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IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Identifying ‘Transit Deserts’ in a South African City – The Case of Cape Town

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Abstract

This dissertation defines and describes the concept of ‘transit deserts’, and the important role public transport plays in the lives of people who have few or no other alternatives. Transit deserts are defined as areas containing large portions of public transport dependent populations with limited access to private vehicles where the level of mass public transport does not adequately service the need of the populations in question (Jiao and Dillivan, 2013). The methodology to identify transit deserts (Jiao and Dillivan, 2013; Jiao, 2017) is tested in this study within a South African context, i.e. Cape Town. Since all available literature on measuring transit deserts was generated in the United States, a clearly defined *modus operandi* was established. Therefore, this dissertation aimed to modify and adapt the existing method to the Cape Town context. An explanation to how certain details related to the existing method were changed to be applicable to a South African city is provided in this study. The modified method involved identifying the public transport dependent population as a measure of public transport need, calculating the supply of public transport, and then measuring the gap between the need and the supply. This study will find that transit deserts exist in Cape Town and are spatially located on the outskirts of the metropolitan, in suburban and rural portions of the city. Transit gaps are also identified in previously marginalised areas known as the Cape Flats. Significantly, this study revealed the need for Cape Town to gather comprehensive transportation network data that is up-to-date and publicly available. This recommendation would allow for a more effective analysis of public transport need and supply in order to report on the location of transit deserts more accurately.

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Robert James Cameron

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Glossary

Built Environment: The area created by humans to be used for human activity, including buildings, housing, urban spaces, and transportation systems. Nature reserves and protected areas are excluded.

Isochrones: Walk distance polygons which show the area reachable from a given location within a distance limit, assuming the public transport users is constrained to the road network.

Public transport dependent population: Individuals who have no other option available to them. Reasons for public transport captivity are not having access to a private vehicle, driver's license ownership, and age.

List of Symbols and Acronyms

BRT	Bus Rapid Transit
CBD	Central Business District
CoCT	City of Cape Town
CR _A	U.S. Carpooling ratio
CR _B	Cape Town carpooling ratio
DoT	Department of Transportation
GIS	Geographic Information System
HH _A	Household drivers
HH _B	Eligible household drivers
HH _C	Ineligible household drivers
ITP	Integrated Transport Plan
NBER	National Bureau of Economic Research
NHTS	National Household Travel Survey
NP _A	Persons living in group quarters
NP _B	Non-institutionalised population living in group quarters
N _Z	Need z-score
P _A	Population age 16 and over
P _B	Population ages 12-15
P _C	Population age 18 and over
P _D	Population ages 12-17
PTI	Public Transport Interchange
S _Z	Supply z-score
TAZ	Travel Analysis Zone
TDA	Transport Development Authority
TDHP	Public Transport Dependent Household Population
TDP	Public Transport Dependent Population
TG	Transit Gap
TOD	Transit Orientated Development
V	Vehicles available

1. INTRODUCTION

1.1 Motivation for Study

Being able to get into a car and drive yourself around is a luxury not everyone can afford. This may be due to not owning a car or perhaps not having enough money to pay for fuel. Either way, travellers are left with few choices but to consider public transport. In Cape Town, 38% of morning peak trips are made by public transport, of which 95% are made by users which fall in the low to low-middle income brackets (Transport and Urban Development Authority, 2017). The greatest disconcert is that most public transport users are located in peripheral areas of the city, a considerable distance from viable economic opportunities. These circumstances seem to resonate with recent studies on ‘Transit Deserts’ (transit deserts) within urban areas. Jiao and Dillivan (2013:24) defines transit deserts as “areas containing a large constituent of transit-dependent populations with limited automobile access, where the level of mass transit service (supply) does not adequately service these populations (demand)”. Their research on transit deserts demonstrated a way to help authorities better plan urban public transport systems to serve those who depend on it most.

Questions that arise are: Do transit deserts exist in Cape Town? If so, where are they located? If found to be located in economically or socially disadvantaged neighbourhoods, the probability of this population moving is small. This is based on the findings of Bischak and Jiao (2018) where, on average, people living in low-income neighbourhoods that have poor access to public transport are often incapable of escaping poverty because of this shortcoming. Research conducted for the National Bureau of Economic Research (NBER), by Stanford and Harvard Universities, reported that access to public transport is the single most important factor in achieving upward social mobility¹ (Chetty and Hendren, 2017). The findings of their study showed that a neighbourhood has significant childhood exposure effects on children’s life outcomes and that their economic opportunities are shaped by the type of neighbourhood they grow up in (Chetty and Hendren, 2017:1). Bischak and Jiao (2018) observe this as a negative economic feedback loop where poor access to public transport feeds unemployment, since finding and more importantly retaining a good job requires a reliable mode of transport.

¹ The capacity or facility for rising to a higher social or economic position (Merriam-webster, 2018).

In the case of South Africa, and in particular Cape Town, there continues to be a significant degree of spatial division of the city into zones of relative advantage and disadvantage. Today, this division is increasingly being defined in terms of the categories of socio-economic status rather than those of ethnicity, which predominated in the apartheid era (Wilkinson 2004: 221). Whilst recent years have seen the Transport and Urban Development Authority (TDA) address disparities, through the provision of integrated opportunities and the development of economic inclusion strategies (Transport and Urban Development Authority, 2017) further research is required to analyse both the public transportation system and the people who depend on it most.

The following section is a brief background of this study, which indicates the root of the problem being investigated, as well as the appropriate context of the problem in relation to theory and practice. Thereafter, the overall aim of the study is specified with the objectives required to achieve this aim. This Chapter concludes with a description of the study area and how the rest of the dissertation will be organised.

1.2 Background of Study

The research problem investigated in this study stems from the Apartheid era planning. The geodemographic method of planning, embodied within the Group Areas Act of 1950, produced certain social and economic processes that have shaped how large South African cities work today². For instance, Cape Town exhibits patterns of disparate urban development where low-income, captive public transport users are located a considerable distance from the commercial and business centre of the city (Wilkinson, 2006). The inner urban areas of Cape Town, as well as certain exurbs, tend to be well served by public transport and are characterised by mixed-use residential and commercial development. However, the city is essentially automobile orientated and mainly suited for middle to high-income communities with private transport who access even local destinations by car³.

With the TDA leaning towards equity-based planning in the future (Transport and Urban Development Authority, 2014) public transport needs to be continuously available for all,

² Group Areas Act was the title of three acts which divided racial groups according to regions on a geographical basis. The enacted ruling restricted non-Whites to different business and residential urban areas than Whites (Mabin, 1992).

³ Private transport makes up 53% of the modal split, with 95% car ownership in middle to high-income communities (Transport and Urban Development Authority, 2017)

especially people in need who require it to gain access to basic necessities of life such as employment and education (Krumholz, 1982; Garrett and Taylor, 1999). Within this context, research on transit deserts in South Africa becomes relevant in relation to both theory and practice.

1.3 Overall Aim of Study

The aim of this research is to obtain a method for calculating and quantifying transit deserts, which can be used for any location in South Africa. This methodology is derived from Jiao and Dillivan (2013) and Jiao (2017) in their studies of transit deserts in the United States (U.S.). Their methodology will throughout this research be referred to as the existing method. The existing method will, therefore, need to be adapted in this study, and used to perform a quantitative analysis of public transport supply and need to show where public transport gaps exist towards identifying possible transit deserts. This adapted method will be referred to as the modified method in this study.

1.4 Objectives of Study

In order to meet the overall aim of the study, the following tasks will be performed in this dissertation:

- Scrutinize the existing method and modify it to be applicable to a South African city;
- Address the limitations set out by previous studies and find ways to improve it;
- Apply the modified method to Cape Town;
- Determine if there are areas where the level of public transport supply does not adequately serve the need (gap analysis); and
- Report on the location of possible transit deserts.

1.5 Study Area

The study area is the City of Cape Town (CoCT) Metropolitan Municipality, which stretches from Gordon's Bay to Atlantis and includes the suburbs of Khayelitsha and Mitchells Plain. The 2013 National Household Travel Survey (NHTS) disaggregated Cape Town into units of geography known as Traffic Analysis Zones (TAZs). The 18 TAZs that were determined by the NHTS will herein be defined as analysis zones. Figure 1-1 shows the built environment and protected areas of Cape Town with analysis zones. The purpose of this map is to give a general indication of how Cape Town's population may be geographically distributed across

each analysis zone. Evidently, nature reserves and protected areas, such as the Table Mountain National Park and the Steenbras Nature Reserve, cover large parts of the study area.

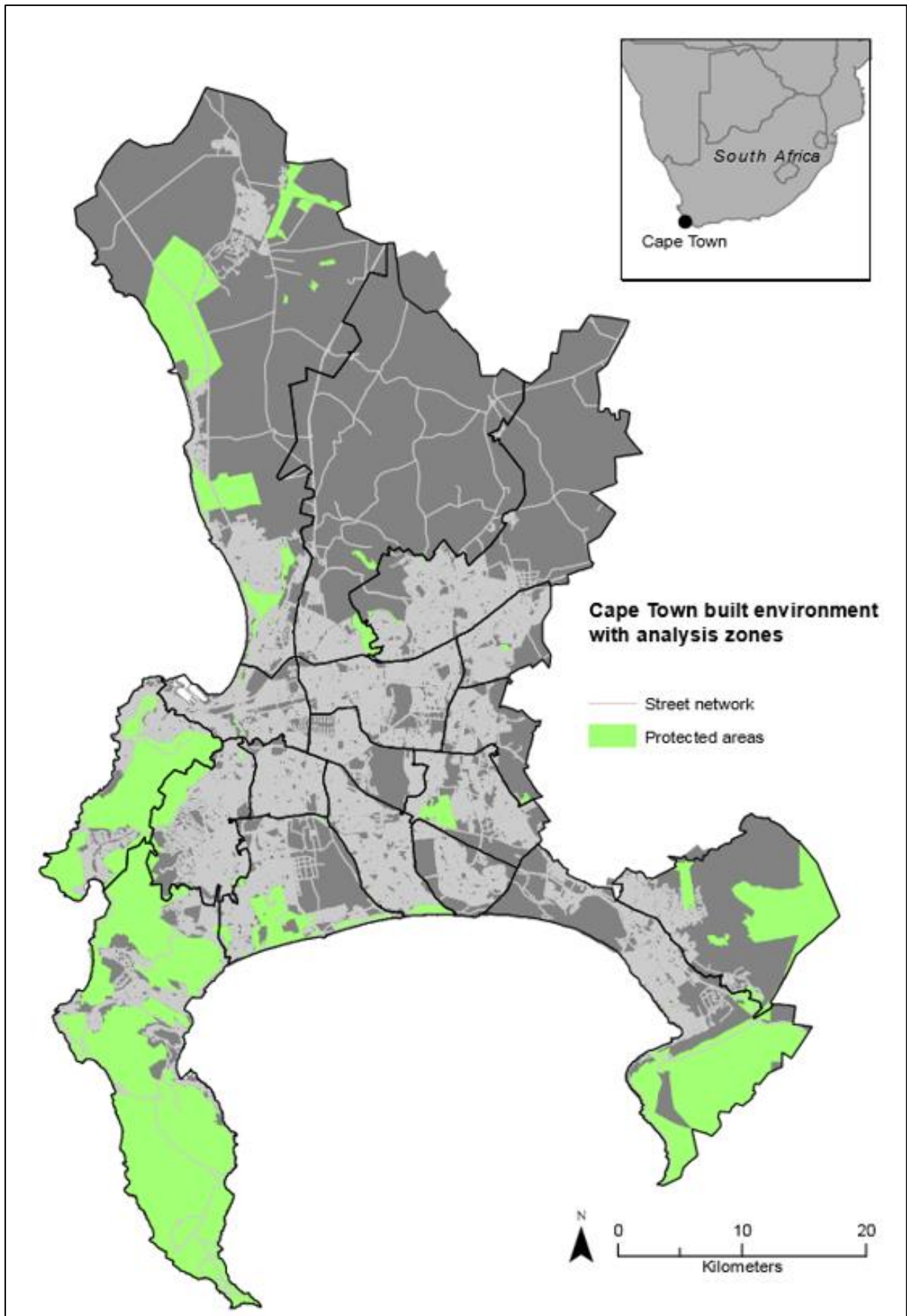


Figure 1-1: Map of Cape Town Showing Built Environment and Protected Areas

1.6 Organisation of Dissertation

Henceforth, this dissertation will be divided into five chapters. Chapter Two describes the literature on transit deserts and provides a critical evaluation of the key elements related to the area of research. This Chapter (2) also provides a brief description of how this research fits within a larger field of study. Chapter Three describes the research methods and the measurement approach adopted in this study. Chapter Four delineates the results obtained from the measurement process. Exploratory analysis of the data is also performed in this Chapter while Chapter Five analyses transit deserts and discusses the findings. Lastly, Chapter Six draws up the conclusions and reports on the implications of the findings with recommendations for future research.

2. LITERATURE REVIEW

Chapter Two is broken down into conceptual categories to explore the nature of transit deserts, its origins and the methodology used to measure and identify transit gaps. The first part traces the intellectual progression of the concept and introduces the most pertinent research conducted. Then the topic under consideration is elaborated on further by examining the characteristics of a transit desert. This is followed by a section on the existing method, which will eventually be modified at a later stage in this study. This Chapter also attempts to contrast and critique the measurement process by weighing in on seemingly contradictory previous studies. Lastly, two cities in the U.S. where transit desert analysis was conducted are used as example case studies.

2.1 Emergence of the Transit Desert Concept

During the 1990's, a series of policy debates in the United Kingdom deliberated on the issue of social exclusion and how it related to people living with poor access to high-quality food (Clark et al., 2002; Wrigley et al., 2002). What followed was the development and implementation of a model which measured the level of food provision in terms of shopping flows and patterns. Geographic Information Systems (GIS) were used to map areas within an urban environment with inadequate access to healthy and affordable food. These areas became known as 'Food Deserts' (food deserts) (Whelan et al., 2002).

The transit desert concept was closely influenced by the food desert discourse. The term was first used in 2007 by Professor David Hulchanski of the University of Toronto in his Three Cities Report. The report referred to Toronto's inner suburbs as transit deserts, being underserved by the public transport system, and suggested light-rail as a potential policy intervention for low-income households (Martin Prosperity Institute, 2011). Jiao and Dillivan (2013:23) of the University of Texas at Austin, later defined transit deserts as "areas that lack adequate public transit service given areas containing populations that are deemed transit-dependent". Their study aimed to analyse and establish a simple method for measuring gaps between public transport demand and supply using GIS. Their method was later applied in a study of five major cities in Texas to identify neighbourhoods that might need more attention regarding transportation access and planning (Jiao, 2017). The approach used by Jiao and Dillivan (2013) did not exist in any prior research and was the first attempt to "evaluate public transport systems based on gaps between demand and supply in a spatial context". Both the food deserts and the transit deserts have driven many American citizens into poverty through

narrowing of access to quality food and transportation (Allan, 2014:4). The rest of the literature review will focus on the topic of this research thesis by first discussing the characteristics a typical transit desert may exhibit.

2.2 Characteristics of a Transit Desert

Transit deserts are usually found in outer-urban areas in neighbourhoods that have historically experienced either minimal development or some sort of economic or demographic shift. An example of this would be urban revitalisation projects where heavily dependent public transport users are relocated to areas with decreased public transport availability. These areas tend to be more automobile orientated with an urban form not as conducive to public transportation. In addition to this, the communities staying in such areas often provide opposition to the implementation and use of public transport and tend to share certain negative assumptions. These negative assumptions may include:

- The cost (capital, operating or maintenance) associated with expanding or building a public transport system would create unnecessary tax expenditure.
- Public transport is associated with criminal activity.
- The quality of life within neighbourhoods would deteriorate, due to noise and air pollution.
- Linking public transport with the negative perception of the 'inner-city' living and that public transport will bring the negative aspects of urban culture and city life into their neighbourhoods.
- These perceived negative effects would culminate and eventually cause property values to decrease (Allen, 2014:5).

Allen (2014:6) suggests that the characteristics that are unique to transit deserts can be derived from three broad categories, namely neighbourhood form and physiography, the time spent and the ease of accessing public transport, and the demographics of users. In terms of neighbourhood form and physiography, transit deserts have an automobile orientated design with street patterns, generally, laid out in curving or irregular grid patterns. These areas have limited land-use diversity and a population density which is usually too low to achieve effective ridership levels. Furthermore, there are multiple difficulties and inefficiencies associated with the time spent and the ease of accessing public transport in a transit desert. Public transport stops are usually located on arterials, which means residents have to travel a

considerable distance to access the service. This significantly increases their overall trip time, as residents often spend as much time walking as waiting for public transport.

Demographics include the people who engage in public transport and the overall perception of public transport users by others. The differences in economic classes is often perpetuated in the method of travelling, whereas bus commuters are often less affluent than riders of light rail (Allen, 2014; Bernstein et al., 2013; Weitz, 2008). Nonetheless, lack of or inadequate service in more affluent neighbourhoods, where the assumption is that everyone is driving a car, may be misguided; just as the inadequate access to light rail or other special services in less affluent areas is inequitable (Allen, 2014). Neighbourhoods that are identified as transit deserts may have any number of these unique characteristics associated with them. Whether transit deserts exist in South Africa and whether they should share similar traits and characteristics than in other part of the world is an interesting topic which will be addressed at a later stage.

2.3 Measuring Transit Gaps

This section examines the existing method created by Jiao and Dillivan (2013) and refined by Jiao (2017), respectively. It also serves as an opportunity to critique the measurement process and identify potential shortcomings in order to address such issues for the sake of improvement.

2.3.1. Calculating the Transit-Dependent Population

Public transport demand was calculated using the 2012 American Community Survey⁴ (Jiao and Dillivan, 2013). Initially, the number of persons in households that are of driving age were derived by subtracting the group quarters population⁵ from the total population age 16

⁴ The American Community Survey measures the changing economic and social characteristics of the U.S. population on an annual basis. This survey is sent to a specific percentage of the population on a rotating basis throughout the decade, while ensuring that households do not receive it more than once every five years (Shays, 2010).

⁵ The group quarters and non-institutionalised populations living in group quarters is defined by the U.S. Census Bureau as “a place where people live or stay, in a group living arrangement, that is owned or managed by an entity or organisation providing housing or services for the residents” (US Census Bureau, 2010:1). Examples of institutional group quarters include hospitals for the mentally or chronically ill, nursing homes, hospices or

and over. It was assumed that persons staying in group quarters are eligible to drive; see formula (2.1).

$$HH_A = P_A - NP_A \quad (2.1)$$

Where:

HH_A = Household drivers

P_A = Population age 16 and over

NP_A = Persons living in group quarters

From this concept, formula (2.2) and (2.3) were employed to eventually determine the public transport dependent population.

$$TDHP = HH_A - V \times CR_A \quad (2.2)$$

Where:

$TDHP$ = Transit Dependent Household Population

HH_A = Household drivers

V = Vehicles available

CR_A = U.S. Carpooling ratio⁶

$$TDP = TDHP + P_B + NP_B \quad (2.3)$$

Where:

TDP = Transit Dependent Population

$TDHP$ = Transit Dependent Household Population

P_B = Population ages 12-15

NP_B = Non-institutionalised population living in group quarters

Inherently, the formulae attempt to identify areas where captive public transport users reside and where the reason for the dependency is a limited number of vehicles available (Steiss,

prison wards. Examples of noninstitutionalised groups include university residences, group homes, military barracks, shelters, missions or flophouses.

⁶ The national level carpooling ratio was determined by the U.S. Census Bureau and was calculated using the 2012 American Community Survey (McKenzie, 2015).

2010). Except for age, any other reasons why individuals might be dependent on public transport is disregarded i.e. income, disability or any other personal circumstances are not accounted for. According to Jiao and Dillivan (2013), this is done to avoid double-counting, as census data related to public transport dependent groups often overlap. On a fundamental level, the areas which display the largest difference between vehicle drivers and vehicles available have a higher probability of being dependent on public transport than areas that have an equal ratio of vehicle drivers and vehicles available. This is intended as a more basic method of determining the demand for public transport regardless of an individual's constraints.

The researchers recognised that census data related to the availability of automobiles were not publicly obtainable at the block group level⁷. Consequently, the data first needed to be collected at the census tract level and then proportionally estimated at the block group level. This estimation was based on the individual size of census tracts and block groups. The results produced a couple of cases where the value for the public transport dependent population was zero. This due to certain block groups having more vehicles available, than household drivers. These anomalies were dealt with by adjusting the public transport dependent population to zero.

The researchers then calculated the public transport dependent population density per block group by dividing the public transport dependent population by the size of each block group. z-scores were then calculated to standardise the results (Jiao and Dillivan, 2013; Jiao, 2017). Finally, the data was then joined with GIS shapefiles to spatially display the demand at the block group level⁸.

2.3.2. Calculating Transit Supply

To calculate supply, geospatial data for predetermined criteria was joined with block group shapefiles. Each criterion was measured at the block group level, divided by acres to get a density value and then standardised by calculating a z-score value. Finally, the z-scores were added together to equate the level of public transport supply for each block group. The criteria used by Jiao and Dillivan (2013) was slightly different to what was used by Jiao (2017). The former, Jiao and Dillivan (2013), selected the following criteria to represent supply;

⁷ The actual public transport gap was measured at the block group level. On average a block group may contain between 600 and 3000 people and constitute roughly 40 census blocks (Caliper, 2018).

1. the number of rail and bus stops in each block group;
2. the frequency of service for each bus and rail stop per day in each block group (average weekday service);
3. the number of routes in each block group; and
4. the length of bike routes and sidewalks in each block group (miles).

Whilst the latter, Jiao (2017), included the four previously mentioned criteria, as well as;

5. the total length of low-speed limit roads in each block group (miles); and
6. the intersection density in each block group.

In addition to these changes, Jiao (2017) modified the first four criteria to account for all relevant modes of public transport (not only rail and bus). The author of this thesis agrees with the inclusion of the additional criteria as this addresses the physical presence of public transport and accessibility⁹. The effectiveness of having a number of public transport facilities or a frequent service diminishes when it becomes difficult to gain access. Finally, the difference between demand and supply z-scores were computed and a final numerical value was calculated for each block group to determine a surplus or shortage of supply (Jiao and Dillivan, 2013; Jiao, 2017).

$$TG = S_z - D_z \quad (2.4)$$

Where:

TG = Transit Gap

S_z = Supply z-score

D_z = Demand z-score

2.3.3. Critique of the Measurement Process

The available literature on transit deserts defines the public transport dependent population as the demand. The methodology states that “the demand was derived from a formula, which measured the transit-dependent population per block group” (Jiao, 2017:530). This population included people that are of driving age but don’t have access to a car, people between the ages

⁹ Accessibility being used in the same context as (Litman, 2017:6) and defined as the physical access to goods, services and destinations.

of 12 and 15 that are too young to drive but are able to use public transport safely and responsibly, and the non-institutionalised population living in group quarters. The author of this thesis suggests that this is an inaccurate representation of demand for the following reason. “A demand is an indication that a public transport service if it were provided, would achieve high ridership” Walker (2018a:1). This definition fails to coincide with the terminology used in the literature, as high ridership levels cannot be guaranteed.

A more suitable definition would be a public transport need, which translates as “people whose lives would be better if they had public transport” as suggested by Walker (2018a:1). These terms are in accord with the two conflicting goals of a public transport service. The goal may be to provide a service with the objective of having high ridership, to this extent exceptional service needs to be provided where there is a demand. However, if authorities only focus on providing a high-ridership service not everyone would be served. To accommodate people that need public transport, a certain amount of service is provided to achieve the non-ridership goal of coverage. This objective usually becomes necessary and important when either (a) people start feeling entitled to receive a service as they also pay taxes or (b) if people are in dire need of a service. Although the outcome of this argument does not lead to the type of service where ridership is desired, it remains to be a justifiable government purpose (Walker, 2015). Henceforth, this study will refer to demand as the public transport need.

The literature on alternate public transport planning methods were also reviewed¹⁰. Consequently, it was determined that transit desert analysis is the most suitable method for addressing this study’s research problem, as alternate methods are based on complicated network modelling. As a strength, transit desert research follows a straightforward GIS method which measures public transport need and supply with relative ease.

2.4 Transit Deserts Analysis

The purpose of the following section is to examine the results obtained from previous studies. Two cases from the literature will be analysed to show how their findings were presented and interpreted. Charlotte, North Carolina was one of the cities analysed by Jiao and Dillivan (2013) in their early research of transit deserts. Then, as part of a more recent study Jiao

¹⁰ See for instance, Nayeem et al., 2014; Nikolić and Teodorović, 2013 and Schöbel, 2011.

(2017) analysed San Antonio, Texas. This section also highlights some of the important contributions made by their research.

2.4.1 Case of Charlotte, North Carolina

In 2013, Professor Junfeng Jiao of the University of Texas at Austin attempted to create a method for calculating and quantifying the supply of transportation service that can be used for any location. In his paper, ‘Transit Deserts: The Gap between Demand and Supply’, Jiao looked at four major cities: Charlotte, North Carolina; Chicago, Illinois; Cincinnati, Ohio; and Portland, Oregon. In all four cases, public transportation was relatively well developed, allowing dependent populations to be fairly well-served. Nonetheless, their results determined that transit deserts do exist and most often occur in neighbourhoods surrounding the city’s historic core or central business district and in isolated rural areas. Figure 2-1 illustrates transit desert analysis in Charlotte, showing maps of demand, supply and gaps (the darker the shading the greater the gap).

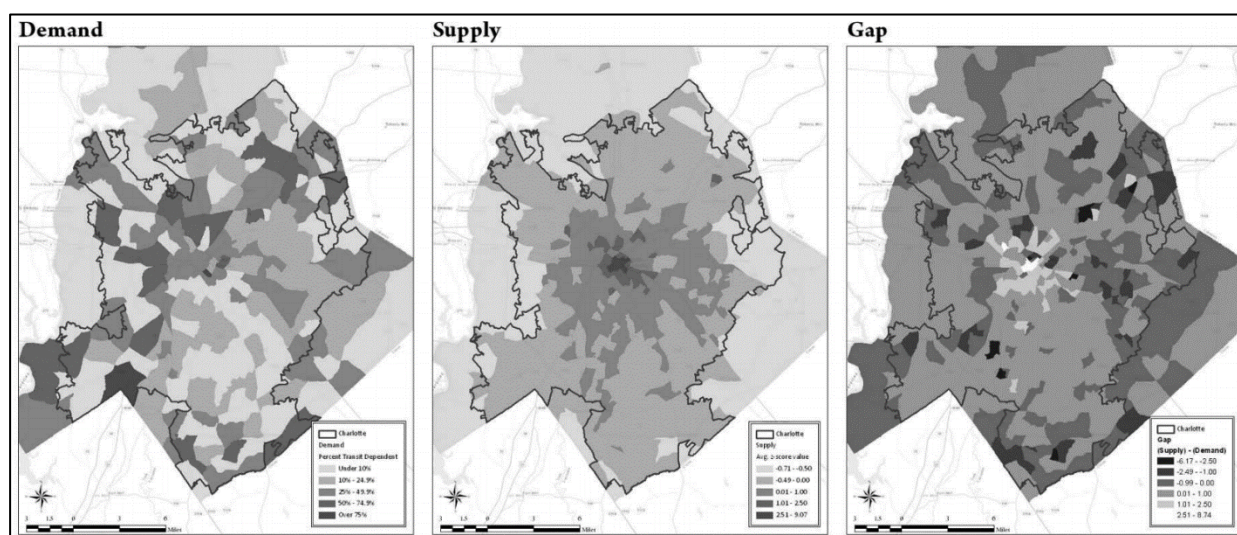


Figure 2-1: Transit Desert Analysis in Charlotte, North Carolina

Data Source: Jiao and Dillivan (2013:31)

The supply map follows a logical pattern, showing a high concentration in the city centre, which gradually decreases with distance. The maps show that there aren’t many block groups with demand outweighing supply with most public transport dependent populations being found in suburban portions of the city. Due to the majority of Charlotte’s population and area growth occurring during the 1950s, large parts of the city are automobile-oriented, leaving the much of the outer-urban areas to be developed at a low density. Overall, the maps turn the focus to neighbourhoods in Charlotte whose public transport needs are being overlooked. In

terms of transportation planning, this will be useful when it comes to discussing the location of new routes and stops as well as how much service certain areas should receive.

2.4.2 Case of San Antonio, Texas

The second study undertaken by Professor Junfeng Jiao, titled ‘Identifying transit deserts in major Texas cities where the supplies missed the demands’, looked at five major Texas cities (Austin, Dallas, Fort Worth, Houston, and San Antonio). This research also identified transit deserts in the urban areas of all five cities, managing to “highlight areas that might require more attention in regard to transportation access and planning” Jiao (2017:530). In terms of supply, the cities followed predictable patterns, with a high concentration of public transport services occurring in and around the city centre with decreasing services as the distance from the centre increases. Furthermore, it was found that public transport dependent population are scattered sporadically throughout each of the cities, without any record of being located in the central part of a city. Figure 2-2 shows transit deserts analysis in San Antonio, Texas. This graphic representation shows portions of the city where gaps exist, where there is either “an excess of service given the demand of the residents in that particular area or where the supply of transit services does not meet the demands of the residents in these areas” (Jiao and Dillivan, 2013:26).

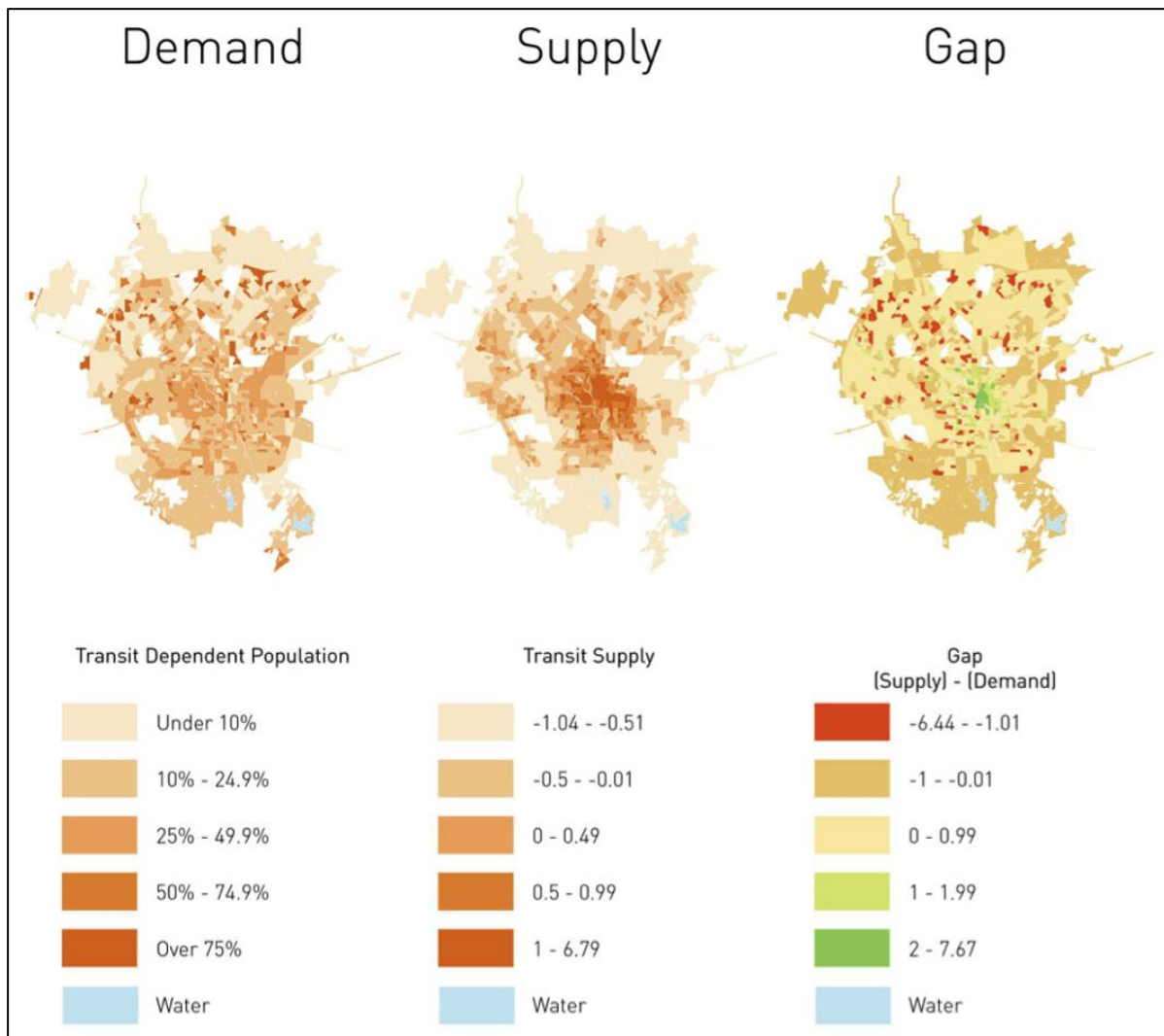


Figure 2-2: Transit Desert Analysis in San Antonio, Texas

Data Source: Jiao (2017:536)

San Antonio had the second highest public transport dependent population with approximately 334 530 people (following Houston with 839 284 people). However, mainly due to it being the only city without a rail service it was identified as having the highest number of transit deserts. Compared to Houston and San Antonio, public transport demands were fairly met in Austin, Dallas, and Fort Worth. Although, transit deserts have been identified in neighbourhoods across all five cities. No clear spatial pattern of their spatial distribution could be identified. Some gaps were located near large universities, which could be attributed to the high concentration of students. Furthermore, some block groups are located near 'downtown', which may be because of lack of transit and infrastructure investment in these outskirts areas, due to the fast development. Gaps were also found in some

are in the newly developed suburban areas as well as areas where the median household incomes are low.

Following a systematic review of the literature it can be asserted that both studies added to the discourse of transportation planning methods by being the first to quantify and calculate locations with inadequate public transport service given a population's need. Nevertheless, the existing method is based on cities located in the U.S. making it inapplicable in South Africa. "In an age where transit systems often operate on limited financial resources, it is extremely important that these systems operate and function as efficiently as possible, serving not only a high number of people but also highly dependent people" Jiao (2017:537). The notion that public transport dependent populations mark an increasingly important demographic of people who often are marginalised from society is an ever so relevant topic in South Africa. Therefore, this research fits within a larger transportation planning field as method and valuable tool to assist authorities in moving towards a more socially just public transport system. The following Chapter discusses the first steps in achieving this.

3. RESEARCH METHODS

Chapter Three begins by discussing how this study was conducted using a flowchart. This is followed by a section on how the data was collected, handled, and processed. The main focus of this chapter is the modified method and how it was used to calculate public transport need and public transport supply in Cape Town. The actions that were taken to investigate this research problem are described thoroughly together with the rationale for the application of specific procedures used.

3.1 Research Approach

Figure 3-1 illustrates the sequence this study followed by indicating key research steps. The flow chart is a condensation of what's to follow within this Chapter and can be used as a reference point for the measurement process.

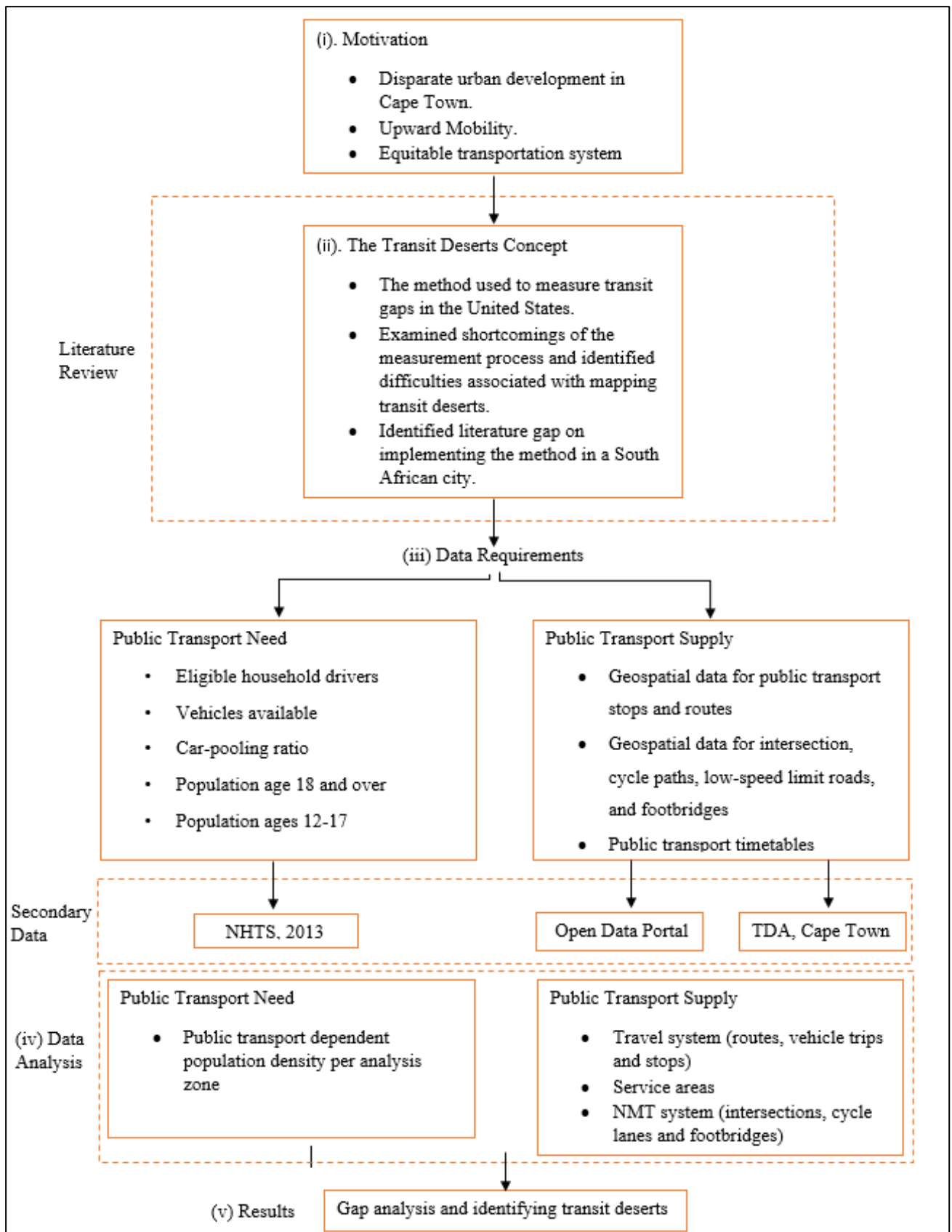


Figure 3-1: Flow Chart of Methodology

The first part of the research approach, namely, (i) Motivation and (ii) Literature Review has been thoroughly discussed in Chapter One and Two respectively. In summary, the research problem investigated is centred around the public transportation system in Cape Town and whether the people who depend on it most are being adequately served. This involves showing where public transport gaps exist towards the identification of possible transit deserts. The studies by Jiao and Dillivan (2013) and Jiao (2017) introduced the existing method of inquiry and analysis. A key gap was identified in the literature in that the existing method is only applicable to cities in the U.S. This study aims to fill this gap by modifying the methodology to a South African context and data availability. Therefore, this research can be placed within the context of existing literature in a supplementary sense. The theoretical framework underpinning this study is that a transit gap exists where the supply of public transport does not adequately serve the need of public transport dependent populations.

3.2 Data Collection

This study made use of secondary datasets. The following section describes these datasets by separating it into two overarching categories, namely data associated with measuring public transport need and data associated with measuring public transport supply. First, the types of data required to investigate the research problem is specified. This section also reports on unanticipated events that were encountered, with an explanation on why missing data did not undermine the validity of this study's findings. Lastly, the techniques used to process and clean the datasets are explained.

3.2.1 Data Requirements

It was deduced that household data at a disaggregated level i.e. Travel Analysis Zone (TAZ) level, would be required to measure the need for public transport. There were three types of data identified to execute this measurement process. First, population data related to age and driver's licence ownership was required to determine the population ages 12-17; the population age 18 and over; eligible household drivers; and ineligible household drivers. Second, vehicle ownership data was required to determine the number of vehicles available for private use by households. The source for these types of data was the National Household Travel Survey. The survey was executed as a joint effort by Statistics South Africa and the Department of Transport (DoT) in February and March 2013. It was designed to assess travel patterns and problems related to the transportation system of the country. The NHTS was based on a representative sample that covered 51 341 households and/or dwelling units, using

a random stratified sample. This study used data related to the Western Cape (WC) province, where the overall response rate was 80.5% (StatsSA, 2014b). Lastly, a car-pooling ratio was required to adjust the public transport dependent population. This ratio was obtained from a study done by Vanderschuren (2006), which observed private vehicle travel during the morning peak on the N2 highway in Cape Town.

In terms of measuring public transport supply, three types of data were identified. First, analysis zone shapefiles were required to spatially display the results at a disaggregated level. Second, geospatial data for predetermined criteria were required to measure the supply of public transport. Shapefiles of the road network, cycle lanes, footbridges, and public transport routes and stops were required. These data sets would eventually be spatially joined in GIS with the analysis zone shapefiles. Lastly, public transport timetables of the relevant modes were required to calculate the average weekday vehicle trip frequency i.e. a Monday timetable running from 05:30am to 21:00 pm. It is important to note that this study will only take account of formal public transport modes such as rail, bus services and bus rapid transit services and will not include the measurement of minibus taxi services. Therefore, for the remainder of this dissertation, public transport will be referred to by this definition. In order to obtain these types of data, the following sources were identified:

- Open Data Portal: This portal makes available data that the CoCT has approved in terms of its Open Data Policy. The geospatial data for the cycle lane network of the city was obtained from here.
- Transport and Urban Development Authority: One of the key urban functions of the TDA is to integrate spatial and transport planning in an attempt to facilitate more efficient land use. The geospatial data for conventional bus routes, Bus Rapid Transit (BRT) routes and stops, rail routes and stops, and footbridges were obtained from here.
- University of Cape Town GIS laboratory acts as a central data warehouse and was used to obtain geospatial data for the road network and nature reserves/protected areas. Although the latter did not form part of the supply measurement process, it did play a crucial role in calculating the density values of all relevant criteria.

3.2.2 Missing Data

The NHTS was based on a representative sample over 342 Travel Analysis Zones (TAZ). The rather large size of this level of geography was unanticipated, whereas, a smaller level of

geography, such as the block group size used by Jiao and Dillivan (2013) and Jiao (2017) would have been more suitable. Although analysis zones do not permit as detailed analysis, the author was still able to calculate transit gaps. The overall aim of the study, namely obtaining a method for calculating and quantifying transit deserts in South Africa, was not affected by this issue.

Geospatial data related to the total length of sidewalks could not be obtained for Cape Town. Although previous studies identified the ‘total length of sidewalks (miles) within each block group’ as part of the supply, there were cases in the literature where this criterion was not measured. For instance, in Jiao (2017) the sidewalk data for Houston, Texas was not available. However, supply is a multifaceted measure and the results obtained in the literature remained valid. Therefore, the lack of sidewalk data for Cape Town does not undermine the findings of this study.

3.2.3 Data Processing

The data processing procedure for each dataset identified in sub-section (3.3.1) can be explained as follows. The population data related to age and driver’s license ownership was determined using the ‘Pivot table’ function in Microsoft Excel. This prepared the data for the measurement process by counting, totalling and summarising it in a table. The number of vehicles available in each analysis zone was determined using a question related to motorised vehicle ownership (Q7.10 of NHTS METADATA). The question emphasised that a vehicle should only be available for private use and that a household member should have access to the vehicle when needed, otherwise the vehicle should not be considered. A table showing the modes that were included in the question is provided in Appendix B. Similar to the data processing procedure performed on the population data, pivot tables were used to determine the number of vehicles available for households in each analysis zone. The summarised tables were then saved for later use during the measurement process.

Due to the nature of geospatial data related to public transport supply, little data processing was required. Most of the work done with these datasets took place within ArcGIS and is explained in detail the following section.

3.3 Data Analysis

This section describes the quantitative analysis process followed to locate transit deserts in Cape Town. The modified method involved identifying the public transport dependent

population as a measure of public transport need, calculating the public transport supply, and then subtracting the supply from the need to measure the gap. The specific instruments of analysis used are specified in this section and include a set of mathematical formulae and GIS software, which was utilised to manipulate the data.

3.3.1 Software

The software was used as a method of testing the modified method. ESRI's ArcGIS mapping and analytics platform was used to capture geographic data, perform geospatial analysis, create maps and analyse the mapped information. This took place at the University of Cape Town GIS laboratory. The lab manages UCT'S ESRI site license which provided access to ESRI's industry standard ArcGIS desktop software. This study greatly benefited from the online training facility offered by the lab, as well as onsite consulting services which helped with troubleshooting and processing issues.

3.3.2 Public Transport Need

The following calculations were done in Microsoft Excel using the summarised tables obtained during data processing. This study suggested modifying the 'transit dependent household population' variable in order to obtain a more realistic estimate. Previously, Jiao and Dillivan (2013:27) and Jiao (2017:530) measured this variable by defining household drivers as members of a household who are of driving age (16 years and older in the U.S.). This study defined household drivers as members of a household who are of driving age (18 years and older in RSA) and in possession of a valid driver's license. The 'household drivers', as calculated with equation (2.1), Section (2.3.1) was defined as 'eligible household drivers'. As a further matter, the 'persons living in group quarters' also formed part of equation (2.1). This study did not consider these people, due to the target population of the NHTS survey only being comprised of private households and residents in workers' hostels. This according to StatsSA (2014:3) whereby "the survey does not account for other collective living quarters, such as students' hostels, old-age homes, hospitals, prisons, and military barracks, and is therefore only representative of non-institutionalised and non-military persons or households in South Africa". Equation (3.1) reflects these changes and calculated the public transport dependent household population as follows:

$$TDHP = HH_B - V \times CR_B \quad (3.1)$$

Where:

TDHP = Public transport dependent household population

HH_B = Eligible household drivers

V = Vehicles available

CR_B = Cape Town carpooling ratio

By calculating the eligible household drivers in the previous equation, the ineligible household drivers were also introduced into the formulae. This variable was defined in this study as household members who are of driving age but not in possession of a driver's licence. Jiao and Dillivan (2013) and Jiao (2017) did not account for the variable, however, this study chose to incorporate it into the formulae for a more accurate estimate of the public transport dependent population. Equation (3.2) shows how this variable was calculated:

$$HH_C = P_C - HH_B \quad (3.2)$$

Where:

HH_C = Ineligible household drivers

P_C = Population age 18 and over

HH_B = Eligible household drivers

Finally, the public transport dependent population was calculated. The number of individuals who can use public transport safely and responsibly was changed to include population ages 12 to 17 years. Thereafter, the public transport dependent population for each analysis zone was determined using Equation (3.3). The public transport dependent population variable was used as a proxy for public transport need.

$$TDP = TDHP + P_D + HH_C \quad (3.3)$$

Where:

TDP = Public transport dependent population

TDHP = Public transport dependent household population

P_D = Population ages 12-17

HH_C = Ineligible household drivers

Analysis zones that exhibit a difference between vehicle drivers and vehicles available have a higher probability of being dependent on public transport than areas with an equal ratio of

people to cars. The above calculation was performed for each analysis zone. In certain cases, there were more vehicles available than household drivers, which resulted in a negative value for the public transport dependent population. In these instances, the public transport dependent population was changed to a value of zero, since it would be illogical for this value to be negative (Jiao and Dillivan, 2013:27; Jiao, 2017:530). Once the public transport dependent population was calculated for each analysis zone, the value was divided by the size of each zone to obtain a density value (divided by the built environment or total zone). Then z-scores were calculated to standardise¹¹ the public transport dependent population density in each analysis zone.

3.3.3 Public Transport Supply

The three modes of mass public transport, which formed part of the measurement process, included Bus Rapid Transit (BRT), passenger rail, and conventional bus services. Public transport supply in each analysis zone was measured using seven criteria. Similar to Jiao and Dillivan (2013:27) and Jiao (2017:531), these criteria address both the physical presence of public transport, as well as the ability to access it. The seven criteria are:

1. The number of vehicle trips within each analysis zone (BRT and rail);
2. the number of routes within each analysis zone (BRT, conventional bus and rail);
3. the size of service area within each analysis zone (400-meter isochrone);
4. the intersection density in each analysis zone;
5. the total length of cycle lanes (kilometres) in each analysis zone;
6. the number of footbridges in each analysis zone; and
7. the total length of low-speed limit roads (kilometres) in each analysis zone.

Besides the number of trips within each analysis zone, all criteria were measured in ArcGIS. A methodology section which explains the details is provided in the Appendix section. Once each of the criteria was measured at the analysis zone level, the value was divided by square kilometres to get the density value and then a z-score was calculated to standardise each criterion. The z-scores of seven criteria were aggregated to represent the level of public transport supply for each analysis zone. Finally, supply and need z-scores were subtracted,

¹¹ The data was standardised in Microsoft Excel. The Average and Standard deviation functions were first utilised, after which the Standardise formula was employed to calculate the z-score of relevant data. The variables were standardised to transform the data into comparable scales and to avoid giving variables with larger ranges greater importance.

and a final numerical value was calculated for each analysis zone to determine an excess or lack of supply (Jiao and Dillivan, 2013:27; Jiao, 2017:531). Analysis zones with notably less supply than need have transit gaps and were identified as possible transit deserts. The following equation was used to perform this calculation.

$$TG = S_z - N_z \quad (3.4)$$

Where:

TG = Transit Gap

S_z = Supply z-score

N_z = Need z-score

3.4 Résumé

This research advocates the development of an equitable transportation system, where public transport is continuously available for those who require it to gain access to basic necessities, such as employment and education. This thesis is also motivated by the upward social mobility argument and attempts to highlight the important role public transport may play in reducing unemployment and alleviating poverty.

The literature inferred that the identification of transit deserts (Jiao and Dillivan, 2013; Jiao, 2017), would be the most suitable methodology to address the research problem being investigated. This methodology involves identifying the public transport dependent population as a measure of public transport need, calculating the supply of public transport, and then measuring the gap between the need and the supply.

There were four data sources identified to conduct this study: NHTS (2013), Open Data Portal, Transport and Urban Development Authority of Cape Town, and the University of Cape Town GIS laboratory. The first source, NHTS (2013), provided population data related to age and driver's licence ownership as well as vehicle ownership data. The remaining sources provided information related to Travel Analysis Zone shapefiles; the geospatial data for predetermined criteria, which will be used to measure the supply of public transport; and public transport timetables of the relevant modes, which will be used to calculate the average weekday vehicle trip frequency. The processing and cleaning of these datasets were mainly conducted in Microsoft Excel. Public transport need was analysed using a set of mathematical

formulae, initially developed by Jiao and Dillivan (2013), which was modified to be applicable to South Africa. Whilst public transport supply, was measured according to predetermined criteria using the ArcGIS software. The results obtained from the measurement process described in this Chapter are reported on in Chapter Four.

4. RESULTS

Chapter Four articulates the results obtained from implementing the modified method in Cape Town. The research problem relates to both the public transport system and the users depending on it. The first section discusses the results of public transport need by reporting on the location of public transport dependent populations. Thereafter, public transport supply is discussed in terms of the travel system (routes, vehicle trips and service areas) and non-motorised system (intersections density, cycle lanes, low-speed roads and footbridges). These results are reported on in a manner, which views the research problem from various perspectives before the findings are analysed collectively. Where applicable, the results of existing research are provided and compared with the findings in this study.

4.1 Public Transport Dependent Population

The public transport dependent population constitutes individuals who have no other transport option available to them (other than walking). These groups of people were defined as not of driving age, or not being in possession of a driver's licence, as well as those households without private vehicles available. Cape Town has a public transport dependent population of approximately 670 000 people spread out over a built environment area of 1 932 square kilometres. Table 4-1 compares Cape Town to three other large cities, where the same method for measuring public transport dependency was employed. Although this compares Cape Town to cities located in a First World country, the comparison is viable since South Africa is considered an anomaly among developing countries, with good infrastructure but significant social and economic problems (Gibb, 2007). Nonetheless, Cape Town has a relatively large public transport dependent population (670 037 people), coming second only to Houston (839 284 people). When comparing the *Dependent Population* to the *Population (2013)*, Houston has the highest dependency percentage (38.22%) followed by Fort Worth (22.46%) Cape Town (17.91%) and Austin (14.7%).

Table 4-1: Public Transport Dependency Comparisons

Measurement	Cape Town	Austin	Fort Worth	Houston
Population (2013)	3 740 026	885 400	792 727	2 195 914
Dependent Population	670 037	130 147	178 059	839 284
Area (sq.km.)	2 459	790.1	904.4	1 623.92
Built Environment Area (sq.km.)	1 932	771.56	880.12	1 552.93

Density (dep.pop/sq.km.)	346.81	168.68	202.31	540.45
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Data Source: Jiao (2017:531) and NHTS (2013a)

The important inference that could be drawn from this data comes from the size of each city. Cape Town has the largest area, which assumably increases the probability of dependent populations being, farther away from infrastructure and services. This is a significant issue, since public transportation thrives on an urban form that is compact and sustained by a stable and ever-increasing population density (Crane, 2000; Transportation Research Board, 1996). To start elaborating on the issue of proximity to public transport more thoroughly, the location of dependent populations were mapped out. Figure 4-1 shows the number of public transport dependent persons in each analysis zone.

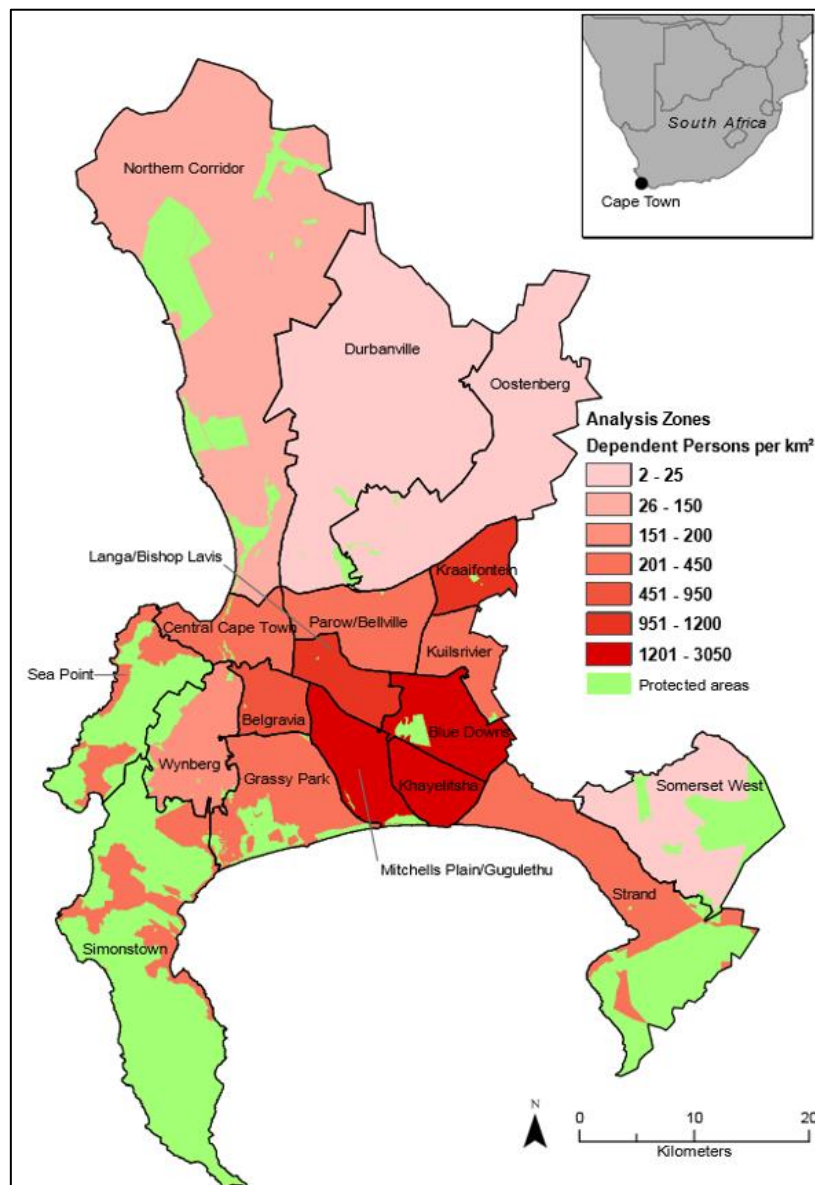


Figure 4-1: Map of Cape Town Depicting Public Transport Dependent Persons

Khayelitsha has the largest public transport dependent population (3 045 persons per square kilometre). This result was unsurprising, since Khayelitsha is considered to be the largest and fastest growing township in South Africa. Mitchells Plain/Gugulethu has the second largest public transport dependent population (2 630 persons per square kilometre) followed by Blue Downs (1 231 persons per square kilometre). Analysis zones, which exhibited low levels of public transport dependency were Somerset West (3 persons per square kilometre), Durbanville (15 persons per square kilometre), and Oostenberg (23 persons per square kilometre).

The size of the public transport dependent population for each analysis zone will be used as a proxy for public transport need in Chapter Five. Before this analysis can proceed, the results pertaining to public transport supply are outlined.

4.2 Travel System

The travel system in this study is defined by the three criteria associated with the formal public transportation itself, which includes the number of routes and vehicle trips as well as the service area around formal public transport stops. These criteria are reported upon together, as they mainly address the physical presence of public transport within each analysis zone, as opposed to the ability to access it.

4.2.1 Routes and Trips

The number of routes (BRT, rail, and conventional bus) and the number of vehicle trips (BRT and rail) were measured for each analysis zone. Table 4-2 reports on these measures in terms of their aggregated z-scores, by ranking analysis zones according to the size of the travel system.

Table 4-2: Travel Systems in Cape Town

Vehicle Trips and Routes							
	Analysis Zone	Rail Trips	BRT Trips	Rail Routes	BRT Routes	Bus Routes	Total z-score
1	Sea Point	0	17 674	0	29	462	4.38
2	Central Cape Town	2 379	11 200	8	48	738	2.30
3	Belgravia	252	0	2	0	838	1.66
4	Langa/Bishop Lavis	188	33	2	10	869	1.31
5	Mitchells Plain/Gugulethu	343	1 321	2	7	1 056	1.16
6	Khayelitsha	130	1 719	2	4	477	0.46
7	Blue Downs	238	0	2	0	613	-0.16
8	Parow/Bellville	1 268	0	4	0	652	-0.26
9	Wynberg	1 268	0	2	0	557	-0.37
10	Grassy Park	126	0	2	0	576	-0.61
11	Northern Corridor	0	28 326	0	53	393	-0.92
12	Kuilsrivier	54	0	1	0	176	-0.95
13	Simonstown	649	0	1	0	145	-1.08
14	Kraaifontein	174	0	1	0	46	-1.31
15	Strand	139	0	1	0	101	-1.37
16	Durbanville	0	0	0	0	278	-1.4
17	Somerset West	0	0	0	0	67	-1.42
18	Oostenberg	0	0	0	0	110	-1.44

Notes: Calculation of z-scores are shown in Appendix B

Sea Point has the largest travel system with approximately 17 500 BRT trips, 400 conventional bus routes, and 30 BRT routes. The extensive infrastructure is attributed to MyCiti Phase 1, with the presence of all four BRT trunk routes. Additionally, Sea Point has a

small built environment area which covers a substantial part of the Central Business District (CBD) and includes the suburbs of Vredehoek, Gardens, Tamboerskloof, and Bo-Kaap.

Central Cape Town has the second largest travel system with approximately 11 200 BRT trips and 2 300 rail trips. Cape Town station, which is the main railway station for the City, is found in this analysis zone and is the starting point for all lines through the city including the Northern and Boland business express lines. This analysis zone has 8 rail routes, 48 BRT routes, and 730 bus routes. Belgravia has the third largest z-score mainly because of its small geographic area. However, a major railway station (Athlone) is found in the centre resulting in 2 rail routes and 252 rail trips. Belgravia also has 838 bus routes.

Oostenberg, Durbanville and Somerset West have the smallest travel systems. As one would recall from Figure 1-1, both Oostenberg and Durbanville have large geographic areas that are mainly covered by rural farmlands with only the southern portions being developed. Consequently, the analysis zones roughly 100 and 250 conventional bus routes, respectively. Somerset West's small z-score is attributed to not having any BRT or rail services in operation and only 67 conventional bus routes.

4.2.2 Service Area

A service area was defined in this study as the public transport systems catchment area from which potential riders are drawn. As previously discussed, a fixed-route public transport system serves the area around designated stops. The literature suggests that this equates to a standard walking distance of 400-meters (Gutiérrez and García-Palomares, 2008; Kimpel et al., 2007; Zhao et al., 2003). Measuring this is useful to show which parts of a city are being served i.e. how many jobs, residential areas or facilities are within a short walk of a public transport stop. Figure 4-2 shows the size of the service area (square kilometres) of each analysis zone. The Northern Corridor has the largest service area (42 square kilometres), followed by Sea Point (18 square kilometres), and Central Cape Town (14 square kilometres). Somerset West, Kuilsrivier and Oostenberg all have small catchment areas.

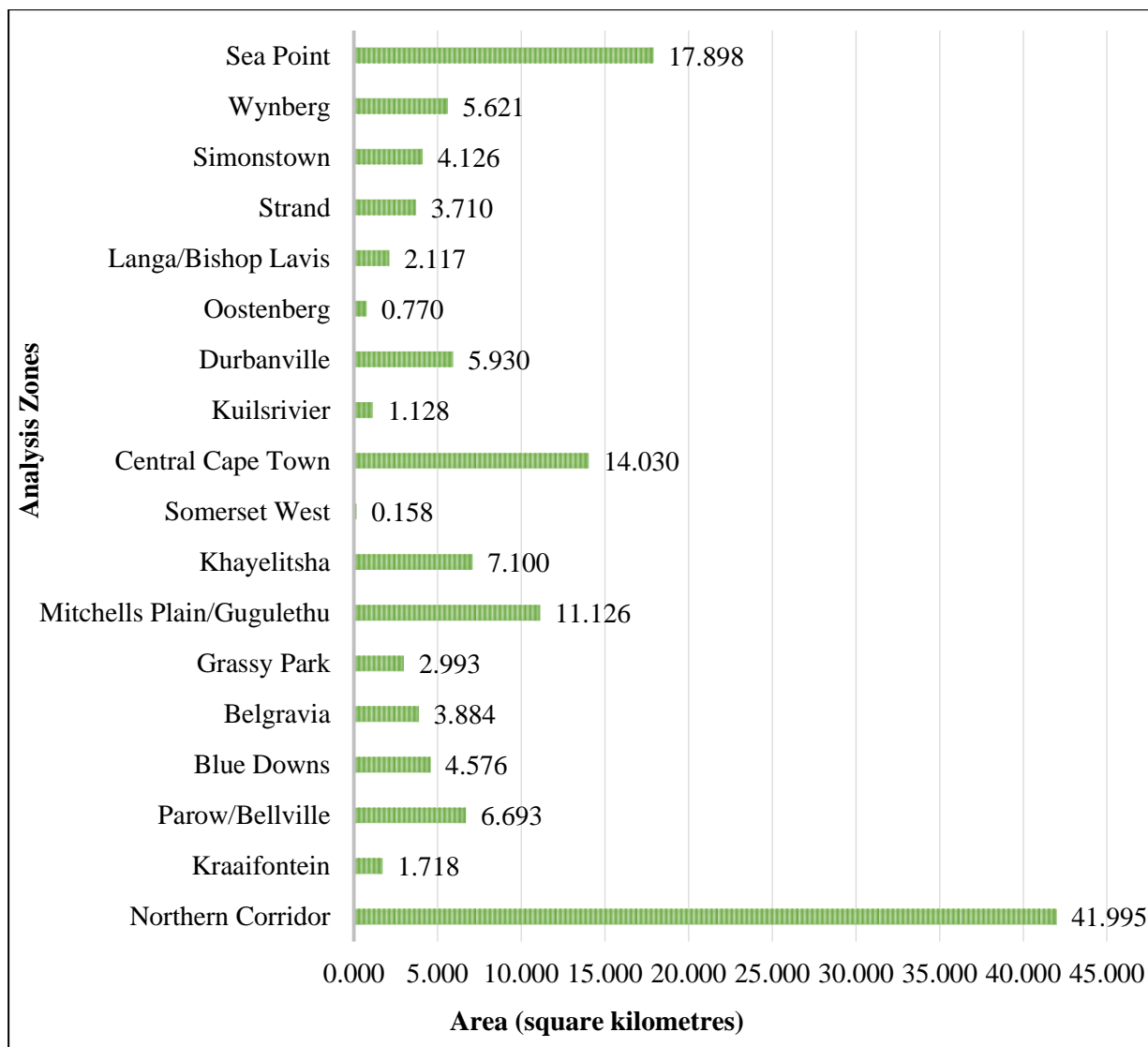


Figure 4-2: The Size of Service Areas for each Analysis Zone

Notes: Data on BRT bus stops, railway stations and Public Transport Interchanges (PTI) were used to calculate size of the service area

The distance most public transport users cover to access public transport in Cape Town is inconsistent with industry standards. A study done by Hitge and Vanderschuren (2015:37) on travel time comparisons between private cars and public transport revealed that the average walking distance a person covers in Cape Town to access public transport is 1.36 kilometres. The authors noted that “the survey was not meant to be representative of Cape Town’s travel patterns, although similar walking times were recorded in the three separate surveys” (Hitge and Vanderschuren, 2015:38). The authors also noted that although some passengers may choose to utilise a feeder service, many cost-sensitive public transport users are known to walk these distances (Hitge and Vanderschuren, 2015:38). Subsequently, their findings prompted exploratory analysis of this measure which saw the 400-meter isochrone around

public transport stops be increased to a 1.36-kilometre isochrone. Figure 4-3 illustrates the results and shows the effect an increased walking distance has on Khayelitsha. A clear difference can be seen with the 1.36-kilometre isochrone as the entire area now becomes accessible by foot

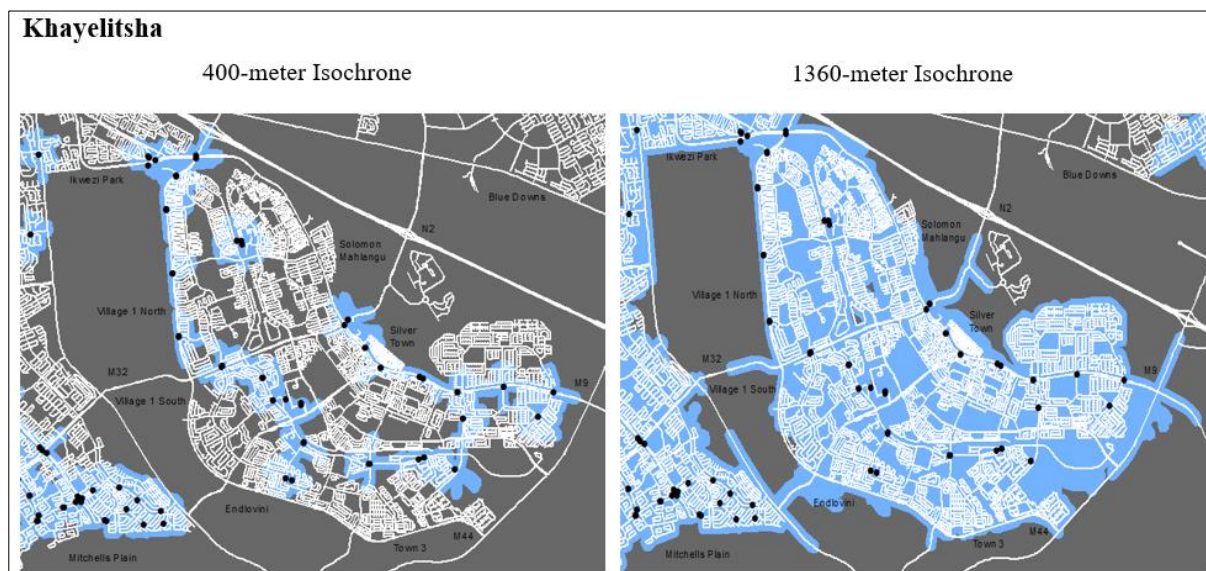


Figure 4-3: Service Area comparison in Khayelitsha

Notes: Khayelitsha was taken as an example to demonstrate the effect of a larger isochrone. The points on the map represents public transport stops, while the blue shading represents the service area.

It is surmised that the larger service area becomes less applicable to areas where few cost-sensitive public transport users reside, for example, the residential neighbourhoods in Sea Point. Consequently, the conventional 400-meter isochrone measure will form part of further analysis. This will also guarantee comparison with international findings.

Although service areas relate to access, the calculation is based on the location of designated stops; which together with routes and vehicle trips address the physical presence of public transport. These criteria form part of public transport supply in the next Chapter.

4.3 Non-Motorised Transport System

Walking or cycling is a travel mode used by many South Africans as a primary way of getting around. According to the Transport and Urban Development Authority (2017) nine per cent of Cape Town's population uses walking or cycling as a main mode of travel. Therefore, non-motorised transport infrastructure plays an important role in the movement patterns of many people and can be beneficial in providing safe and secure access.

The non-motorised transport system in this study is defined by the four criteria associated with walking and cycling and includes, intersection density, cycle lane lengths, low-speed roads and footbridges. These criteria are reported on simultaneously, as they mainly address the ability to access public transport within each analysis zone, as opposed to the physical presence of public transport. They form part of the built environment by either improving the mobility or safety of non-motorised travel. Figure 4-4 shows the measures which constituted the non-motorised system at a disaggregated level.

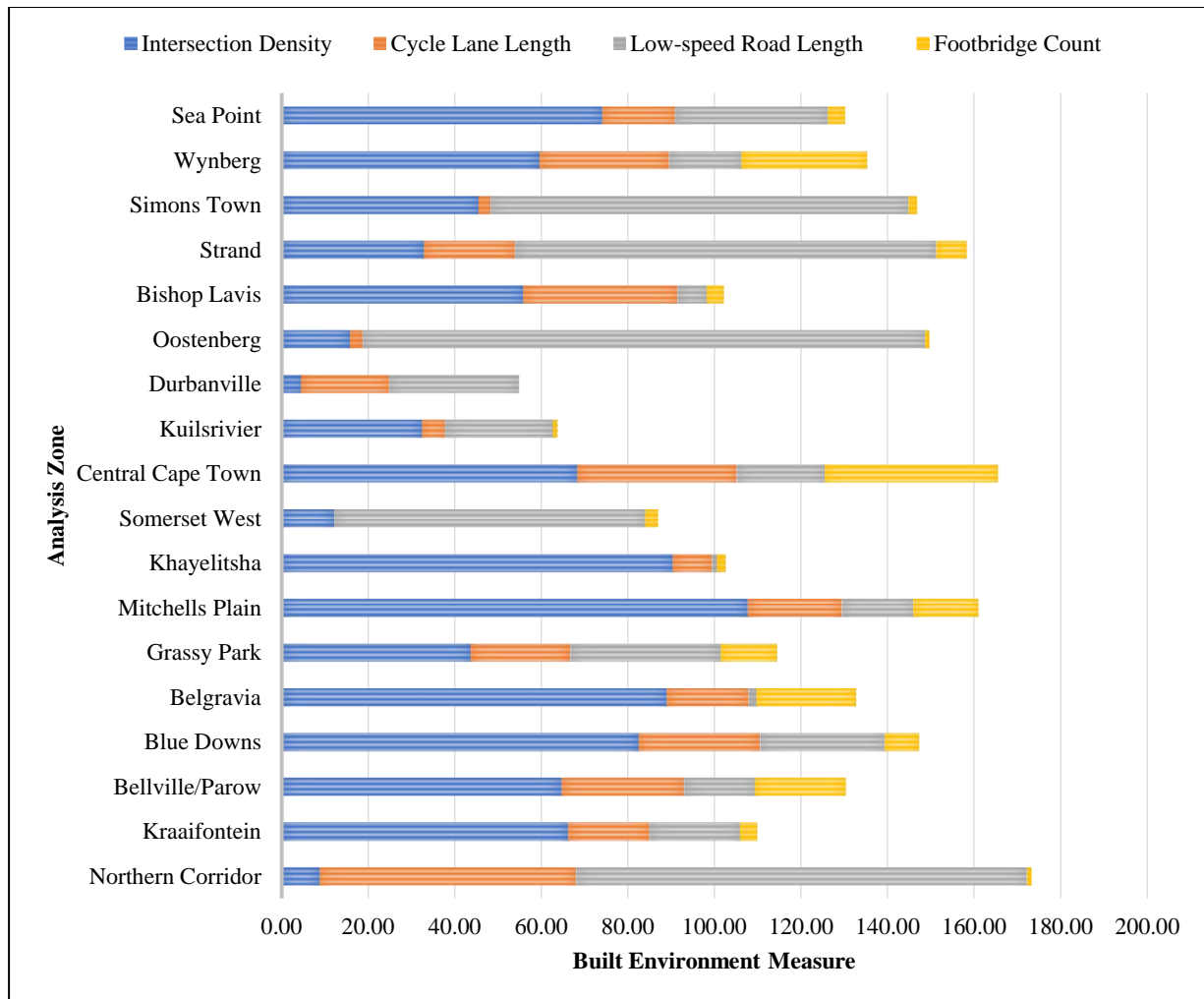


Figure 4-4: Built Environment Measures Related to Non-Motorised Transport

Notes: Graph displaying the absolute values of relevant criteria. See Appendix B, Figure 4-4 for detailed summary.

A neighbourhood's intersection density plays an important role in improving the ease of access to public transport. Previous studies have shown that intersection density is not only an indication of a neighbourhood's walkability but also plays a significant role in increasing public transport use (Ewing and Cervero, 2010:265; McCormack et al., 2012). In this study,

Mitchells Plain had the highest intersection density (107.67 per square kilometre) followed by Khayelitsha (90.42 per square kilometre) and Belgravia (89 per square kilometre). Essentially, analysis zones with high intersection densities would contain smaller block sizes, which correlates strongly with encouraging people to engage in non-motorised travel (Ewing and Cervero, 2010:276).

The availability of cycle lanes plays an important role in improving accessibility, particularly for non-drivers (Litman, 2018:2). The longest cycle lanes can be found in the Northern Corridor (59 kilometres), Central Cape Town (37 kilometres) and Bishop Lavis (36 kilometres). The CoCT annual report included a draft cycling strategy, which aims to increase the mode share of cycling in Cape Town from the current one per cent to eight per cent by 2030 (City of Cape Town, 2017:16). The figures indicate that a total amount of R158 million has already been spent over the last two years on non-motorised infrastructure (City of Cape Town, 2017:16). The results of the current study show that Somerset West has the shortest cycle lane length, however, the annual report indicates major roads in Somerset West are receiving new cycle lanes and pedestrian walkways. Additionally, the construction of new sidewalks and pedestrian walkways are also set to occur in Central Cape Town, Bishop Lavis, Grassy Park, Bellville, and Wynberg (City of Cape Town, 2017:17).

The total length of low-speed limit roads in each analysis zone have the potential to bring about a large positive impact on safety in the urban environment by creating a more pedestrian friendly environment. There are fewer accidents where the speed limit is lower, and the crashes that do occur are less severe (Archer et al, 2007). Low-speed roads were measured as having a speed limit of 40 kilometre per hour or less. The analysis zone with the longest low-speed roads are Oostenberg (130 kilometres) followed by the Northern Corridor (104 kilometres) and Strand (97 kilometres). Footbridges also aid in providing safe access to public transport. Central Cape Town has the highest number (40) followed by Wynberg (29) and Belgravia (23).

Table 4-3 ranks the analysis zones using two weighting methods. The ‘equal weighted’ method gives each criterion an equal score and ‘access weighted’ method places priority on the intersection density and cycle lane criteria¹².

¹² Note that this weighting is for analysis purposes only.

Table 4-3: Non-Motorised Transport Systems in Cape Town

Equal Weighted	Analysis Zone	z-score	Access Weighted	Analysis Zone	z-score
1	Central Cape Town	1.07	1	Central Cape Town	1.02
2	Belgravia	0.82	2	Belgravia	0.96
3	Sea Point	0.63	3	Bishop Lavis	0.83
4	Mitchells Plain	0.51	4	Mitchells Plain	0.82
5	Blue Downs	0.34	5	Sea Point	0.68
6	Bishop Lavis	0.31	6	Blue Downs	0.60
7	Wynberg	0.26	7	Kraaifontein	0.40
8	Simonstown	0.25	8	Wynberg	0.28
9	Kraaifontein	0.21	9	Bellville/Parow	0.22
10	Bellville/Parow	0.11	10	Khayelitsha	0.18
11	Grassy Park	-0.19	11	Grassy Park	-0.23
12	Khayelitsha	-0.19	12	Simonstown	-0.30
13	Strand	-0.19	13	Strand	-0.44
14	Kuilsrivier	-0.46	14	Kuilsrivier	-0.63
15	Somerset West	-0.71	15	Northern Corridor	-1.04
16	Oostenberg	-0.77	16	Oostenberg	-1.05
17	Northern Corridor	-0.91	17	Somerset West	-1.08
18	Durbanville	-1.1	18	Durbanville	-1.24

Notes: The z-scores were obtained by aggregating the non-motorised transport system criteria.

See Appendix B for detailed methodology and summary of results.

Central Cape Town and Belgravia have, in both cases, the largest z-score when it comes to access in terms of non-motorised transport measures. Central Cape Town's score may be attributed to having the second-longest cycle paths (37 kilometres) after Northern Corridor (59 kilometres). Furthermore, Central Cape Town has forty footbridges, compared to second on the list, Wynberg, with twenty-nine. Belgravia's is also highly ranked, due to the areas high intersection density (89 per square kilometre). Sea Point and Bishop Lavis have comparable geographic areas (33 square kilometres vs. 40 square kilometres) and footbridge count (4 vs. 4). However, Sea Point has a higher intersection density (74.09 per square kilometre vs. 55.83 per square kilometre) and longer low-speed roads (35 kilometres vs. 7 kilometres).

Durbanville has the smallest non-motorised transport z-score for both weighting methods. This may be attributed to having a low intersection density (4.61 per square kilometre), short low-speed road length (30 kilometres) and zero footbridges spread out over a relatively large area (349 square kilometres). The Northern Corridor is ranked second smallest with the equal weighted method mainly due to it have one footbridge. Although this analysis zone has a large intersection count (4 104) it covers the largest area (462 square kilometres). Somerset West and Oostenberg both have small non-motorised transport z-scores, due to a short cycle lane length and a small footbridge count.

4.4 Résumé

Using various spatial analysis functions available in ArcGIS, public transport need and supply were calculated. Public transport need per analysis zone was calculated using the formulae presented previously (See Chapter Three, Section 3.3.2). The results were reported on in terms of public transport dependent population size per analysis zone. Public transport supply was calculated in ArcGIS based on seven predetermined criteria (See Chapter Three, Section 3.3.3). The results were reported on separately, in terms of the travel system (routes, vehicle trips and services areas) and the non-motorised transport system (intersections, cycle lanes, low-speed roads and footbridges).

In the next Chapter the public transport need and supply will be analysed together. The seven supply criteria will provide z-score values, which are summed to obtain a final supply total per analysis zone. The public transport need z-score values for each analysis will then be subtracted from the supply to get the public transport service discrepancy. The final maps

presented in Chapter Five illustrate this difference between public transport need and supply graphically.

5. ANALYSIS AND DISCUSSION

The analysis conducted in this Chapter will compare the level of public transport need for an analysis zone by calculating the difference against the amount of formal public transport supply. This modified method assesses each unit of geography and provides transportation planners with an evaluation tool that compares Cape Town's supply and public transport need levels among other geographic areas of the metropolitan. It is important to note that this study only took account of formal public transport modes such as rail, bus services and bus rapid transit services and subsequently excluded minibus taxi services from the measurement process. The maps that are produced from this method could help guide discussions towards achieving an equitable public transport system.

Chapter Five is organised into two parts. The first part is a discussion on how the existing method (Jiao and Dillivan, 2013; Jiao, 2017) was changed to be applicable in Cape Town. This adapted method, which will be referred to as the 'modified method', will then be discussed in terms of the outcomes of application in Cape Town. Here the complexities and contradictions of implementation are specified. The second part of the Chapter analyses the findings obtained from implementing the modified method in Cape Town. In this section analysis zones with notably less supply than need is seen to have transit gaps and identified as possible transit deserts.

5.1 The Modified Method

Public Transport Needs: In this research, the public transport dependent population was redefined as a proxy for public transport needs, as opposed to the existing method defining it as a proxy for public transport demand. The rationale being that a demand denotes high levels of public transport ridership if a service were to be provided (Walker, 2018a:1), which is an outcome this research could not guarantee. Alternatively, a need indicates that if public transport were to be provided people's lives would be improved. Changing the terminology is significant, especially within the context of this research, as it directly refers to the upward social mobility argument, which underpins the study.

The formulae used in the existing method defined and calculated the 'household drivers' variable as individuals residing in a household who are of driving age, namely population age 16 and over. As new insight to scholarship, this study suggested a more realistic definition by making a discernment between eligible household drivers and ineligible household drivers. As

such, the ‘household drivers’ variable was redefined and calculated in the modified method as individuals residing in a household who are of driving age and in possession of a driver’s licence. This change allows for a more accurate measure of public transport needs, since ineligible household drivers are legally not permitted to drive a car and would, therefore, be dependent on public transport.

The final change made to the existing method was, due to shortcomings related to the sample design of the National Household Travel Survey (NHTS). The 2013 NHTS technical report stated that the design of the survey excluded households and individuals who live in institutions such as boarding houses, residential hotels, military barracks and hospital accommodation (NHTS, 2013b:25). Whilst the American Community Survey accounted for these groups of people (See Chapter Two, Section 2.3.1) the formula used in the modified method needed to be aligned with the NHTS which excluded these population groups. Table 5-1 compares the modified method to the existing method by providing a summary of the changes that were made to the need measurement process.

Table 5-1: Summary of Changes made to the Need Measurement Process

	Existing Method	Modified Method
<i>Terminology</i>	Demand	Need
<i>Level of geography</i>	Block Groups	Travel Analysis Zones
<i>Driving age</i>	16	18
<i>People too young to drive but able to use public transport safely and responsibly</i>	Ages 12-15	Ages 12-17
<i>Household drivers variable</i>	Persons who are of driving age	Persons who are of driving age and in possession of a driver’s licence.
<i>Sample design of survey used</i>	Differentiated and accounted for institutional group quarters as well as non-institutional group quarters	Excluded institutionalised and non-institutionalised populations

Public Transport Supply: The methodological steps undertaken to calculate public transport supply remained the same. Consistent with Jiao and Dillivan (2013) and Jiao (2017) the modified method was based on predetermined criteria, which were added together to represent the level of public transport supply. This involved joining the relevant geospatial data to a specific level of geography, calculating density values and then normalising the values with a z-score. Only the level of geography was changed from block groups (not used in South Africa) to Travel Analysis Zones. (TAZ's). Consequently, there were no fundamental changes made to the modified method. However, a distinction can be made in terms of the criteria used in the existing method (See Chapter Two, section 2.3.2) and the criteria used in the modified method (See Chapter Three, section 3.3.3). This study introduced two new built environment measures, as part of the criteria in the modified method. These measures were introduced following the recommendation made by Jiao (2017:537), which suggested refining or broadening the criteria to eventually obtain a more comprehensive measure of public transport supply. Therefore, in addition to the existing criteria identified by Jiao (2017) the modified method included:

- a) the size of service areas within each analysis zone (Bus Rapid Transit, rail and public transport interchanges); and
- b) the number of footbridge within each analysis zone.

The first measure (a) was based on an existing criterion, namely, 'the number of rail and bus stops in each block group' which was changed to the service area around formal public transport stops. The reason for this change being that a conventional fixed-route public transport system serves only the areas and people within a short distance of designated stops. For instance, a map showing all the stops within the city will inadvertently overestimate the area served by the public transport system. Furthermore, the inclusion of criterion (a) as a measure of supply is supported within the broader field of public transport service planning (El-Geneidy et al., 2014; Murray and Wu, 2003; and Fielding, Glauthier, and Lave, 1978). Since, the percentage of the population served by public transportation within a metropolitan region is a key system performance measure, which is dependent on how service areas are being defined.

Cape Town's transport network is made up of approximately 200 footbridges that were built to help pedestrians and cyclists cross busy roadways or intersections. The second measure (b) was introduced, since the purpose of footbridges are to improve safety and mobility for non-motorised travel (Matthews, 2017). Hence, this research recognised the important safety

contribution of such infrastructure and the difference that footbridges make with regard to ease of access to public transport. The two new built environment measures were chosen by the author of this study as they fulfil the requirements stipulated by Jiao (2017), that, criteria need to address both the physical presence of public transport, as well as the ability to access it. Table 5-2 compares the modified method to the existing method by providing a summary of the changes that were made to the supply measurement process.

Table 5-2: Summary of Changes made to the Supply Measurement Process

	Existing Method	Modified Method
<i>Level of geography</i>	Block Groups	Travel Analysis Zones
<i>Built environment</i>	Excluded bodies of water (where applicable)	Excluded nature reserves and protected areas (total of 527 square kilometres)
<i>Criteria (refined)</i>	The number of public transport stops within each block group	The size of service areas within each analysis zone
<i>Criteria (new)</i>	n/a	The number of footbridges within each analysis zone

Outcomes of applying the modified method: The application of the modified method was executed without any major complications. The usability of ArcGIS mapping and analytics platform, which enabled the analysis, proved to be effective in achieving the quantified objectives stipulated in Chapter One. Any troubleshooting or processing issues were solved onsite with the help of software experts.

This type of study is largely dependent on the availability of appropriate data sets in the required geo-spatial format. Throughout the data collection process various problems were encountered with existing data sets. The complexities occurred, because of publicly available data sets being out-of-date and some non-existent. For instance, the criterion which measured the total length of sidewalks in the existing method was excluded from the modified method, due to it not being available in Cape Town. Subsequently, higher quality data needed to be obtained and were requested from the relevant custodian departments working in the City of Cape Town, as well as from public transport service providers. This delayed the research

process considerably, as the long waiting period for the data sets were unanticipated. Due to time restrictions associated with completing a minor dissertation, the number of conventional bus trips could not be calculated. The measure required a shapefile with the location of Golden Arrow bus stops, which would then be cross-referenced with timetables to calculate the number of trips. However, this data layer was not publicly available and efforts to obtain the data from relevant data sources proved to be unsuccessful. While these shortcomings do not affect the main aim of the study, it does reveal a significant need to gather more comprehensive data that is up-to-date and publicly available.

The outcome of transit desert analysis is to create a graphic representation of neighbourhoods in an urban environment whose public transport needs are being overlooked. However, there was a certain degree of contradiction with the modified method. Due to survey data from the NHTS 2013 only being obtainable at the Travel Analysis Zone level, the effectiveness of being able to graphically display transit gaps was reduced. The reason being that such a large level of geography includes multiple neighbourhoods, which may not all require the same amount of attention. The major implication of this to the study was that transit desert analysis is conducted on a larger scale.

Overall, it is important to note that the validity of the measurement process was not undermined by the changes made to the modified method or by the complexities that were encountered. The formulae continue to identify areas where there are a limited number of motor vehicles available for private use instead of reasons why individuals are incapable of driving, like monthly household income or disability; as Jiao and Dillivan (2013) intended. The next section analyses and interprets the findings of the modified method.

5.2 Transit Desert Analysis: Cape Town

The definition of transit deserts used in the current research originates from Jiao (2013:23) and Jiao and Dillivan (2017:24). It describes analysis zones which contain a large constituent of public transport dependent populations with limited access to private motorised vehicles, where the level of public transport supply does not adequately serve the needs of the populations in question. In this research, transit deserts were identified in different parts of Cape Town. Spatially, most transit deserts were located on the outskirts of the metropolitan in suburban and rural portions of the city (See Figure 5-1).

Transit deserts were identified through a gap calculation, by subtracting need and supply z-scores (See formula 3.4). The final numerical value calculated for each analysis zone

determined an excess or lack of supply in relation to the dependent population size. Analysis zones with less supply than public transport needs were shown to have transit gaps, while analysis zones displaying a significant difference were identified as possible transit deserts. Table 5-3 illustrates the gap calculation and shows the analysis zones in Cape Town with a lack of supply.

Table 5-3: Gap Calculation for Analysis Zones with a Lack of Supply

	Analysis Zone	Supply	Need	Gap	Description
1	<i>Durbanville</i>	-6.49	-0.79	5.70	<i>Lack (Transit Desert)</i>
2	<i>Oostenberg</i>	-5.30	-0.78	4.52	<i>Lack (Transit Desert)</i>
3	<i>Somerset West</i>	-5.10	-0.81	4.29	<i>Lack (Transit Desert)</i>
4	Northern Corridor	-4.69	-0.70	3.99	Transit Gap
5	Kuilsrivier	-3.42	-0.57	2.85	Transit Gap
6	Khayelitsha	0.31	2.70	2.39	Transit Gap
7	Strand	-2.72	-0.45	2.27	Transit Gap
8	Grassy Park	-1.92	-0.35	1.57	Transit Gap
9	Kraaifontein	-0.97	0.30	1.27	Transit Gap

Durbanville, Oostenberg, and Somerset West exhibit the largest gap and are identified as transit deserts. Spatially, these areas are located to the north east and far south east of the city centre in analysis zones with mainly affluent suburban neighbourhoods (Somerset West) or residential suburbs surrounded by farmlands (Durbanville and Oostenberg). Urban sprawl and the separation of land uses, which ensued from modernist and apartheid city models (Botha, 2015:1), resulted in low-density development, which is not conducive to mass public transport. This left most analysis zones surrounding Central Cape Town, especially areas identified as transit deserts, to be predominantly automobile-oriented. Additionally, Northern Corridor, Kuilsrivier, Khayelitsha, Strand, Grassy Park, and Kraaifontein further exhibit a lack of supply and are shown to have transit gaps. These areas are located sporadically across the metropolitan with no clear spatial distribution. However, when household income and race are taken into consideration a clear pattern emerges. The size of Travel Analysis Zones (TAZ)

resulted in the analysis of transit deserts to take place on a relatively large geographic level. It should therefore not be assumed that all areas within ‘transit deserts’ TAZ’s have a supply and demand discrepancy. For that reason, only some areas in zones identified as transit deserts may require attention which accordingly may be referred to by the international terminology of transit deserts.

These analysis zones were overlaid with data related to household income and race revealing that analysis zones with transit gaps fall into the low-income category with many households earning less than R4 500 per month (Frith, 2011a). Furthermore, these areas are correlated with mainly Black African or Coloured populations (Frith, 2011b). Strand is an exception, as this analysis zone can be compared more to Somerset West’s suburban neighbourhood. However, Strand has a relatively large business and industrial district. According to the modified method, the public transport dependent populations residing in these analysis zones (Table 5-3) are not being adequately served. Therefore, this study finds that the neighbourhoods in these analysis zones require the most attention with regard to transportation access and planning.

The gap calculation also revealed that certain analysis zones have adequate supply in relation to the dependent population size, whilst analysis zones displaying a significant difference are identified as having excess supply. Table 5-4 illustrates the gap calculation and shows the analysis zones in Cape Town with adequate supply.

Table 5-4: Gap Calculation for Analysis Zones with Excess Supply

	Analysis Zone	Supply	Need	Gap	Description
1	Sea Point	10.23	-0.33	10.59	Excess
2	Central Cape Town	7.80	-0.35	8.15	Excess
3	Belgravia	5.01	0.17	4.84	Excess
4	Mitchells Plain/Gugulethu	3.93	2.22	1.71	Adequate
5	Wynberg	0.43	-0.61	1.04	Adequate
6	Parow/Bellville	0.06	-0.31	0.37	Adequate
7	Blue Downs	0.98	0.61	0.37	Adequate
8	Simonstown	-0.32	-51	0.19	Adequate

9	Langa/Bishop Lavis	0.59	0.56	0.03	Adequate
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In contrast to transit deserts identified in Table 5.3, Sea Point, Central Cape Town, and Belgravia are regarded as having excess levels of supply. These areas form part of the main commercial and business districts of Cape Town, where public transport needs are well catered for. Belgravia is also well-served being adjacent to Central Cape Town and includes commercial (Athlone CBD and Gatesville) and industrial zones (Athlone Industria 1 and 2) while also being served by a large railway station. This research does not imply that excess supply is an undesirable outcome, since most of the supply is utilised by the rest of the population travelling to these analysis zones. The inference being made relates to the degree of importance, in that the public transport dependent populations living in Sea Point, Central Cape Town, and Belgravia have more than enough supply. Therefore, another key finding is that further public transportation investment and planning need to be shifted to areas with a high concentration of dependent users for the sake of upward social mobility and transit equity.

Whilst Mitchells Plain/Gugulethu, Wynberg, Parow/Bellville, Blue Downs, Simonstown, and Langa/Bishop Lavis have been measured as being adequately served, the context of Cape Town's transportation system may change this interpretation. The overall measure of public transport supply in this study is a significantly overestimated, compared to reality, since Cape Town's passenger rail service is dysfunctional and unstable (Herron, 2017). There is an array of issues contributing to this problem, and on any given day commuters deal with defective rolling stock, speed restrictions, signal equipment failure, defective track circuits, vandalism, cable theft and/or low overhead power. This has led to a failing urban rail system where certain days almost 60% of trains are cancelled (Herron, 2017). According to the operator of commuter rail Metrorail, few Cape Town trains run on time, and at least 40% of scheduled trains do not run at all (Metrorail, 2017). Therefore, from the findings of this study it is not conclusive that the analysis zones measured as adequate, are in reality being properly served.

A certainty, which can be drawn from Table 5-4, comes from analysis zones showing excess supply. This is because high levels of supply in these areas is attributed to MyCiti BRT. This system is relatively new with planning of the first phase having started in 2007, and the first network being launched in 2011. This research cannot quantify to what extent the MyCiti service has provided upliftment. However, effective operations, growing passenger numbers

and recorded cases of accessibility to new economic opportunities, especially for the poorer socio-economic strata (MyCiti, 2016:17), may be testament to the upward social mobility argument framed in this research. MyCiti will soon start rolling out phase 2, which would increase the number of routes in Wynberg, Grassy Park, Mitchells Plain and Khayelitsha

As a consolidation of this study's findings, Figure 5-1 shows maps of need, supply and gaps for Cape Town. The maps are intended for support and clarification purposes and were produced in ArcGIS using the modified method. The gap map (Figure 5-1) is interpreted in terms of the shading – the darker the colour, the greater the gap.

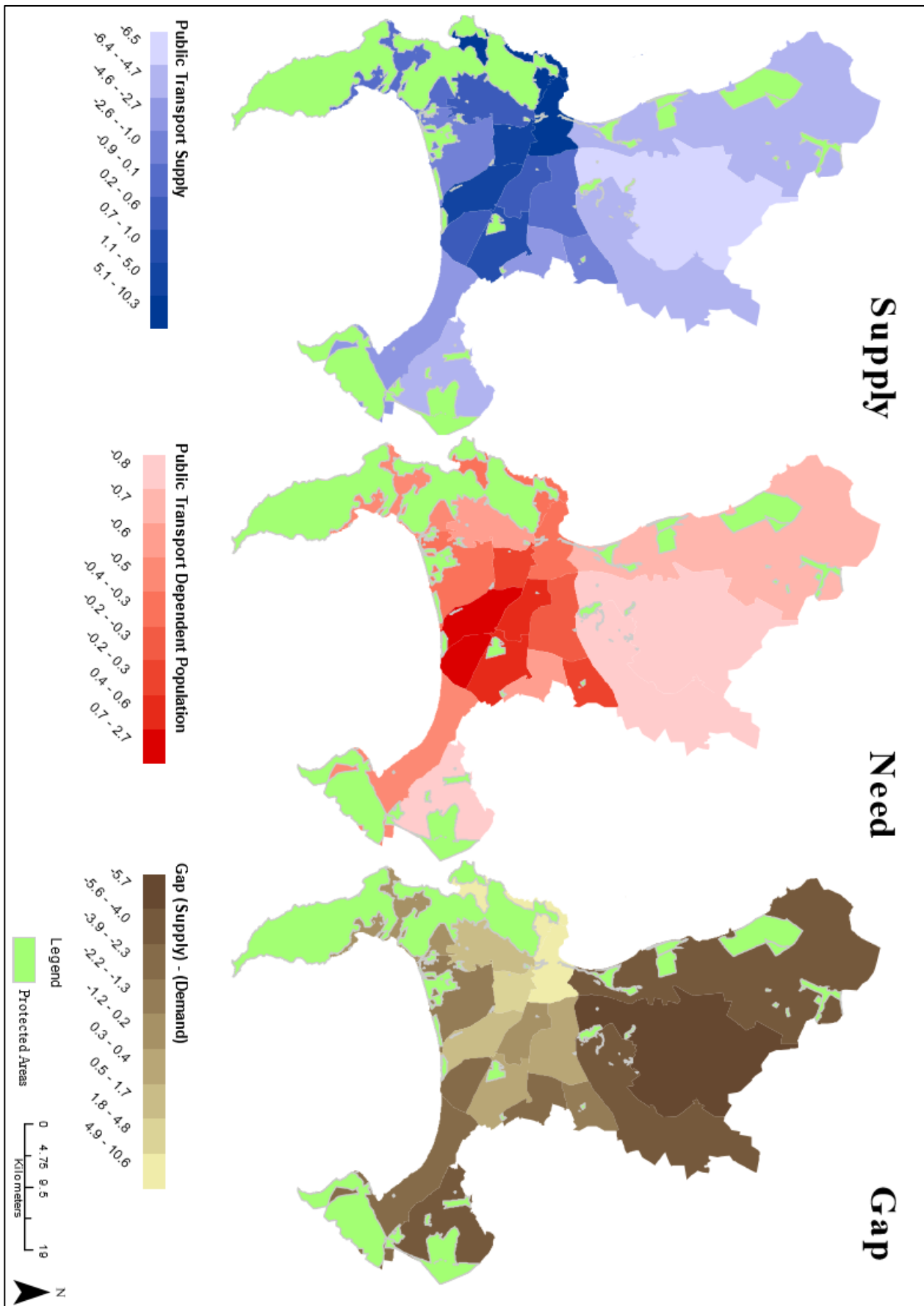


Figure 5-1: Maps of Need, Supply and Gap for Cape Town

In terms of the supply map in Figure 5-1, a high concentration of public transport services is found in or adjacent to the city centre with decreasing services as the distance from the city centre increases. This is relatively predictable with existing studies obtaining a similar finding (Jiao, 2017:533). The areas with relatively high concentrations of supply also extend along the major railway corridor running east, away from the central business district (CBD). Although not planned in this manner, this development is in line with sustainable land use theories, such as corridor development or Transit Orientated Development (TOD). Public transport dependent populations (Figure 5-1 Needs Map) are most dense in the Cape Flats region and to the far north of the CBD, originating from low-income towns as Atlantis and Mamre. These areas experience the highest level of public transport dependency, due to lower rates of car ownership. This stemmed from neighbourhoods being subject to past apartheid policy planning that gave rise to marginalised communities, while business development policies, which aimed to address the marginalisation of these neighbourhoods, unfortunately, failed. As previously discussed in this section, transit deserts were located on the outskirts of the metropolitan in suburban and rural portions of the city (Figure 5-1 Gap Map).

In sum, the analysis conducted in this Chapter compared the level of public transport need for an analysis zone and calculated the difference against the amount of public transport supply. The modified method assessed each unit of geography and provided transportation planners with an evaluation tool that compared Cape Town's supply and public transport need levels among other geographic areas of the metropolitan. The maps in Figure 5-1 could help guide discussions towards achieving an equitable public transport system. Significantly, this research aimed to fill a gap in the literature by modifying and transferring the existing transit desert methodology to Cape Town in an attempt to identify areas where the needs of social upliftment are not being addressed.

6. CONCLUSION

Chapter Six provides a synthesis of the lessons learned in this study. The aim of this research was to obtain a method for calculating and quantifying transit deserts, which can be used for any location in South Africa. The first part addresses the manner in which the research aim was fulfilled, by presenting a synopsis of each Chapter, and restating how the objectives of the study was achieved. This is followed by a brief discussion on suggestions for improvements that can be made to the research. Finally, recommendations for future research are proposed.

6.1 Reviewing the Research Aim and Objectives

This study set out to examine the public transportation system in Cape Town to investigate whether the people who depend on it most are being adequately served. This research problem is established upon the economic principle of a derived demand, in that public transport is not used for the intrinsic sake of travelling but instead for the utility of engaging in the activity at the end of a trip. Whilst it is this utility which makes public transport matter, the value reaches beyond access to jobs and improving income. In South Africa, it is the prospect of upward social mobility and the notion that future generations should be ‘better off’ than their parents, that motivated this research.

The motivation for this research, as restated in the previous paragraph, was made credible by previous research, which proved that access to public transport is the single most important factor in achieving upward social mobility (Chetty and Hendren, 2017) with practitioners observing this relationship between supply and public transport needs as a negative economic feedback loop (Bischak and Jiao, 2018). Furthermore, the transit equity discourse, which advocates public transport be continuously available for all, especially people who require it to gain access to basic activities, such as employment and education helped supplement the rationale for conducting the research. The relevance of the research is confirmed when considering South Africa’s political past, as well as the current socio-economic climate. The latest Gini Coefficient¹³ for South Africa was measured at 0.63 making it the world’s most economically unequal country in terms of income distribution (World Bank, 2018).

¹³ The Gini Coefficient is used as an indicator of economic development in a country, by measuring the degree of income equality in a population (Economist, 2018).

Additionally, with high concentrations of low-income people being located a considerable distance from main places of employment, adequate access to public transport should be an inexcusable necessity.

Scrutinize the existing method and modify it to be applicable to a South African city; and address the limitations set out by previous studies and find ways to improve it.

A review of the literature determined transit desert analysis as the most suitable method for addressing the research problem. It offers a straightforward approach by using GIS to measure public transport needs and supply, as opposed to complicated network modelling (Nayeem et al., 2014; Nikolić and Teodorović, 2013 and Schöbel, 2011). Although the concept is relatively novel within the field of transportation planning, Klier and Haase (2015) noted that the existing studies on transit deserts (Jiao and Dillivan, 2013; and Jiao, 2017) optimised city level public transport planning by presenting an efficient methodology to quantify public transport supply and needs. With these studies taking place in the United States, the existing method was first modified and then applied to Cape Town.

Significantly, this fulfilled the main aim of this research study, whilst advancing past research on the topic in two ways. First by adding value to the supply measurement process and secondly by providing new insight to contextualising of the public transport dependent population. The introduction of two new criteria is an exemplification of the former. The service area criterion was derived from the location of public transport stops and refined to not only address the physical presence of stops but also the area within a short distance of it. The footbridge criterion was included as it improves the built environment by providing safety and mobility for non-motorised transport users. In terms of new insight to the scholarship, this study suggested defining the household driver variable as persons who are of driving age and are in possession of a driver's licence, namely eligible household drivers. A distinction was, therefore, made within the measurement process between ineligible household drivers and eligible household drivers. As a further matter, the study established and advocates that the public transport dependent populations should be considered as a public transport need, as opposed to a demand.

Apply the modified method to Cape Town; determine if there are areas where the level of public transport supply does not adequately serve the need (gap analysis); and report on the location of possible transit deserts.

The modified method was then tested in Cape Town. The methodology involved identifying the public transport dependent population as a measure of public transport needs, calculating the public transport supply, and then subtracting the supply from the needs to measure the gap. ArcGIS software facilitated this process and allowed the transit gaps to be measured as the analysis zone level. Maps of needs, supply and gaps were generated, which visually highlighted the areas in Cape Town where the public transport needs outweigh existing services. Altogether, this research holds a methodological significance with the provision that the appropriate transportation network and schedule data is available. By being able to see the location of transit gaps, in order of importance, agencies may be able to effectively adjust the planning and operation of public transport services to better serve their communities. In addition, investment in infrastructure may be realigned to ensure limited resources are used productively.

The findings of this research study might not provide a definite way of solving social equity issues, but it does act as a step in the right direction. Recognising that public transport dependent populations in Cape Town is an important demographic of people that might still be marginalised and excluded from gaining access to the basic necessities of life. Thus, in keeping with McGrath and Jiao (2017) it is necessary for public transport authorities to justify service adjustments. The modified method employed in this study may have the potential to supplement this required evidence.

6.2 Limitations of Study and Suggestions for Improvement

In this study only Bus Rapid Transit, rail and conventional bus services were considered. Mini-bus taxis did not form part of the measurement process for the following reasons (Van Dalsen, 2018):

- privately owned segment of the transport sector which is informally run;
- only formalised, in the sense that drivers require permission to transport and owners having to be part of recognised taxi associations (given permits to operate certain routes);
- an informal employment structure, which lends itself to exploitative labour practices; and
- flexible wage rates confirmed for the most part on a verbal basis.

As a result of the above reasons, taxis seldomly follow designated routes and often use back roads and emergency lanes. Additionally, oversaturated routes cause drivers to operate in other association's territory in an attempt to complete enough trips to reach a daily revenue target for the vehicle owners. This makes analysing minibus taxi supply, on a comparative basis with other parts of the transport sector very challenging. However, minibus taxis are the most frequent and affordable mode of transport in South Africa (Kgwedi and Krygsmann, 2017) and should, therefore, be included as part of transit desert analysis. A possible solution to this may be through the use of tracking equipment or mobile applications to measure the routes and trips undertaken by a representative sample of minibus taxis, a contribution this study offers to address this problem.

The inclusion of the service area criteria has already been justified in the previous Chapter (see section 5.1). Therefore, for future transit desert analysis in South Africa a more comprehensive definition will be required. This definition should be based on the type of public transport system, as supported by Kimpel, Dueker and El-Geneidy (2007), as well as the socio-economic status of an analysis zone as revealed by Hitge and Vanderschuren (2015). Therefore, service areas should not assume that all public transport stops are alike for a given mode. As it is recognised that the walking distance to rail is different from the walking distance to a bus stop. Moreover, the findings of Hitge and Vanderschuren (2015) introduces the possibility of differentiating the size of service areas on a socio-economic basis. Analysis zones in this study, that are known to have mostly cost-sensitive public transport users, like Khayelitsha, would have a larger service area than wealthier established areas, such as Sea Point. This is relevant, especially because of South Africa's economically unequal income distribution (World Bank, 2018). It should be noted that this study is the first attempt to include the criterion of service areas into the transit desert measurement process and conversation.

6.3 Recommended Future Research

This research study proposes a methodology that can be employed in any South African city to measure the needs and supply of public transport. This minor dissertation showed that the public transport supply and need can be subtracted to measure transit gaps and identify transit deserts. However, this analysis took place on a relatively large geographic level. It should therefore not be assumed that all areas within 'transit deserts' TAZ's have a supply and demand discrepancy. For that reason, only some areas in zones identified as transit deserts

may require attention which accordingly may be referred to by the international terminology of transit deserts. Therefore, the following is recommended for future research:

- i. Obtain relevant datasets on a smaller geographic level, like suburb level. The modified method adopted in this study can then be used to analyse transportation system of Cape Town more effectively and report on the location of transit deserts more accurately.
- ii. This study also encountered data related issues, that were non-existing (sidewalk data), inadequate (data related minibus taxis) or inaccessible (data related to the locations of Golden Arrow Bus stops). Although these shortcomings did not affect the main aim of the study, it does reveal a significant need for Cape Town to gather comprehensive data that is up-to-date and publicly available.

Identifying transit deserts may be a valuable tool in assisting transportation planners during decision making. The modified method proposed in this research may be a pertinent topic of discussion, seeing that Cape Town's Transport and Urban Development Authority are leaning towards equity-based planning in the future (Transport and Urban Development Authority, 2014). This study can, therefore, be used to help guide discussions to areas where public transportation needs are overlooked.

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7. APPENDIX

A. Methods for Calculating Public Transport Supply

In this Appendix, the methods for calculating public transport supply within the ArcGIS software are described. Some of the criteria underwent similar testing and were subject to the same spatial analysis tools. These are discussed together accordingly.

The number of trips within each analysis zone (BRT and rail)

This criterion was calculated for an average weekday. The trips were derived from the relevant timetables which were obtained from official service provider websites. The process involved manually counting the number of trips per day. First, the geospatial data for public transport stops needed to be spatially joined in ArcGIS with analysis zone shapefiles. This allowed a spreadsheet to be generated showing which analysis zone a specific stop is located in. These spreadsheets were then cross-referenced with the timetables and the number of production points originating from a specific analysis zone was manually counted, and then aggregated. Figure 7-1 is a typical weekday timetable for a BRT route and demonstrates how the timetables were used to calculate the number of trips.

261: OMURAMBA - SALT RIVER - ADDERLEY		Timetable effective: 2 April 2016																														
MONDAY TO FRIDAY																																
Direction: to Adderley																																
Omuramba	Dep	05:30	05:45	06:00	06:15	06:30	06:45	07:00	07:15	07:30	07:45	08:00	08:15	08:30	08:45	09:00	09:15	09:40	10:10	10:40	11:10	11:40	12:10	12:40	13:10	13:40	14:10	14:40	15:10	15:40	16:10	16:36
Kiwi		05:33	05:48	06:03	06:18	06:33	06:48	07:03	07:18	07:33	07:48	08:03	08:18	08:33	08:48	09:03	09:18	09:43	10:12	10:42	11:12	11:42	12:12	12:42	13:12	13:42	14:12	14:42	15:12	15:42	16:12	16:38
Democracy North		05:34	05:49	06:04	06:19	06:34	06:49	07:04	07:19	07:34	07:49	08:04	08:19	08:34	08:49	09:04	09:19	09:44	10:13	10:43	11:13	11:43	12:13	12:43	13:13	13:43	14:13	14:43	15:13	15:43	16:13	16:39
Venus		05:35	05:50	06:05	06:20	06:35	06:50	07:05	07:20	07:35	07:50	08:05	08:20	08:35	08:50	09:05	09:20	09:45	10:14	10:44	11:14	11:44	12:14	12:44	13:14	13:44	14:14	14:44	15:14	15:44	16:14	16:40
Goudbom		05:36	05:51	06:06	06:21	06:36	06:51	07:06	07:21	07:36	07:51	08:06	08:21	08:36	08:51	09:06	09:21	09:46	10:15	10:45	11:15	11:45	12:15	12:45	13:15	13:45	14:15	14:45	15:15	15:45	16:15	16:41
Crassula		05:37	05:52	06:07	06:22	06:37	06:52	07:07	07:22	07:37	07:52	08:07	08:22	08:37	08:52	09:07	09:22	09:47	10:16	10:46	11:16	11:46	12:16	12:46	13:16	13:46	14:16	14:46	15:16	15:46	16:16	16:42
Zastron		05:38	05:53	06:08	06:23	06:38	06:53	07:08	07:23	07:38	07:53	08:08	08:23	08:38	08:53	09:08	09:23	09:48	10:17	10:47	11:17	11:47	12:17	12:47	13:17	13:47	14:17	14:47	15:17	15:47	16:17	16:43
Quest		05:39	05:54	06:09	06:24	06:39	06:54	07:09	07:24	07:39	07:54	08:09	08:24	08:39	08:54	09:09	09:24	09:49	10:18	10:48	11:18	11:48	12:18	12:48	13:18	13:48	14:18	14:48	15:18	15:48	16:18	16:44
Mansfield		05:40	05:55	06:10	06:25	06:40	06:55	07:10	07:25	07:40	07:55	08:10	08:25	08:40	08:55	09:10	09:25	09:50	10:19	10:49	11:19	11:49	12:19	12:49	13:19	13:49	14:19	14:49	15:19	15:50	16:20	16:46
Tygerhof		05:41	05:56	06:11	06:26	06:41	06:56	07:11	07:26	07:41	07:56	08:11	08:26	08:41	08:56	09:11	09:26	09:51	10:20	10:50	11:20	11:50	12:20	12:50	13:20	13:50	14:20	14:50	15:21	15:51	16:21	16:47
Boundary		05:43	05:58	06:13	06:28	06:43	06:58	07:13	07:28	07:43	07:58	08:13	08:28	08:43	08:58	09:13	09:28	09:53	10:21	10:51	11:21	11:51	12:21	12:51	13:21	13:51	14:21	14:51	15:22	15:52	16:22	16:48
Moores		05:44	05:59	06:14	06:29	06:44	06:59	07:14	07:29	07:44	07:59	08:14	08:29	08:44	08:59	09:14	09:29	09:54	10:22	10:52	11:22	11:52	12:22	12:52	13:22	13:52	14:22	14:52	15:23	15:53	16:23	16:49
Dunfer		05:45	06:00	06:15	06:30	06:45	07:00	07:15	07:30	07:45	08:00	08:15	08:30	08:45	09:00	09:15	09:30	09:55	10:23	10:53	11:23	11:53	12:23	12:53	13:23	13:53	14:23	14:53	15:24	15:54	16:24	16:50
Nasrec		05:46	06:01	06:16	06:31	06:46	07:01	07:16	07:31	07:46	08:01	08:16	08:31	08:46	09:01	09:16	09:31	09:56	10:24	10:54	11:24	11:54	12:24	12:54	13:24	13:54	14:24	14:54	15:25	15:55	16:25	16:51
Shedden		05:47	06:02	06:17	06:32	06:47	07:02	07:17	07:32	07:47	08:02	08:17	08:32	08:47	09:02	09:17	09:32	09:57	10:25	10:55	11:25	11:55	12:25	12:55	13:25	13:55	14:25	14:55	15:26	15:56	16:26	16:52
Forests		05:52	06:07	06:22	06:37	06:52	07:07	07:22	07:37	07:52	08:07	08:22	08:37	08:52	09:07	09:22	09:37	10:02	10:26	10:56	11:26	11:56	12:26	12:56	13:26	13:56	14:26	14:56	15:31	16:01	16:31	16:57
Rowan		05:55	06:10	06:25	06:40	06:55	07:10	07:25	07:40	07:55	08:10	08:25	08:40	08:55	09:10	09:25	09:40	10:05	10:27	10:57	11:27	11:57	12:27	12:57	13:27	13:57	14:27	14:57	15:37	16:07	16:37	17:03
Bevoortshoek		05:58	06:13	06:28	06:43	06:58	07:13	07:28	07:43	07:58	08:13	08:28	08:43	08:58	09:13	09:28	09:43	10:08	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:40	16:10	16:40	17:06
Olson		06:03	06:18	06:33	06:48	07:03	07:18	07:33	07:48	08:03	08:18	08:33	08:48	09:03	09:18	09:33	09:48	10:13	10:34	11:04	11:34	12:04	12:34	13:04	13:34	14:04	14:34	15:04	15:43	16:13	16:43	17:09
Flora		06:04	06:19	06:34	06:49	07:04	07:19	07:34	07:49	08:04	08:19	08:34	08:49	09:04	09:19	09:34	09:49	10:14	10:35	11:05	11:35	12:05	12:35	13:05	13:35	14:05	14:35	15:05	15:44	16:14	16:44	17:10
SHIB (Boarding Hours)		06:05	06:20	06:35	06:50	07:05	07:20	07:35	07:50	08:05	08:20	08:35	08:50	09:05	09:20	09:35	09:50	10:15	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06	14:36	15:06	15:45	16:15	16:45	17:11
SHIB (Boarding H)		06:06	06:21	06:36	06:51	07:06	07:21	07:36	07:51	08:06	08:21	08:36	08:51	09:06	09:21	09:36	09:51	10:16	10:37	11:07	11:37	12:07	12:37	13:07	13:37	14:07	14:37	15:07	15:46	16:16	16:46	17:12
Elbert Mall		06:07	06:22	06:37	06:52	07:07	07:22	07:37	07:52	08:07	08:22	08:37	08:52	09:07	09:22	09:37	09:52	10:17	10:38	11:08	11:38	12:08	12:38	13:08	13:38	14:08	14:38	15:08	15:47	16:17	16:47	17:13
Dustin		06:08	06:23	06:38	06:53	07:08	07:23	07:38	07:53	08:08	08:23	08:38	08:53	09:08	09:23	09:38	09:53	10:18	10:40	11:10	11:40	12:10	12:40	13:10	13:40	14:10	14:40	15:10	15:51	16:21	16:51	17:17
Forestburg		06:09	06:24	06:39	06:54	07:09	07:24	07:39	07:54	08:09	08:24	08:39	08:54	09:09	09:24	09:39	09:54	10:19	10:41	11:11	11:41	12:11	12:41	13:11	13:41	14:11	14:41	15:11	15:54	16:24	16:54	17:20
Harlow		06:10	06:25	06:40	06:55	07:10	07:25	07:40	07:55	08:10	08:25	08:40	08:55	09:10	09:25	09:40	09:55	10:20	10:42	11:12	11:42	12:12	12:42	13:12	13:42	14:12	14:42	15:12	15:55	16:25	16:55	17:21
Barrow		06:11	06:26	06:41	06:56	07:11	07:26	07:41	07:56	08:11	08:26	08:41	08:56	09:11	09:26	09:41	09:56	10:21	10:43	11:13	11:43	12:13	12:43	13:13	13:43	14:13	14:43	15:13	15:56	16:26	16:56	17:22
Rosend		06:12	06:27	06:42	06:57	07:12	07:27	07:42	07:57	08:12	08:27	08:42	08:57	09:12	09:27	09:42	09:57	10:22	10:44	11:14	11:44	12:14	12:44	13:14	13:44	14:14	14:44	15:14	15:57	16:27	16:57	17:23
Orkney		06:14	06:29	06:44	06:59	07:14	07:29	07:44	07:59	08:14	08:29	08:44	08:59	09:14	09:29	09:44	09:59	10:24	10:45	11:15	11:45	12:15	12:45	13:15	13:45	14:15	14:45	15:15	15:58	16:28	16:58	17:24
Adderley	Arr	06:20	06:35	06:50	07:05	07:20	07:35	07:50	08:05	08:20	08:35	08:50	09:05	09:20	09:35	09:50	10:05	10:30	10:48	11:18	11:48	12:18	12:48	13:18	13:48	14:18	14:48	15:18	16:01	16:31	17:01	17:27

Northern Corridor
= n * f
= 11 * 31
341 trips

Central Cape Town
= (n - 1) * f
= (19 - 1) * 31
= 558 trips

n = 11

n = 19

Figure 7-1: Calculating the Number of Trips on an Average Weekday using a Timetable

Data Source: MyCiti, 2018

The total length of cycle lanes (kilometres) in each analysis zone; and the total length of low-speed limit roads (kilometres) in each analysis zone.

The cycle lane and low-speed limit roads criteria were calculated similarly. First, geospatial data for each of the criteria were spatially joined in ArcGIS with travel analysis zone shapefiles. Then the ArcGIS Intersect tool was used to cut the cycle lanes and the low-speed limit roads where analysis zone boundaries were crossed. Thereafter, an output field was produced to show the length of cycle lanes (kilometres) and the length of low-speed limit roads (kilometres) found in each analysis zone. This study only considered existing cycle lanes and disregarded the data for any under-construction or planned infrastructure. This due to uncertainty surrounding the timeframe and success of such projects. Furthermore, this study defined low-speed roads as 40 kilometres per hour or less.

The intersection density in each analysis zone; and the number of footbridges in each analysis zone.

The intersection density and footbridge density criteria were also calculated using a similar method. First, geospatial data for each of the criteria were spatially joined in ArcGIS with travel analysis zone shapefiles. Then the ArcGIS Spatial join tool was used to count the number of intersections and footbridges in each analysis zone. This geoprocessing tool enabled each analysis zone to be given a summary of the numeric attribute of the points which fall inside it and a count field showing the number of intersection as well as the number of footbridges were developed. These values were then divided by square kilometres to get a density value for each analysis zone.

The size of service area within each analysis zone (400-meter isochrone)

The service area criterion was calculated by creating isochrones around public transport stops, as opposed to circular buffers. The motive being, people are, for the most part, constrained to walk along streets or sidewalks and cannot walk in a straight line in every direction from a designated stop. Having to circumvent a main road or geographic feature the 400-meter maximum distance will be covered before you reach 400-meters as the crow flies. Essentially, circular buffers around stops drastically overestimate the area within a short walk of each stop, and, in turn, the area served by the public transport system as a whole (Morang, 2016). Therefore, isochrones allow for a much more accurate estimate of the area served by the public transport system. The BRT bus stops, railway stations and public transport interchange shapefiles were merged together using ArcGIS Merge tool and are were collectively referred

to as public transport stops. The Spatial join tool was then used to join the public transport stops with analysis zone shapefiles. After which the ArcGIS Service Area tool was used to create a 400-meter walk distance polygon around each stop and calculate the size of the service areas. This distance limit was then increased to 1.36 kilometres for analysis purposes (See Chapter Four, section 4.2.2). This operation was run twice, first time with the 400-meter distance and the second time with the 1.36-kilometre distance.

The number of routes within each analysis zone (BRT, conventional bus and rail)

To measure the number of routes within each analysis zone geospatial data for rail routes, bus routes and BRT routes were spatially joined in ArcGIS with travel analysis zone shapefiles. Then the ArcGIS Intersect tool was used to cut the routes where analysis zone boundaries were crossed. An output field was then produced which counts the number of times a specific route runs through an analysis zone. Figure 7-2 shows BRT route (T01), which runs from Dunoon to the Waterfront via Table View and the Civic Centre and illustrates how a single route is defined in this study. This shows the route running through three analysis zones (approximately drawn) and attributed the route count per analysis zone accordingly. Forward and reverse routes were counted separately. The same process was followed for all three modes and the number of routes were eventually aggregated and then divided by the size of an analysis zone to obtain a density value.

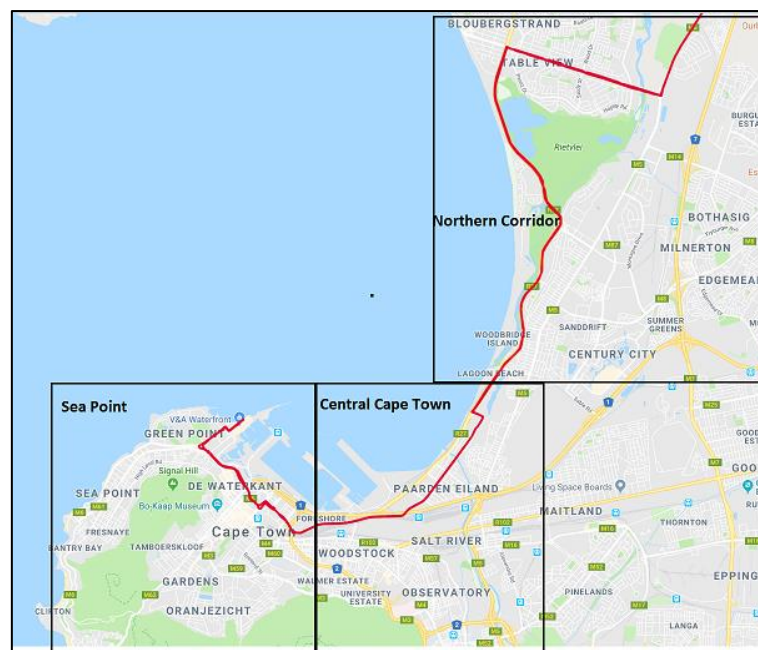


Figure 7-2: Graphic Representation of how a Route is Defined in this Study

Source: Google Maps, 2018

B. Data for Figures and Tables

FIGURE 1-1

Map of Cape Town Showing Built Environment and Protected Areas

Analysis Zone	Area with nature reserves included (sq.km)	Area without nature reserves (sq.km)
Northern Corridor	539	462
Kraaifontein	39	39
Parow/Bellville	74	74
Blue Downs	64	59
Belgravia	34	34
Grassy Park	103	83
Mitchells Plain/Gugulethu	58	55
Khayelitsha	38	38
Somerset West	148	106
Central Cape Town	54	53
Kuilsrivier	42	41
Durbanville	353	349
Oostenberg	231	230
Langa/Bishop Lavis	40	40
Strand	189	110
Simonstown	273	55
Wynberg	85	71
Sea Point	95	33

Notes: The first step within the ArcGIS software was to choose the coordinate system of the datasets. This study used a projected coordinate system based on a map projection known as transverse Mercator. This is the standard projection system for the City of Cape Town with the central meridian running through the town of Stellenbosch (19 degrees). Various data sets could now be integrated and used in analytical operations. This table represents the data used for Figure 1-1 and was the first operation performed within ArcGIS. It entailed overlaying the nature reserves and protected area shapefiles with analysis zone shapefiles to calculate the built environment area per analysis zone. These areas were used during the calculation of density values.

TABLE 4-1
Public Transport Dependency Comparisons

Analysis Zone	Transit Dependent Population	Built Environment Area
Northern Corridor	42627	462
Kraaifontein	37729	39
Parow/Bellville	31900	74
Blue Downs	72626	59
Belgravia	28963	34
Grassy Park	33287	83
Mitchells Plain/Gugulethu	144638	55
Khayelitsha	115692	38
Somerset West	318	106
Central Cape Town	21233	53
Kuilsrivier	8674	41
Durbanville	4948	349
Oostenberg	5258	230
Langa/Bishop Lavis	47586	40
Strand	34247	110
Simonstown	14483	55
Wynberg	12211	71
Sea Point	13615	33
Total	670037	1932

FIGURE 4-1

Map of Cape Town Depicting Public Transport Dependent Persons

Analysis Zone	Built Environment Area	Public Transport Dependent Population	Persons/sq.km
Northern Corridor	462	42627	92,27
Kraaifontein	39	37729	967,40
Parow/Bellville	74	31900	431,08
Blue Downs	59	72626	1230,95
Belgravia	34	28963	851,84
Grassy Park	83	33287	401,05
Mitchells Plain/Gugulethu	55	144638	2629,78
Khayelitsha	38	115692	3044,53
Somerset West	106	318	3,00
Central Cape Town	53	21233	400,63
Kuilsrivier	41	8674	211,56
Durbanville	349	4948	14,18
Oostenberg	230	5258	22,86
Langa/Bishop Lavis	40	47586	1189,66
Strand	110	34247	311,34
Simonstown	55	14483	263,33
Wynberg	71	12211	171,99
Sea Point	33	13615	412,59

TABLE 4-2
Travel System in Cape Town

Analysis Zones	Area	Routes	Density	zscore	Trips	Density	zscore	Total
Northern Corridor	462	446	0,97	-0,96	28326	61,31	0,04	-0,92
Kraaifontein	39	47	1,21	-0,93	174	4,46	-0,38	-1,31
Parow/Bellville	74	656	8,86	0,03	1268	17,14	-0,29	-0,26
Blue Downs	59	615	10,42	0,23	238	4,03	-0,39	-0,16
Belgravia	34	840	24,71	2,03	252	7,41	-0,36	1,66
Grassy Park	83	578	6,96	-0,21	126	1,52	-0,41	-0,61
Mitchells Plain/Gugulethu	55	1065	19,36	1,35	1664	30,25	-0,19	1,16
Khayelitsha	38	483	12,71	0,52	1849	48,66	-0,05	0,46
Somerset West	106	67	0,63	-1,00	0	0,00	-0,42	-1,42
Central Cape Town	53	794	14,98	0,80	13579	256,21	1,50	2,30
Kuilsrivier	41	177	4,32	-0,54	54	1,32	-0,41	-0,95
Durbanville	349	278	0,80	-0,98	0	0,00	-0,42	-1,40
Oostenberg	230	110	0,48	-1,02	0	0,00	-0,42	-1,44
Langa/Bishop Lavis	40	881	22,03	1,69	221	5,53	-0,38	1,31
Strand	110	102	0,93	-0,96	139	1,26	-0,41	-1,37
Simonstown	55	146	2,65	-0,75	649	11,80	-0,33	-1,08
Wynberg	71	559	7,87	-0,09	1268	17,86	-0,28	-0,37
Sea Point	33	491	14,88	0,79	17674	535,58	3,59	4,38
			Mean	8,60		Mean	55,80	
			Std Dev	7,95		Std Dev	133,81	

Analysis Zones	Rail Trips	BRT Trips	Total
Northern Corridor	0	28326	28326
Kraaifontein	174	0	174
Parow/Bellville	1268	0	1268
Blue Downs	238	0	238
Belgravia	252	0	252
Grassy Park	126	0	126
Mitchells Plain/Gugulethu	343	1321	1664
Khayelitsha	130	1719	1849
Somerset West	0	0	0
Central Cape Town	2379	11200	13579
Kuilsrivier	54	0	54
Durbanville	0	0	0
Oostenberg	0	0	0
Langa/Bishop Lavis	188	33	221
Strand	139	0	139
Simonstown	649	0	649
Wynberg	1268	0	1268
Sea Point	0	17674	17674

Analysis Zone	Rail Routes	BRT Routes	Bus Routes	Total
Northern Corridor	0	53	393	446
Kraaifontein	1	0	46	47
Parow/Bellville	4	0	652	656
Blue Downs	2	0	613	615
Belgravia	2	0	838	840
Grassy Park	2	0	576	578
Mitchells Plain/Gugulethu	2	7	1056	1065
Khayelitsha	2	4	477	483
Somerset West	0	0	67	67
Central Cape Town	8	48	738	794
Kuilsrivier	1	0	176	177
Durbanville	0	0	278	278
Oostenberg	0	0	110	110
Langa/Bishop Lavis	2	10	869	881
Strand	1	0	101	102
Simonstown	1	0	145	146
Wynberg	2	0	557	559
Sea Point	0	29	462	491

FIGURE 4-2

Bar Chart showing the Size of Service Areas for each Analysis Zone

Analysis Zone	400-meter Service Area (square kilometres)
Northern Corridor	41,995
Kraaifontein	1,718
Parow/Bellville	6,693
Blue Downs	4,576
Belgravia	3,884
Grassy Park	2,993
Mitchells Plain/Gugulethu	11,126
Khayelitsha	7,100
Somerset West	0,158
Central Cape Town	14,030
Kuilsrivier	1,128
Durbanville	5,930
Oostenberg	0,770
Langa/Bishop Lavis	2,117
Strand	3,710
Simonstown	4,126
Wynberg	5,621
Sea Point	17,898

FIGURE 4-4**Built Environment Measures Related to Non-Motorised Transport**

Analysis Zone	Intersection Density	Cycle Lane Length	Low-speed Road Length	Footbridge Count
Northern Corridor	8,88	59	104	1
Kraaifontein	66,15	19	21	4
Bellville/Parow	64,76	28	16	21
Blue Downs	82,53	28	29	8
Belgravia	89,00	19	2	23
Grassy Park	43,72	23	35	13
Mitchells Plain	107,67	22	17	15
Khayelitsha	90,42	9	1	2
Somerset West	12,25	0	72	3
Central Cape Town	68,34	37	20	40
Kuilsriver	32,54	5	25	1
Durbanville	4,61	20	30	0
Oostenberg	15,87	3	130	1
Bishop Lavis	55,83	36	7	4
Strand	32,97	21	97	7
Simons Town	45,51	3	96	2
Wynberg	59,62	30	17	29
Sea Point	74,09	17	35	4

TABLE 4-4 EQUAL WEIGHTED
Non-Motorised Transport System in Cape Town

Analysis Zone	Area	Intersection	Density	zscore	W	Cycle	Density	zscore	W	Lowspeed	Density	zscore	W	Fbridge	Density	zscore	W	Tot
Northern Corridor	462	4104	8,88	-1,44	-0,36	59	0,13	-0,80	-0,20	104,15	0,23	-0,61	-0,15	1	0,002	-0,79	-0,20	-0,91
Kraaifontein	39	2580	66,15	0,43	0,11	19	0,48	0,63	0,16	20,96	0,54	0,12	0,03	4	0,103	-0,34	-0,09	0,21
Bellville/Parow	74	4792	64,76	0,38	0,10	28	0,38	0,22	0,05	16,41	0,22	-0,62	-0,15	21	0,284	0,47	0,12	0,11
Blue Downs	59	4869	82,53	0,96	0,24	28	0,47	0,59	0,15	28,84	0,49	0,01	0,00	8	0,136	-0,19	-0,05	0,34
Belgravia	34	3026	89,00	1,18	0,29	19	0,56	0,92	0,23	1,85	0,05	-1,01	-0,25	23	0,676	2,21	0,55	0,82
Grassy Park	83	3629	43,72	-0,30	-0,08	23	0,28	-0,20	-0,05	34,74	0,42	-0,15	-0,04	13	0,157	-0,10	-0,03	-0,19
Mitchells Plain	55	5922	107,67	1,79	0,45	22	0,40	0,27	0,07	16,54	0,30	-0,43	-0,11	15	0,273	0,42	0,10	0,51
Khayelitsha	38	3436	90,42	1,22	0,31	9	0,24	-0,36	-0,09	1,19	0,03	-1,07	-0,27	2	0,053	-0,56	-0,14	-0,19
Somerset West	106	1299	12,25	-1,33	-0,33	0	0,00	-1,31	-0,33	71,83	0,68	0,45	0,11	3	0,028	-0,67	-0,17	-0,71
Central CT	53	3622	68,34	0,50	0,13	37	0,69	1,47	0,37	20,39	0,38	-0,23	-0,06	40	0,755	2,56	0,64	1,07
Kuilsrivier	41	1334	32,54	-0,67	-0,17	5	0,13	-0,79	-0,20	25,04	0,61	0,30	0,07	1	0,024	-0,69	-0,17	-0,46
Durbanville	349	1608	4,61	-1,58	-0,40	20	0,06	-1,08	-0,27	30,00	0,09	-0,94	-0,23	0	0,000	-0,80	-0,20	-1,10
Oostenberg	230	3651	15,87	-1,22	-0,30	3	0,01	-1,26	-0,31	129,89	0,56	0,19	0,05	1	0,004	-0,78	-0,19	-0,77
Bishop Lavis	40	2233	55,83	0,09	0,02	36	0,89	2,25	0,56	6,80	0,17	-0,74	-0,18	4	0,100	-0,35	-0,09	0,31
Strand	110	3627	32,97	-0,66	-0,16	21	0,19	-0,55	-0,14	97,31	0,88	0,94	0,24	7	0,064	-0,51	-0,13	-0,19
Simons Town	55	2503	45,51	-0,25	-0,06	3	0,05	-1,10	-0,27	96,45	1,75	2,99	0,75	2	0,036	-0,63	-0,16	0,25
Wynberg	71	4233	59,62	0,22	0,05	30	0,42	0,38	0,09	16,78	0,24	-0,58	-0,15	29	0,408	1,02	0,26	0,26
Sea Point	33	2445	74,09	0,69	0,17	17	0,51	0,73	0,18	35,34	1,07	1,38	0,35	4	0,121	-0,26	-0,06	0,63
			Mean	53,04			Mean	0,33			Mean	0,48			Mean	0,18		
			Std Dev	30,57			Std Dev	0,25			Std Dev	0,43			Std Dev	0,22		

TABLE 4-4 ACCESS WEIGHTED

Analysis Zone	Area	Intersection	Density	zscore	W	Cycle	Density	zscore	W	Lowspeed	Density	zscore	W	Fbridge	Density	zscore	W	Tot
Northern Corridor	462	4104	8,88	-1,44	-0,58	59	0,13	-0,80	-0,32	104,15	0,23	-0,61	-0,06	1	0,002	-0,79	-0,08	-1,04
Kraaifontein	39	2580	66,15	0,43	0,17	19	0,48	0,63	0,25	20,96	0,54	0,12	0,01	4	0,103	-0,34	-0,03	0,40
Bellville/Parow	74	4792	64,76	0,38	0,15	28	0,38	0,22	0,09	16,41	0,22	-0,62	-0,06	21	0,284	0,47	0,05	0,22
Blue Downs	59	4869	82,53	0,96	0,39	28	0,47	0,59	0,23	28,84	0,49	0,01	0,00	8	0,136	-0,19	-0,02	0,60
Belgravia	34	3026	89,00	1,18	0,47	19	0,56	0,92	0,37	1,85	0,05	-1,01	-0,10	23	0,676	2,21	0,22	0,96
Grassy Park	83	3629	43,72	-0,30	-0,12	23	0,28	-0,20	-0,08	34,74	0,42	-0,15	-0,02	13	0,157	-0,10	-0,01	-0,23
Mitchells Plain	55	5922	107,67	1,79	0,71	22	0,40	0,27	0,11	16,54	0,30	-0,43	-0,04	15	0,273	0,42	0,04	0,82
Khayelitsha	38	3436	90,42	1,22	0,49	9	0,24	-0,36	-0,14	1,19	0,03	-1,07	-0,11	2	0,053	-0,56	-0,06	0,18
Somerset West	106	1299	12,25	-1,33	-0,53	0	0,00	-1,31	-0,52	71,83	0,68	0,45	0,05	3	0,028	-0,67	-0,07	-1,08
Central CT	53	3622	68,34	0,50	0,20	37	0,69	1,47	0,59	20,39	0,38	-0,23	-0,02	40	0,755	2,56	0,26	1,02
Kuilsrivier	41	1334	32,54	-0,67	-0,27	5	0,13	-0,79	-0,32	25,04	0,61	0,30	0,03	1	0,024	-0,69	-0,07	-0,63
Durbanville	349	1608	4,61	-1,58	-0,63	20	0,06	-1,08	-0,43	30,00	0,09	-0,94	-0,09	0	0,000	-0,80	-0,08	-1,24
Oostenberg	230	3651	15,87	-1,22	-0,49	3	0,01	-1,26	-0,50	129,89	0,56	0,19	0,02	1	0,004	-0,78	-0,08	-1,05
Bishop Lavis	40	2233	55,83	0,09	0,04	36	0,89	2,25	0,90	6,80	0,17	-0,74	-0,07	4	0,100	-0,35	-0,04	0,83
Strand	110	3627	32,97	-0,66	-0,26	21	0,19	-0,55	-0,22	97,31	0,88	0,94	0,09	7	0,064	-0,51	-0,05	-0,44
Simons Town	55	2503	45,51	-0,25	-0,10	3	0,05	-1,10	-0,44	96,45	1,75	2,99	0,30	2	0,036	-0,63	-0,06	-0,30
Wynberg	71	4233	59,62	0,22	0,09	30	0,42	0,38	0,15	16,78	0,24	-0,58	-0,06	29	0,408	1,02	0,10	0,28
Sea Point	33	2445	74,09	0,69	0,28	17	0,51	0,73	0,29	35,34	1,07	1,38	0,14	4	0,121	-0,26	-0,03	0,68
			Mean	53,04			Mean	0,33			Mean	0,48			Mean	0,18		
			Std Dev	30,57			Std Dev	0,25			Std Dev	0,43			Std Dev	0,22		

Non-Motorised Transport System in Cape Town

Notes: This table represents the data used for Table 4-4 and Table 4-5 and illustrates the equal weighting method which was employed for analysis purposes. Once each of the criteria was measured at the analysis zone level, the value was divided by the built environment area (square kilometres) to get a density value and then a z-score was calculated to standardize each criterion. The non-motorised score was then obtained by aggregating the z-scores for each analysis zone. The equal weighted score gives each criterion a weighting of 25 percent. In South Africa, project prioritisation of non-motorised transport is usually based on documentation in the Integrated Transport Plan (ITP) and consultation with the relevant stakeholders. The prioritisation of such projects is also often influenced by financial cost-benefit analysis, while multi-sector objectives such as “improved mobility options with geographic reach” and “potential safety improvements” also play a role (Department of Transport and Public Works, 2009:29). In terms of this study, the intersection density and cycle lane criteria gravitate more towards the former objective while the footbridge density and low-speed road criteria are more inclined to the latter. By assigning a higher weight to the criteria which mainly improve mobility (rather than safety) more emphasis is placed enabling the dependent populations access to public transport. Hence, the access weighted score gives the intersection density and the cycle lanes density each a weighting of 0.40 and the low-speed road and footbridge density each a weighting of 0.10

FIGURE 5-1; TABLE: 5-3; and TABLE: 5-4

Maps of Need, Supply and Gap for Cape Town

Analysis Zone	Supply	Need	Difference
Sea Point	10,26	-0,33	10,59
Central Cape Town	7,80	-0,35	8,15
Belgravia	5,01	0,17	4,83
Mitchells Plain/Gugulethu	3,93	2,22	1,71
Blue Downs	0,98	0,61	0,37
Langa/Bishop Lavis	0,59	0,56	0,03
Wynberg	0,43	-0,61	1,04
Khayelitsha	0,31	2,70	-2,39
Parow/Bellville	0,06	-0,31	0,37
Simonstown	-0,32	-0,51	0,18
Kraaifontein	-0,97	0,30	-1,27
Grassy Park	-1,92	-0,35	-1,57
Strand	-2,72	-0,45	-2,27
Kuilsrivier	-3,42	-0,57	-2,85
Northern Corridor	-4,69	-0,70	-3,98
Somerset West	-5,10	-0,81	-4,29
Oostenberg	-5,30	-0,78	-4,52
Durbanville	-6,49	-0,79	-5,70

Table 7-1: List of the modes that were included in Question 7.10

Question Code	Description
Q710MOTOR	Motorcycles and scooters
Q710CAREMP	Car, bakkies, station wagons, and 4x4s owned by employer or company
Q710CARHH	Car, bakkies, station wagons, and 4x4s owned by the household
Q710CARVFR	Car, bakkies, station wagons, and 4x4s owned by relatives or friends
Q710MBUS	Minibus taxis or kombis
Q710TRUCK	Trucks
Q710OTHR	Other

Notes: Table showing the list of modes included in the National Household Travel Survey. This question was used to determine the number of vehicles available, as calculated in Equation (3.1). Data Source: NHTS (2013a)

