlaid, a first glimpse of the best sites was given:

Figure 39 (p. 107) Scatterplot: Final ARIA vs Service Area Size



Please note that there is little to no correlation between the variables (coefficient of 0.33). The graphed results, when juxtaposed with the site distribution shown in figure/table 36 (p.118), confirms the theory that entities that are closer together tend to share similar qualities (Tobler, 1979 in Yu et al., 2015b). Most of the best sites lie in the north of the study area, as pointed out in the Metro ARIA section (p.119). the cluster of sites in the red circle are the “least accessible” are mostly in the south-east of the study area. Exceptions are 204 Main Street (east side). Moreover, some of the “least accessible” in the northernmost part of the study area: 33 Height Street and 35 Siemert Street.

Standard Distance: Extending the idea of services density and compactness, the ESRI ArcMap Standard Distance tool was used to measure the dispersion of service points around each site. A smaller standard distance means greater clustering of service points and potentially better travel cost value. A single representative distance measure in metres explains the dispersion of features around the site (*How Standard Distance Works*, n.d.). Standard Distance Deviation is similar to standard deviation (SD) in conventional statistics (Flores et al., 2013; Levine, 1996).

There was more inconsistency between the Metro ARIA results and the Service Area results on the one hand and the results of the Standard Distance analysis on the other. Seemingly the least accessible, least compact sites had the smallest standard distances:

Table 32 Results of the Elliptical Standard Distance Analysis

FID_	ID	Map	Address	StdDist (Metres)	Rank	SA Rank	ARIA Rank
16	778	Dilapidated/ abandoned	Marshall St	687	1	24	24
11	424	Dilapidated/ abandoned	62 Frederick St	699	2	19	10
10	421	Dilapidated/ abandoned	124 Marshall St	705	3	21	16
6	378	Dilapidated/ abandoned	19b Marshall St	713	4	16	19
0	199	Dilapidated/ abandoned	102a Albert St	725	5	7	22
22	384	Dilapidated/ abandoned	City and Suburban	732	6	8	21
17	325	Dilapidated/ abandoned	73 Plein Street	745	7	1	3
21	210	Dilapidated/ abandoned	204 Main Street	749	8	9	8
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	750	9	21	6
20	384	Dilapidated/ abandoned	Miriam Makeba St	777	10	16	11
8	403	Dilapidated/ abandoned	69 Joubert St	782	11	14	2
14	461	Dilapidated/ abandoned	101b President St	783	12	21	9
23	239	Dilapidated/ abandoned	33 Height St	788	13	4	13
18	326	Dilapidated/ abandoned	Jeppe Street	790	14	3	7
15	462	Dilapidated/ abandoned	138 Jeppe St	792	15	13	1
4	288	Dilapidated/ abandoned	217 Commissioner St	795	16	11	15
7	394	Dilapidated/ abandoned	41 Rissik St	798	17	15	5
3	278	Dilapidated/ abandoned	208 Commissioner St	801	18	5	17
2	232	Dilapidated/ abandoned	35 Siemert Rd	805	19	12	18
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	810	20	18	4
5	292	Dilapidated/ abandoned	61 Nugget St	810	21	2	14
13	455	Dilapidated/ abandoned	48 Simmonds St	817	22	20	12
19	228	Dilapidated/ abandoned	Mosely Street	827	23	6	20
1	221	Dilapidated/ abandoned	60 End St	832	24	10	23

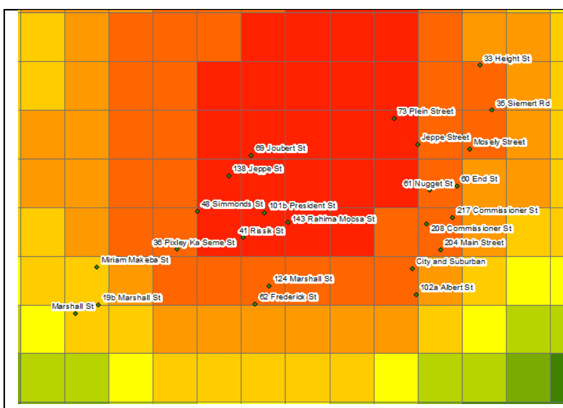
In the event that the incongruity of the results of the standard distance analysis was due to intense clustering of one type of service around a single site e.g. spaza shops, it was decided to check the variety of service types around each site. But yet, the results showed that service type distribution was almost similar across the sites. This is the main anomaly of the study, that requires further investigation.

Kernel Density Estimation: next, the KDE 'smoothing method' was used. Among other things, KDE may also be used for hot-spot and cool-spot identification and analysis (Levine, 1996), (De Smith et al., 2015). It uses a weight function (called kernel function) to estimate the intensity of point distributions in a grid cell, relating distributions to the intensity in Neighbouring cells (Yu et al., 2015). A search radius called a bandwidth determines is the size of the cell in which point estimations are made, which in turn determines the degree of smoothing applied to the data. Bandwidth size makes the most significant impact on the results (Zambom & Dias, 2012). The KDE function in ESRI ArcMap measures in Euclidean distances and the bandwidth is fixed. That is, the algorithm detected the amount of clustering and automatically adjusted the bandwidth accordingly.

The function places a grid over the study area and measuring the distance from each grid cell to each data point. The resulting z-score represents incident density for each grid cell.

In this research, a hundred columns were randomly selected for the grid. Even though KDE avoids the vagaries of the Grid-based (quadrat) and Voronoi analyses in that it removes the arbitrariness of grid-size and shape (Borruso, 2003), the random selection of 100 columns for the study area still introduced a level of arbitrariness.

Furthermore, it is found that had a different number of columns been selected, the grid cells could have been refined more, with more calibrated results. It is found that the resulting grid was quite grainy:



FID	ID	Type	Address	Z_values	Rank	SA Rank	ARIA Rank	SD dist Rank
8	403	Dilapidated/ abandoned	69 Joubert St	7.841520	1	14	2	11
12	398	Dilapidated/ abandoned	143 Rahima Moosa St	7.214683	2	21	6	9
7	394	Dilapidated/ abandoned	41 Rissik St	7.089068	3	15	5	17
14	461	Dilapidated/ abandoned	101b President St	7.089068	3	21	9	12
15	462	Dilapidated/ abandoned	138 Jeppe St	6.975465	5	13	1	15
17	325	Dilapidated/ abandoned	73 Plein Street	6.954494	6	1	3	7
18	326	Dilapidated/ abandoned	Jeppe Street	6.954494	6	3	7	14
13	455	Dilapidated/ abandoned	48 Simmonds St	6.395264	8	20	12	22
10	421	Dilapidated/ abandoned	124 Marshall St	5.743255	9	21	16	3
11	424	Dilapidated/ abandoned	62 Frederick St	5.743255	9	19	10	2
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	5.420941	11	18	4	20
1	221	Dilapidated/ abandoned	60 End St	5.132836	12	10	23	24
5	292	Dilapidated/ abandoned	61 Nugget St	5.132836	12	2	14	21
23	239	Dilapidated/ abandoned	33 Height St	4.414795	14	4	13	13
0	199	Dilapidated/ abandoned	102a Albert St	4.371919	15	7	22	5
22	384	Dilapidated/ abandoned	City and Suburban	4.371919	15	8	21	6
3	278	Dilapidated/ abandoned	208 Commissioner St	4.337578	17	5	17	18
4	288	Dilapidated/ abandoned	217 Commissioner St	4.337578	17	11	15	16
21	210	Dilapidated/ abandoned	204 Main Street	4.337578	17	9	8	8
2	232	Dilapidated/ abandoned	35 Siemert Rd	4.324417	20	12	18	19
19	228	Dilapidated/ abandoned	Mosely Street	4.324417	20	6	20	23
20	384	Dilapidated/ abandoned	Miriam Makeba St	2.933264	22	16	11	10
6	378	Dilapidated/ abandoned	19b Marshall St	2.085471	23	16	19	4
16	778	Dilapidated/ abandoned	Marshall St	2.085471	23	24	24	1

This would have removed the duplicates in the final results. Nevertheless, the results were more consistent with the findings of Metro ARIA and, to a far lesser extent, the Service Area Size and Shape. The next section addresses the limitations of the research.

5.2.2 Limitations

A number of limitations were highlighted in the research.

Firstly, in the Metro ARIA analysis, the network analysis applied some constraints that have made an impact on the results:

1) Distance cost was chosen instead of time cost. So, the final route is not necessarily the fastest, but the closet. This introduces some uncertainty, as human behavior and cognition may take into account the full choice-range: most convenient versus quickest.
2) Furthermore, although constraints such as turn-restrictions, closed roads, one-way roads, it however did not include issues such as the condition of the roads, different maximum speeds (limits) assumed for different road types and the ability to travel at these speeds deteriorating with increasing population density, as well as the impact of extreme weather-related barriers, as it was with the Australian analysis. This would improve the extent to which the results reflect the real situation on the ground.
3) It was also mentioned that a universally applicable continuous variable score model is required for South Africa because the breaks in the Australian Index befits the local Australian situation. Running a 5-class break analysis in this study only yielded results up to 6.65 which, not altogether wrong, may obscure
4) Somenahalli et al. (2016): their data was not used for accessibility scoring, but as an input into a GWR model. Their application could not be used as a guideline for scoring in this research.

Regarding the service area shape and size: this was a creative approach with no direct foundational literature. Some direction was found in the work of Landex, Hansen, & Andersen (2006). For this reason, there is a gap in the robustness of the methodology, which effectually requires further development.

Limitations regarding the use of the KDE methods in this research relate to the inherent vagaries of using planar distance instead of network distance. It assumes that the real world is represented as a flat, homogeneous and isotropic space, as such. Researchers have pointed to the inadequacy of this approach (Miller 1994 in Yu et al. 2015, Borruso 2003, Flores et al. 2013). It has a tendency to overestimate the clustering tendency of network phenomenon, therefore it is preferable to use It is the network rather than Euclidean distance when observing social and economic phenomena in urban space

(Lu and Chen, 2007; Steenberghen et al., 2010; Okabe and Sugihara, 2012 in Yu et al. 2015). This limitation also holds for the way in which the Standard Distance analysis was conducted. It also utilised the planar distance method. A suggestion for any future work.

Some comments on the selected services analysed for the redevelopment sites.

For the health variable, it would have been ideal to include doctor's rooms in the CBD. These are plentiful, and many operate beyond normal working hours. A lot of the doctors cater to the low-income market and are therefore quite affordable for would-be consumers of Affordable Housing. In a study conducted by Nxumalo, Makweng, Baloyi, Tayob, & Tian in 2016, a sample of five so-called 'bad buildings' in the Johannesburg CBD was surveyed for access to a number of basic services.

A total of 276 interviews were completed with adults living in the buildings. Often for many people, some of the prohibitive factors that keep their access to health services beyond their reach are long distances, queues, and high costs of service. However, 96% of the interviewees in this study indicated that they have good access to health facilities. The researchers posited that the reason for such a high rate could be directly linked to the fact that residents were located in the inner city, in close proximity to a number of public health facilities. They point out that unlike in the informal settlements, suburban periphery or in rural areas, these residents do not struggle to access health facilities, most of them stating that the clinics were within walking distance (Nxumalo et al., 2016).

The education analysis did not take into account the quality of the school and that [especially] university campuses can have different faculties and specializations. It treats all schools as equitable and selects purely on the basis of distance. In fact, a study by Machard & Mckay (2015)demonstrates how counter-intuitive human choice can be. Her work, again conducted in the Johannesburg CBD, shows that many parents in peripheral suburbs and some low-income areas expend a lot of their income, sending their children to private and semi-private schools in the Johannesburg CBD. She writes "some parents would rather their children travel great distances, at great cost, and often spend a great deal of time on public transport, instead of enrolling in a nearby township school" (p. 152). Of the major reasons parents gave for sending their children to CBD schools, none related to proximity or location (good academic results (65%), good discipline (52%), quality of teaching (45%), good school management (37%)). Only a handful said they chose the school for "class size, facilities and location". Out of all the Metro ARIA results, the education scores were the only ones that seemingly did not follow the trend.

Regarding the provision of retail, it must be mentioned that though the CBD is generally a key hub of shopping and retail in the City of Johannesburg, indeed a key hub especially for cross-border, pan-African shopping according to Zack (2017), there appears to be a lack of conventional supermarkets and a preponderance of spaza shops (see p.70 where 8 supermarkets can be counted in the core of the study area). Although this is in alignment with the lifestyle of the Affordable Housing target market as reflected in the literature, concerns must be raised about the quality aspect of food security for this segment of the population (Battersby 2011, Battersby & Peyton 2014, poor Battersby & Peyton, 2014; Peyton, Moseley, & Battersby-Lennard, 2015).

Lastly, the general assumptions of the research are quite simplistic in that they assume people patronize the closest facility, which in reality is not necessarily the case. Patrons consider quality, availability of services, price, specialized expertise and a myriad of other factors.

In the final analysis, there was no indication of which method had the most influence on the final results. A weighting of the rankings is therefore also recommended as part of future work. The next sections present some thoughts on future work.

5.3 Future Work

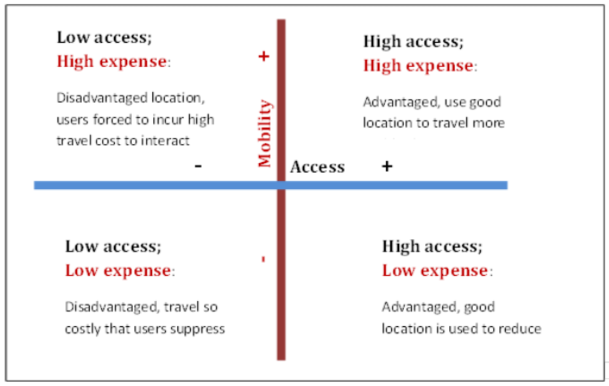
The Accessibility/Remoteness Index of Australia (ARIA) was developed as a geographic remoteness continuum model to measure the ease or difficulty of getting from one place to another, specifically for service provision (Taylor & Lange, 2016). Metro ARIA was developed as a derivative, along with other derivatives meant to measure access to specific service types: PhARIA for measuring access to pharmacies; GPARIA for measuring access to GPs and Cardiac ARIA (APMRC 2015b, APMRC 2014, Coffee et al. 2012, AURIN 2015; Taylor and Lange 2015 in Taylor and Lange 2016). A characteristic of the ARIA methodology highlighted as one of its advantages is its flexibility for adaptation. Indeed, the foundational ARIA methodology was criticized for lacking specificity for access to particular services (Taylor and Lange 2016).

In this research, a key piece of future work that is required is to *delve deeper* into travel choices of the target market. The literature indicated that the new research trajectory is to attempt to incorporate activity-based modeling (ABA) into LUTI models (Acheampong & Silva, 2015); for example, how mobility dependent individuals such as children affect trip scheduling. According to Clarke (2014), though ABA models have been criticized as greatly oversimplifying reality, they would help to make in-roads particularly in a complex sector of the population such as the affordable housing market, who use unconventional means of survival, as the work of Mosselson (2017a) attests. ABA manages to capture the complexities inherent in urban processes (Acheampong & Silva, 2015). It was indicated that new directions in research, necessitate rigorous testing for further accuracy, causative investigations and policy-related linkages (Clarke, 2014). While these ideas fell beyond the scope of this research, the provided they next and necessary step of this work.

Acheampong & Silva, 2015 indicated that ABA sits in the realm of space-time geography and integrates aspects of human behavior modeling and economic choice theory (utility maximization). According to classical utility maximization theory, people select the most accessible residential locations to their workplaces to minimize commute costs, all things being equal (Acheampong & Silva, 2015). The literature showed that while residential choice location was initially thought to be a long-term decision, independent of employment location choice (Waddell 1993, Waddell et. al 2007 in Acheampong & Silva, 2015), more recent work indicates that “residential and job location choices as well as subsequent housing and job mobility decisions are jointly determined” (see Boschmann 2011, Habib, Miller, and Mans 2001, Kim, Pagliara and Preston 2005, Pinjari and Bhat 2011, Tilahun and Levinson 2013, Waddell et al. 2007, Yang, Zheng and Zhu, 2013 in Acheampong & Silva, 2015, p.17). This behaviour was reflected in Mosselson’s survey (2017b) of the Johannesburg CBD.

An element that was left out of the scope of this research was the concept of mobility. Mobility, specifically mobility in the form of transport costs is the second aspect of the transport component of land-use-transport interaction modeling (LUTI) (together with accessibility). Venter (2014, p.27) distinguishes between transport accessibility and transport mobility: “Mobility usually refers to the amount of travel undertaken, while accessibility captures a subtler notion of the ability to participate in activities, or the quality of access afforded by a land use-transport system”. From conducting an accessibility study across 27 former black-African Townships in South Africa, he conceptualised a four-quadrant model expressly to integrate the two aspects:

Figure 42 The Four Quadrants Defined by Accessibility and Mobility levels



Source: Venter 2014, p.32

For the affordable housing sector, good quality sites would fall in the lower right quadrant. Integrating the mobility aspect, there is a gap and opportunity to survey the target market, as with the Mosselson's work (2017a), Marchand (2015) and the PlanAct 5-Bad-Building case-study approach. Understanding the choice processes of poor urban households is necessary to refine the network analysis and bring it closer to reality, bringing about more realistic ARIA scores, service area sizes and shapes and perhaps even standard distance results.

There is also an opportunity also to test these results using network (rather than planar) methods with both Standard Distance and Kernel Density Estimation. Moreover, regarding KDE, other than calibrating it further to make the grid less grainy, KDE could be run for the entire city to see how the CBD currently compares as a service delivery hot-spot compared to the rest of the city.

Finally, this research has identified a need for a standard and stable classification of Metro ARIA scores into the five required groups, which is not dependent on sample size or the changing position of natural breaks in the data. This can also be empirically derived through field surveys, as expressed above. A properly calibrated classification that suits the local situation, and is stable.

5.4 Conclusion

The motivation for this research emanates from on-going efforts to address the housing backlog of 2.1 million units (Tomlinson, 2015) which South Africa has been battling, specifically within the social/affordable housing sphere (income earners of between R3500 and R7000 per month). The majority of this backlog lies in the Low-Income population bracket.

The chief intervention being used to address the housing backlog is the Republic of South Africa's Social Housing Act No. 16 of 2008, which provides for institutions and programs to supply Affordable Housing to Low-income groups through a system of Municipal Restructuring Capital Grants (RCG) and Subsidies. Over and above this, the legislation was also promulgated to redress the spatial fragmentation of cities, the dividend of South Africa's social-racial engineering experiment called apartheid. The literature pointed to a misalignment between this objective and resultant projects on the ground, with a preference for projects on the urban fringe where land is cheaper. Far from amenities for the very target group the legislation is intended to benefit (HDA Report, 2013). Moreover, the literature points to brownfield development or refurbishing and repurposing of existing buildings as one method of arresting urban degeneration (Meyer, 1998).

In realizing this anomaly, the City of Johannesburg, in its 2017/18 adjustment budget, increased the amount given to the Johannesburg Social Housing Company (JOSHCO) by R219 million for the purpose of purchasing buildings to be refurbished for Social Housing within the Inner City (Mashaba, 2017).

This is not a significant amount, judging from the overall budget. It calls for prudent fiscal decision-making regarding which properties to purchase. For this reason, the key objective of this research was to put forward a method to identify where amongst the possible sites within the Johannesburg to optimally locate social housing. The purpose is to contribute towards sound fiscal spending through rational decision-making and to contribute methodologies for implementation with existing housing policies and spatial planning efforts. Specifically those that are aimed at rejuvenating the Johannesburg CBD. Studies show that rising costs of living particularly impact low-income households, especially food and transport costs which take up a large portion of low-income households budgets (Ismail et al., 2016), (Battersby, 2011),(Peyton, Moseley, & Battersby, 2015). For this reason, a tweaking of the weightings was applied in this research to the Metro ARIA analysis, to reflect this reality of the South African urban poor.

As such, the research question was as follows:

> *"Where are the best potential sites for re-development for social housing in the Johannesburg CBD located?"*

The results are listed in table 43. The top 4 locations are:

			
73 Plein Street	Jeppe Street Building	204 Main Street Building	69 Joubert Street Building

Find interactive map here: https://www.google.co.za/maps/@-26.2024609,28.0381046,15z/data=!3m1!4b1!4m2!6m1!1s1m930KuqRHYnM7WqAvxBv-vTrQT0?hl=en

Incidentally, another rather dilapidated property opposite 73 Plein Street, 110 Plein Street, is on the market.

The objectives of the research, which have been attained, were as follows:

- To determine which properties have not been on the market in the last 3 decades and the current condition of such properties. All properties in the study area have been. Only those that exchanged hands once only were used;
- To identify potential buildings and sites for redevelopment to social housing from such sites. See table 43;
- To assess how far each potential site is from amenities and services or service clusters, that are required most by low-income populations. See Chapter 3;
- To identify the sites which are closest to most amenities as the best sites for re-development to social housing. See above graphic and table 43.

The HDA Report (2013) which was compiled to understand whether the RCG subsidies were being used in the right locations, showed that the CBD is by far the location of choice when it comes to proximity to amenities. This was confirmed by the findings of this research, using a triangulation of methods incorporating Metro ARIA, Service Area Size and Shape, Standard Distance and Kernel Density Estimation. The only anomaly was the results of the Standard Distance Analysis.

Taylor and Lange (2016) point to the significance of measures of accessibility for their ability to provide a measure of spatial inequality of resources. It is important in a policy context to link need with access, and in so doing be able to plan interventions they say.

A note from the researcher

Issues of social justice and equity are close to my heart. The housing and urban poverty issue is a particularly emotive one, as it touches on the seemingly inordinate homelessness one witnesses in the Johannesburg CBD daily. It is ironic that the CBD appears to be at the nexus of homelessness, 'bad' buildings and unequaled physical access to all parts of the city and the economic benefits it offers. That there should be a social solution that touches all these issues seems trite. Perhaps for me, it was timely that at the time this research was birthed, a new city government was coming into power. One that seems to have a heart for the very issues I lay here. Of particular importance was the reconfirming of the observation I held compiling this research, *that there can be a happy medium between all players and stakeholders in the CBD, where property values do not need to be impinged upon by dereliction, lawlessness and neglect, nor do the urban poor need to be excluded from these spaces*. I believe the role of local government in this scenario is crucial to almost 'force' an accommodation of social imperatives in the unfolding betterment of the city, and to resist the displacing mechanism of 'glocal' capital, for the sake of urban poor South Africans. I believe we are in a day where our local government is finally taking this role to heart.

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Appendix

1. First-Cut Selection of Redevelopment Sites before Hierarchical Nearest Neighbour Analysis

ID	Address	Y	X	Note
199	102a Albert St	-26.207905	28.051762	Dilapidated/ abandoned commercial
210	204 Main Street	-26.205412	28.053814	Dilapidated/ abandoned commercial
212	31 Nugget street	-26.205835	28.053122	Dilapidated/ abandoned
213	204-206a Main St	-26.20546	28.053766	Dilapidated/ abandoned commercial
214	204-206b Main St	-26.20546	28.053766	Dilapidated/ abandoned commercial
267	39 Nugget St	-26.204977	28.05282	Dilapidated/ abandoned: Another fire-tragedy. The homeless were living here.
221	60 End St	-26.202456	28.054011	Dilapidated/ abandoned: This building is being utilised as business premises.
225	18 Moseley St	-26.200508	28.055225	Dilapidated/ abandoned
228	7 Moseley St	-26.200697	28.054211	Dilapidated/ abandoned
232	35 Siemert Rd	-26.198632	28.055973	Dilapidated/ abandoned commercial
234	1Aii Nind St	-26.1968791	28.0556434	Dilapidated/ abandoned commercial
239	33 Height St	-26.195782	28.055372	Dilapidated/ abandoned
240	17-39 Buxton St	-26.196487	28.054853	Dilapidated/ abandoned: Vagrancy outside Doornfontein Station
256	208a Marshall St	-26.206438	28.052891	Dilapidated/ abandoned: Vagrancy in the municipal open space along Nugget Street
264	198 R29, City and Suburban	-26.206427	28.052038	Dilapidated/ abandoned in construction
277	43 Marshall St	-26.206394	28.051201	Dilapidated/ abandoned commercial
278	208 Commissioner St	-26.204369	28.052332	Dilapidated/ abandoned commercial
288	217 Commissioner St	-26.204044	28.053778	Dilapidated/ abandoned commercial: This building is being utilised as business/storage facilities.
292	61 Nugget St	-26.202667	28.052479	Dilapidated/ abandoned burnt down retail. Further only this street is Transistor House - re-built. There is some prositution here as well.
313	83 Nugget St	-26.200636	28.052079	Dilapidated/ abandoned. This is the Cape York building that burnt down during winter (Shange N., 2017, Jul 06; Moagi C., 2017, Jul 10).
320	7 Claim St	-26.199175	28.050495	Dilapidated. For Sale
325	73 Plein St	-26.199051	28.050512	Dilapidated/ abandoned
326	122 Goud St	-26.200033	28.051498	Dilapidated. To Let
336	208b Marshall St	-26.206409	28.052689	Dilapidated/ abandoned
348	39 Mooi St	-26.206949	28.051315	Dilapidated/ abandoned commercial building
349	40 Mooi St	-26.206978	28.05135	Dilapidated/ abandoned commercial building
363	Cnr. West, 25 Commissioner St	-26.206555	28.034037	Dilapidated/ abandoned commercial
378	19b Marshall St	-26.208431	28.034019	Dilapidated/ abandoned
384	18b Miriam Makeba St	-26.206451	28.033854	Dilapidated/ abandoned
394	41 Rissik St	-26.20504	28.042126	Dilapidated commercial. In construction
403	69 Joubert St	-26.200899	28.042564	Dilapidated/ abandoned.
406	36 Pixley Ka Seme St	-26.205643	28.038418	Dilapidated/ abandoned in construction. A government building caught in a controversial protest. This building together with a few others around the same block.
421	124 Marshall St	-26.207465	28.043557	Dilapidated/ abandoned.
424	62 Frederick St	-26.208391	28.042778	Dilapidated/ abandoned.
398	143 Jeppe St	-26.204268	28.0446	Dilapidated/ abandoned. Another of the buildings hi-jacked and evacuated by the city (eNCA, 2017, Jul 20).
455	48 Simmonds St	-26.203728	28.039557	Dilapidated/ abandoned. Part of the planned government precinct
461	101b President St	-26.203794	28.04331	Dilapidated/ abandoned.
462	138 Jeppe St	-26.201929	28.0413	Old, informally occupied.Fattis Mansions (dubbed "mnyamandowo") the day after the evacuation (eNCA 2017, Jul 20; Modise K., 2017, Jul 25).

2. Final Selection of Redevelopment Sites after Hierarchical Nearest Neighbour Analysis

FID	ID	MAP	ADDRESS	XCoord	YCoord
0	199	Dilapidated/ abandoned	102a Albert St	28.051762	-26.207905
1	221	Dilapidated/ abandoned	60 End St	28.054011	-26.202456
2	232	Dilapidated/ abandoned	35 Siemert Rd	28.055973	-26.198632
3	278	Dilapidated/ abandoned	208 Commissioner St	28.052332	-26.204369
4	288	Dilapidated/ abandoned	217 Commissioner St	28.053778	-26.204044
5	292	Dilapidated/ abandoned	61 Nugget St	28.052479	-26.202667
6	378	Dilapidated/ abandoned	19b Marshall St	28.034019	-26.208431
7	394	Dilapidated/ abandoned	41 Rissik St	28.042126	-26.20504
8	403	Dilapidated/ abandoned	69 Joubert St	28.042564	-26.200899
9	406	Dilapidated/ abandoned	36 Pixley Ka Seme St	28.038418	-26.205643
10	421	Dilapidated/ abandoned	124 Marshall St	28.043557	-26.207465
11	424	Dilapidated/ abandoned	62 Frederick St	28.042778	-26.208391
12	398	Dilapidated/ abandoned	143 Jeppe St	28.0446	-26.204268
13	455	Dilapidated/ abandoned	48 Simmonds St	28.039557	-26.203728
14	461	Dilapidated/ abandoned	101b President St	28.04331	-26.203794
15	462	Dilapidated/ abandoned	138 Jeppe St	28.0413	-26.201929
16	778	Dilapidated/ abandoned	Marshall St	28.0327642	-26.2088542
17	325	Dilapidated/ abandoned	73 Plein Street	28.050512	-26.199051
18	326	Dilapidated/ abandoned	Jeppe Street	28.051824	-26.200368
19	228	Dilapidated/ abandoned	Mosely Street	28.054722	-26.200604
20	384	Dilapidated/ abandoned	Miriam Makeba St	28.033969	-26.20652
21	210	Dilapidated/ abandoned	204 Main Street	28.0531109	-26.20566581
22	384	Dilapidated/ abandoned	City and Suburban	28.0515219	-26.20660528
23	239	Dilapidated/ abandoned	33 Height St	28.05528933	-26.19638267

3. Statistics for the Run of the Nearest Neighbour Analysis for Amalgamating Sites

```
Nearest Neighbor Hierarchical Clustering:
-----------------------------------------

    Sample size..................: 39
    Likelihood of grouping
      pair of points by chance...: 0.50000 (50.000%)
    Z-value for confidence
      interval...................: 0.000
    Measurement type.............: Direct
    Output units.................: Meters, Square Meters, Points per Square Meters
    Standard Deviations .........: 1.0
    Clusters found...............: 9
    Simulation runs..............: 0
    Start time.............: 11:52:45 AM, 09/23/2017
    End time...............: 11:52:47 AM, 09/23/2017

    Displaying 9 ellipse(s) starting from 1
```

Order	Cluster	Mean X	Mean Y	Rotation	X-Axis	Y-Axis	Area	Points	Density
1	1	28.05327	-26.20571	33.70321	60.26009	105.48747	19970.11480	7	0.000351
1	2	28.05148	-26.20669	49.60348	49.26729	75.29316	11653.70719	4	0.000343
1	3	28.05176	-26.20791	0.00000	160.93440	160.93440	81366.87741	1	0.000012
1	4	28.05529	-26.19638	79.04494	124.94318	77.87782	30568.64707	3	0.000098
1	5	28.05472	-26.20060	78.26465	160.93440	73.02223	36919.33231	2	0.000054
1	6	28.05233	-26.20437	0.00000	160.93440	160.93440	81366.87741	1	0.000012
1	7	28.05179	-26.20033	49.15590	62.63838	160.93440	31669.36128	2	0.000063
1	8	28.05050	-26.19911	7.01285	160.93440	9.81772	4963.74393	2	0.000403
1	9	28.03395	-26.20650	32.35079	15.27301	160.93440	7721.88485	2	0.000259

4. Statistics for the Run of the Kernel Density Estimation Analysis

```
Kernel Density Estimate:
------------------------

    Probability function...: Quartic
    Reference points.......: 8600
    Incident points........: 5240
    Measurement type.......: Direct
    Type of calculation....: Absolute Densities
    Start time.............: 06:29:44 PM, 09/14/2017
    End time...............: 06:30:03 PM, 09/14/2017

    Displaying 45 estimates(s) starting from 1
```

Location	Absolute Densities	Scientific
00001	0.3556387287	3.556387e-001
00002	0.3766901970	3.766902e-001
00003	0.4180015051	4.180015e-001
00004	0.4370387863	4.370388e-001
00005	0.4240788111	4.240788e-001
00006	0.4030266320	4.030266e-001
00007	0.3762053768	3.762054e-001
00008	0.3357643314	3.357643e-001
00009	0.3127352548	3.127353e-001
00010	0.2855135710	2.855136e-001
00011	0.2487343943	2.487344e-001
00012	0.2163720163	2.163720e-001
00013	0.1902150560	1.902151e-001
00014	0.1666896303	1.666896e-001
00015	0.1450604416	1.450604e-001
00016	0.1243914427	1.243914e-001
00017	0.1087252635	1.087253e-001
00018	0.0876573522	8.765735e-002
00019	0.0732264408	7.322644e-002
00020	0.0671368863	6.713689e-002
00021	0.0644087122	6.440871e-002
00022	0.0640861151	6.408612e-002
00023	0.0605551603	6.055516e-002
00024	0.0589222722	5.892227e-002
00025	0.0635804594	6.358046e-002
00026	0.0726929115	7.269291e-002
00027	0.0734119807	7.341198e-002
00028	0.0776218573	7.762186e-002
00029	0.0784872078	7.848721e-002
00030	0.0794850464	7.948505e-002
00031	0.0806180675	8.061807e-002
00032	0.0834343523	8.343435e-002
00033	0.0844830276	8.448303e-002
00034	0.0855640941	8.556409e-002
00035	0.0866213343	8.662133e-002
00036	0.0877802425	8.778024e-002
00037	0.0892120605	8.921206e-002
00038	0.0858783600	8.587836e-002
00039	0.0869185800	8.691858e-002

5. Model: Generating Standard Deviational Ellipses for Re-development Sites