Development of a Geographical Information System Based Transport Assessment Approach in Rural South Africa

The Case of Healthcare Accessibility in Cape Winelands District Municipality

Dissertation presented in partial fulfilment of the requirement for the degree of Masters in Science, Civil Engineering

Special field: Transport Studies,

In the Department of Civil Engineering, EBE Faculty,

University of Cape Town

October 2019

By: Stephane Simon Masamba Ma-Kiese

Dedication

This thesis is dedicated to the memory of my grandfather, Simon Masamba Makela.

"*Il est grand celui qui respecte le petit.*"

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Acknowledgments

First and foremost, I would like to express my sincere gratitude to the almighty God, who enabled me to reach the completion of this thesis. My constant and daily prayers to him have come into realisation that I am grateful to mention today.

My special thanks go to my supervisor, Associate Professor Marianne Vanderschuren, whose support and encouragement I am eternally grateful for. Thank you for all your support and guidance in these years of my Masters. Your valuable suggestions and comments always served as a source of inspiration and encouragement. I would like to thank you again for your hand of generosity when you spared no effort to offer me jobs as her research assistant on several occasions to cover my financial fall outs.

I also extend a special token of appreciation to Associate Professor Mark Zuidgeest who showed me support and kindness that went beyond his responsibilities. Your advice and research resources provided clarity and direction.

Many thanks go to my family for their constant encouragement, support and faith in me. My family was a constant source of reinsurance and always believed in me. The emotional support that you provided was a tower of strength on which I held tight. To my parents who paid for my tuition fees, this is for you, I am forever grateful.

I would like to thank Thomas Slingsby and Nicholas Lindenberg in the UCT GIS Laboratory for all your help with ArcGIS computations. Last but not least, thank you to Cheryl Wright in the Department of Civil Engineering for your valuable time and constructive feedback on multiple draft versions. This thesis would not have been completed without your assistance.

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Abstract

For communities in urban and rural areas, access to healthcare facilities is a very significant concern of service delivery to both public policy makers and urban planners. Many healthcare systems set one of their primary objectives to achieve equity and ease of access to healthcare facilities for the populations that they serve. Spatial distribution of population, transport infrastructure, as well as spatial distribution of healthcare facilities are key characteristics that influence the disparities in spatial accessibility to healthcare facilities. Regardless of the permanent interest in transport accessibility, it is often uncertain how different types of accessibility measures relate to one another and which conditions are best for applications. In general, the current study undertakes a statistical comparison among three spatial accessibility measures (representing the main categories of spatial accessibility models) to determine whether they are comparable and/or interchangeable. Specifically, this study aims to use a geographical information system based approach combined with spatial accessibility measures, in a case study, derived from fine spatial resolution datasets, to characterise and divulge spatial variations in individual's access to healthcare facilities and identify deprived locations/local communities in a selected District Municipality of the Western Cape, South Africa. Results indicate that the main categories of spatial accessibility measures provide different interpretations of accessibility that cannot be reproduced by each other. However, the accessibility measures show a significant similar trend in variations of individual's accessibility to healthcare services for the communities of Cape Winelands District Municipality. The study establishes that within the Cape Winelands there exist spatial variations in the distribution of accessibility to healthcare and characterises these variations.

Key Words: Transport assessment, spatial accessibility, geographical information systems, rural access to health.

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List of Acronyms

AAZ	Accessibility Analysis Zones
BFS	Breadth First Search
CRS	Coordinated Reference Systems
CWDM	Cape Winelands District Municipality
DFS	Depth First Search
DM	District Municipality
DoH	National Department of Health
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
HCF	Healthcare Facility
IDW	Inverse Distance Weighted
IMD	Index of Multi Deprivation
KPAs	Key Performance Areas
KPIs	Key Performance Indicators
LM	Local Municipality
MoE	Margin of Error
MTT	Minimum Travel Time
NCDs	Non-Communicable Diseases
NDP	National Development Plan
NHI	National Health Insurance
NHTS	National Households Travel Survey
NIDS	National Income Dynamics Survey
NLTSF	National Land Transport Strategic Framework
NRTS	National Rural Travel Strategy
PHG	Primary Healthcare Gravity
TB	Tuberculosis
TCPHG	Two-step Cluster Primary Healthcare Gravity
RAI	Rural Accessibility Index
STI	Sexually Transmitted Infections
TAZ	Traffic Analysis Zone
WHO	World Health Organization

Chapter 1: Introduction

1.1. Background to Study

Movement of information, goods and people have always been essential gears of human societies. Every aspect of our lives and daily routine is affected somehow by transportation, including our homes, where we go to work, go to school and go to shops. Promising changes are anticipated when progress in transportation is achieved. These changes are observable in the ways of living and the ways in which societies are structured. Subsequently, progress in transportation has a major impact on the expansion of civilisations. Even though other amenities like energy, water and food supply are similarly important in influencing the formation of urban societies, the transport sector contribution is clearly observed in the formation, patterns, size and development of societies. Mankind lived in settlements located near banks of major rivers, ports or intersection of trade routes since the early ages of civilisation. These settlements developed in size and population into cities and major trade centres, adopting a variety of spatial patterns because of increased availability, speed and reduced cost of transport. Nowadays, it can be observed that almost half of the world's population is concentrated in urbanised areas and rely heavily on transport systems to meet their mobility needs. As these urban centres continue to grow and to develop, the dependency on transport systems increases. Similarly, for rural areas, their sizes, patterns of settlement and growth can be associated with the development of transport systems. However, the benefits from transportation advancements and investments may differ between urban and rural communities, as they depend on governmental efforts to address the communities' respective challenges to transport.

Much of the developing world still faces transport challenges that are, generally, known to have profound effects on the populations. One effect of transport challenges, generally observed in societies, is a vicious cycle that links low mobility with low income. Other visible indicators of non-efficient transport systems include high individual effort for trip making, low numbers of long-distance trip making, low numbers of goods movement, poor use of services and limited market interaction. These indicators are observed – with the use of transport surveys – because of the inability to overcome certain constraints to transport, such as long walking distances, limited modal choice, high transport cost, poor service frequency and unsafe transport. The constraints that individuals face with transportation are limiting factors to their levels of access to a multitude of activity opportunities. A well-functioning transport system should make possible adequate and equitable access to activities, such as work, education, healthcare, governmental service and many more for the development of the society that it serves. In areas that are far from roads, the problems of access to activity opportunities are amplified.

The World Summit on Sustainable Development (Social Council, 2002) promotes an integrated approach to policy-making at national, regional, and local levels of transport services and systems. This integrated approach aims to stimulate sustainable development with an effort to eradicate poverty and change unsustainable patterns of consumption and production in societies. This approach includes policies and planning for land use, infrastructure, transport systems and goods delivery networks. Furthermore, it aims to include actions to: (a) Implement transport strategies for sustainable development, reflecting specific regional, national and local conditions, to improve the affordability, efficiency and convenience of transportation; (b) promote investment and partnerships for the development of sustainable, energy efficient multi-modal transportation systems, including public mass transportation systems, and better transportation systems in rural areas, with technical and financial assistance for developing countries.

According to the Rural Transport Programme (South African Department of Transport, 2008) until the early 2000s, the governments of developing countries, along with financial institutions and aid donors, suspected that the construction of fairly high standard rural roads was the most effective way of addressing rural transport problems. Many investments in road construction projects were observed throughout the world, especially in developing countries, including in Africa. Nowadays, this belief does not always apply anymore. Even though better road access is crucial to improve rural transport, there is an increased awareness that a wider perspective should be adopted to address transport problems. Key difficulties within rural transport systems, such as low service density, transportation cartels (arising from limited competition), and inadequate infrastructure, need to be considered. Amongst the causes of these difficulties, low density of demand, weak tax base, poor infrastructure funding and weak institutional structure also need to be considered. Thus, an ideal solution to transport problems in urban and rural environments should be derived from a blend of policies and measures that are designed to address a wide range of constraints to accessibility.

The term accessibility was defined as ‘the potential of opportunities for interaction’ by Hansen (1959). Many of the constraints discussed contribute to diminish the potential of opportunities for interaction. These constraints, that negatively affect accessibility, are usually detected in rural areas and low-to-medium income countries. Rural transport development holds the potential for improving the livelihoods of rural inhabitants. Quality of life can improve when people's ability to reach the locations of activities, services and desired goods is improved. The South African Government (South African Department of Transport, 2007) implemented a National Rural Transport Strategy (NRTS). The NRTS covers the rural transport component of the National Land Transport Strategic Framework (NLTSF) which, in turn, is a legal requirement in terms of Clause 21 of the National Land Transport Act (Act 22 of 2000). The NRTS is aimed at providing transportation solutions to rural areas. To achieve its objectives, the main operational aims and rationale of the NRTS are, firstly, to achieve improved strategic guidance and coordination – both within the transport sector and within the broader cluster of key rural service delivery sectors – and secondly, to facilitate accelerated service delivery in neglected geographical and functional areas (South African Department of Transport, 2007). The NRTS advocates the promotion of a coordinated rural nodal and linkage development and the development of a demand-responsive, balanced and sustainable rural transport system to be the main strategic thrusts of said initiative.

In practice, access improvement to transport for populations in rural areas, and developing countries, is crucial in the promotion of rural development. It is a facilitating mean for increased uptake of human development services (educational and health, …), for inclusion of different ethnic and other groups, for improved employment opportunities, for stimulated growth and for poverty reduction (Roberts and Rastogi, 2006). The development and implementation of Rural Accessibility Index (RAI) was a necessary measure pioneered by the World Bank to develop sustainable rural transport infrastructure. Ultimately, the aim of RAI was to show the proportion of the rural population, which has adequate access to the transport system.

A study done in South Africa (Vanderschuren et al. 2013) has proved that RAI values can be used to prioritise investments within a district municipality and between district municipalities. Moreover, it recognised that investment decision support is possible based on limited data collection, and that Geographical Information Systems (GIS) are a useful tool in analysing limited datasets to compute RAI. An overall accessibility index, based on aggregates of the scores of various Key Performance Areas (KPAs), was developed. KPAs were identified to be spatial, temporal/time, travel mode, infrastructure, opportunity, and cost aspects. Through surveys, individual's travel times were used as Key Performance Indicators (KPIs) to compute the RAI model and map accessibility levels to various activities for 26 rural district municipalities. For further research, it was agreed that various combinations of KPAs should be considered to enhance RAIs models.

1.2. Research Problem

In over 20 years that the Republic of South Africa endured a peaceful transition from the apartheid regime to a constitutional democracy, substantial social progress was achieved to reverse the discriminatory practices that permeated all aspects of life before 1994. Yet, rural poverty in South Africa can be associated with a lack of access to basic services, social and economic activities. The development of a functional rural transportation system is imperative to the development of social equality. It is, therefore, of major importance to address accessibility issues in the rural areas, as well as urban areas. Currently, expressing RAIs that evaluate rural accessibility needs and prioritises these needs is one of the most promising methods of addressing said issues. However, no sophisticated enough models have yet considered various combinations of KPAs (spatial, temporal/time, travel mode, infrastructure, opportunity, and cost aspects) and KPIs, other than travel time and/or distance, to compute a RAI for South African district municipalities (maybe there are). To better understand how RAIs can inform planning and investment decisions, the purpose of this research is to develop a Geographical Information System (GIS) based approach to characterise spatial accessibility in relation to demographics, socio-economics, transport infrastructure and opportunities distributions. To do so, this research investigates how accessibility measures that consider the combinations and weightings of KPIs, can identify rural transport infrastructure gaps for South Africa's district municipalities. Cape Winelands District Municipality (CWDM) was selected as the case study for this research. CWDM is a district municipality in the Western Province of South Africa. Furthermore, to determine the accuracy of a limited dataset in the computation of accessibility measures, a statistical analysis compared the results of RAIs.

The inadequate access to resources, goods, economic and social services and opportunities – including credit, technology, communications and information – represent the main problems that many rural South Africans experience daily; especially the rural poor. Yet, the well-being and health of the South African population remains vulnerable to a burden of infectious and non-communicable diseases, persistent social disparities and inadequate human resources to provide care for a growing population. Appropriate responses to South African healthcare challenges would be to address the social determinants of health (which lie outside the health system) as a national priority, strengthen the healthcare system and facilitate universal coverage for healthcare (Mayosi et al., 2014). The Department of Transport (2007) recognised the struggle of rural people to be a topic of discussion in numerous policy studies and strategic interventions for rural areas. Despite the fact that nearly half of the population of South Africa occupy rural land, these areas contain 72% of those members of the population that are poor (South African Department of Transport, 2007). This situation needs to be tackled by researchers, policy makers and planners to ensure sustainable development in the society. These gaps in the understating of accessibility to healthcare in South Africa need to be filled.

There is an increasing trend in research that focuses on the topic of accessibility. Recent studies have shown that GIS is an appropriate tool for the development accessibility measures. South Africa's Policy makers and planners are more than ever tolerant to develop and adopt new approaches to assess the transport system. The transport system should, ultimately, reflect an adequate and equitable distribution in the levels of accessibility to all necessary activities that serve suitability and development goals.

Unlike their urban counterparts, inhabitants of rural areas may often remain isolated and deprived, because they have relatively lower access to basic economic opportunities, healthcare services, education services and social services. The 'deprivation trap' is a theory outlined by international literature (Chambers, 1983) to explain the persistence of poverty. Chambers (1983) listed isolation as one of the five 'clusters of disadvantage' that interact amongst lack of assets, physical weakness, vulnerability and powerlessness to trap people in a situation of disadvantage. The term 'deprivation trap' was designed to represent the rural context, a context in which individuals and their households are often remotely located and lack access to markets or information. This context promotes poverty.

1.3. Research Significance

This research is important because it enables interested parties of the transport sector with means to benefit the social agenda in a variety of ways. People who live in rural areas remain prone to poverty if their level of access to social and economic services remain low. It is important to address the knowledge gaps in relation to the barriers to accessibility. Long travel times and distances are amongst barriers to accessibility. Hansen (1959) defined the term accessibility in scientific fashion as 'the potential of opportunities for interaction'. Accessibility is a crucial constituent of transport and geography, in general, since it is an expression of mobility either in terms of people, freight or information. Mobility reflects choices made by potential travellers and spatial accessibility is a means to appraise the influences of infrastructure investment and associated transport policies on regional development. Spatial accessibility problems are of utmost importance for planners, country officials, education and health authorities and transport officials.

Easy and equitable access to healthcare services by communities, in any geographic area, is a vital consideration of human service delivery to the people that live in the specific area. Design guidelines, standards and legislation that aim to mitigate the barriers to transport accessibility already exist in many countries and international organisations. For example, Brazil, with the Federal Constitution of 1988 that mandates the creation of accessibility standards for public buildings, service facilities and transportation; also, the World Bank road investment programs, for instance, with a poverty reduction strategy primarily designed to benefit the poor with the improvement of access to education, healthcare services and nutrition programs. This research is expected to inform South African urban planners, health authorities and policy makers in sight for an assessment of regulatory frameworks, monitoring, or enforcement of design guidelines, standards and legislation on transport accessibility.

1.4. Research Objectives

The aim of this study is to develop a GIS based approach that characterises spatial accessibility to healthcare services by communities located within a district municipality of the Western Cape in South Africa. South Africa's spatial variations in population distribution, socio-economic distribution, healthcare facilities locations and transportation infrastructures, along with a historic legacy of Apartheid regime, are presumed to influence the spatial accessibility to healthcare services. It is presumed that spatial accessibility to healthcare is relatively poor at certain localities in the case study area for this research. The research objectives are:

- To illustrate variations in spatial accessibility to healthcare services in terms of the transportation infrastructures, healthcare services and spatial distribution of the population;
- To identify communities and locations where spatial accessibility to healthcare service facilities is relatively poor;
- Finally, to accomplish the thought objectives for the particular case study area, i.e. the Cape Winelands District Municipality area (CWDM), at a satisfactory spatial resolution using a GIS based analytical approach.

1.5. Research Questions

These research questions were proposed from having identified the research objectives. The questions were put forward to guide the research and, accordingly, provide answers to the thesis:

- What are the spatial distribution characteristics of the population, transport infrastructure and healthcare service facilities in the selected case study area?
- What are the spatial accessibility characteristics to healthcare service facilities by communities in the selected case study area?
- How can spatial clusters of disadvantaged locations and communities in the selected case study area be identify with a satisfactory spatial resolution using a GIS-based approach?

1.6. Research Scope and Limitations

This section presents the scope and conditions that were identified to impact and restrict the methods and analysis of the research. The research was conducted as a desk-study. The Cape Winelands municipality was chosen as the case study because it met the minimum characteristics of typical South African rural areas, the necessary data to conduct the study were available for the entire region, as well as the proximity to the Author's base location. The choice of Cape Winelands as the study area adequately serves the purpose of demonstrating the methodology, which can then be applied to different case study.

This research was specifically delimited in a couple of ways. First, the investigation of spatial accessibility was limited to the healthcare services opportunities and did not include other activities. The study only considered primary healthcare services for the analysis. Only a selected list of categories was sampled for the study. The seven categories of primary healthcare, considered in this study, were dental health clinics, district hospital, emergency medical services, medical health clinics, medical practitioners, pharmacies and regional hospitals. Second, the finest demographics data for the case study was obtained from the South African Census of 2011. Census blocks were used to geographically delineate the Accessibility Analysis Zones (AAZ) for the study. Third, the analysis was only conducted for specific modes. The two modes of transport that were considered in the study were walking and use of private vehicles. Even though public transport plays a crucial element in the lives of the rural poor in South Africa, time and resources allocation were the limiting factors that did not allow for incorporating this mode of transport for the study. Therefore, a strong need and opportunity for further research on the topic is provided to include the public transport mode as part of the investigation.

Limitations to the research were also identified in terms of the methodology used to evaluate spatial accessibility. The three spatial accessibility measures that were used in this study each have a set of assumptions and limitations that were identified as potential weakness to the study outside the control of the Author. For example, individuals' traveller behaviour and time constraints cannot be featured in the formulation of any of these accessibility measures, and therefore are not considered. These limitations were identified from the literature and provide the needs and opportunities for further research. Another issue that is common to all measures of spatial accessibility is the aggregation of results. This problem is strongly correlated with the availability of data used to measure spatial accessibility. The level of aggregation for the analysis of spatial accessibility was determined by the size of survey blocks from the South African Census blocks of 2011.

A standard value for home-based trip was used for the distance decay parameter for the accessibility measures. Distance decay is a geographical term which describes the effect of distance on spatial interactions. The distance decay effect states that the interaction between two locations declines as the distance between them increases. Distance decay parameters are generated through formulas, roadside surveys, household travel surveys or borrowed from other study areas or models. There was no resource allocated to undergo such investigation for this study. Hence, the use of a standard distance decay parameter, which was borrowed from another model, adequately serves the purpose of demonstrating the methodology. This eventually leads to opportunities for further research on the estimation of distance decay parameters for South African rural areas.

The cumulative measure of spatial accessibility was only sensitive to two variables, i.e. network characteristics (travel distance and travel time) and shortest straight-line distance. The Primary Healthcare Gravity measure, however, was sensitive to the healthcare service opportunities' attractiveness of healthcare facilities, in addition to the travel distances and travel time variables. The Two-step Cluster Gravity measure further included capacities of healthcare facilities on top of the sensitivity of the initial gravity measure. These measures were limiting the study in several ways.

The gravity models assume that each destination location is equally attractive to all individuals. In other words, Healthcare facilities were distinguished from one another by a parameter of attractiveness, but this parameter was equally perceived by the population. Utility-based models are the only models that consider individuals' preference in the calculation of spatial accessibility. However, utility-based measures of accessibility were not considered for the analysis of spatial accessibility, due to the complexity of the method and availability of funding for the study.

1.7. Thesis Structure and Content

The breakdown of chapters of this document is outlined as follows:

Chapter 1: Introduction

> The introduction chapter provides a background to the study. It presents the research problem, highlights the objectives of the study, outlines the significance of the research work, and discusses the limitations of the study.

Chapter 2: Review of Literature on Accessibility and Healthcare

> The literature review chapter presents discussions of the background studies carried out in defining the research approach and process. This chapter also provides an overview of the health sector in South Africa, as well as a synthesis of the applications of the research approach and process in the specific field of interest study.

Chapter 3: Methodology of GIS Based Transport Assessment

> The methodology chapter presents an overview of the research approach and research process. It outlines the solution model formulation and preliminary solution process, as well as, the development of the solution process and computation results.

Chapter 4: Case Study of Cape Winelands District Municipality

> The case study chapter presents a comprehensive description and discussion of the study area and tool for the study. It consists of an account of the proposed methodology in Chapter 3.

Chapter 5: Spatial Accessibility for Local Communities

> The results chapter comprises an analysis of the model results, validation of the model and an application of the model to the case study. It presents an analysis of spatial accessibility to healthcare and findings of disadvantaged local communities.

Chapter 6: Accessibility Index to Healthcare in CWDM

This chapter includes the final calculated accessibility indices for the CWDM as well as the results of the various IDW analyses computed in ArcGIS and a comparison of the outcomes of these analyses.

Chapter 7: Conclusions and Recommendations

This chapter consists of concluding remarks and recommendation based on the research objectives, which were converted into research questions.

Chapter 2: Review of Literature on Accessibility and Healthcare

The aim of this chapter is to review the literature to establish the relevance of research that was conducted to date.

First, there is a review of literature on accessibility indicators. The literature shows that many approaches were used to define the key concepts of access, accessibility and spatial accessibility (i.e. Cameron, 1995; Ansari, 2007). Similarly, there are a number of approaches used to measure and assess these concepts in practice. Access, accessibility and spatial accessibility are related terms, but each represent different concepts. The healthcare literature shows that these terms are often used interchangeably.

This chapter also provides an overview of the health sector and healthcare challenges in South Africa based on recent literature. It presents an historical development of the health sector, key figures on government expenditures in the health sector, as well as the challenges and burden of diseases faced by the people of South Africa.

The following sections attempt to clarify the key terms access, accessibility and spatial accessibility, within the context of the work that is presented in this study.

2.1 Definitions and Interpretations of Key Terms

A review of the literature that consolidates definitions and interpretations of the terms ‘Access’, “Accessibility, and “Spatial Accessibility” is presented in this section.

2.1.1 Access

The ‘degree of fit’ between users and services is an acceptable way to describe the term ‘access’. Availability, accessibility, accommodation, affordability and acceptability of a service are amongst the factors that might impact on the ‘degree of fit’ (Penchansky and Thomas, 1981). The demographics, including social, economic and cultural characteristics of the population, are also linked to ‘access’. Subsequently, location of service facilities and the transportation network are also linked to ‘access’. This means that access is patterned both spatially and socially (Field et al., 2004). From a land-use perspective there is an incentive to spatially allocate resources. Regions with more resources are likely to attract people and increase the demand to reside in the surroundings. Access to an existing resource or facility (e.g. a road network or a clinic) is commonly understood as the capacity of an individual or group to obtain the service when it is needed (Schneider and Symons, 1971). However, amongst academics, researchers, policy makers, politicians and the public, the meaning of access can vary. This can be associated with the differences in education, background, professional practices and cultural context.

For about four decades of studies, ‘access’ is still generally recognised by scholars, that focus on studying access issues, not to be a well-defined term (Aday and Andersen 1974, Penchansky and Thomas 1981). Therefore, in the literature, strong recommendations were found that the term ‘access’ cannot be understood on its own. Instead, it must be differentiated from other related terms that are interchangeable with it. Interchangeable terms to ‘access’ are accessibility, availability, affordability, barrier, right of entry, right of use, mobility and level of permission (Bagheri, Benwell et al., 2005; Guagliardo et al., 2004).

There are features of access. A distinction of features of access was proposed by Penchansky and Thomas (1981): ‘spatial’ and ‘socio-economic’ features. Spatial (geographic) features of access were then illustrated in terms of availability, accessibility and accommodation. While socio-economic features of access were illustrated in terms of affordability and acceptability. Figure 2-1 presents the classification of access, with spatial features (blue) and socio-economic features (yellow). Over 20 years later, Khan (2002) also considered access as both spatial (geographic) and non-spatial qualities for his research. Bagheri, Benwell et al. (2005) and Guagliardo et al. (2004), instead, regarded availability and accessibility as spatial components for spatial access. Many terms have appeared in the literature that relate to access. Resource allocation, social justice and equity are the terms frequently used by social scientists and planners. They empower policy makers and planners to decide when to take an action, and for whom the benefits of the action will be distributed, i.e. the familiar jargon ‘who gets what’ and ‘who pays’ (Talen, 1998).

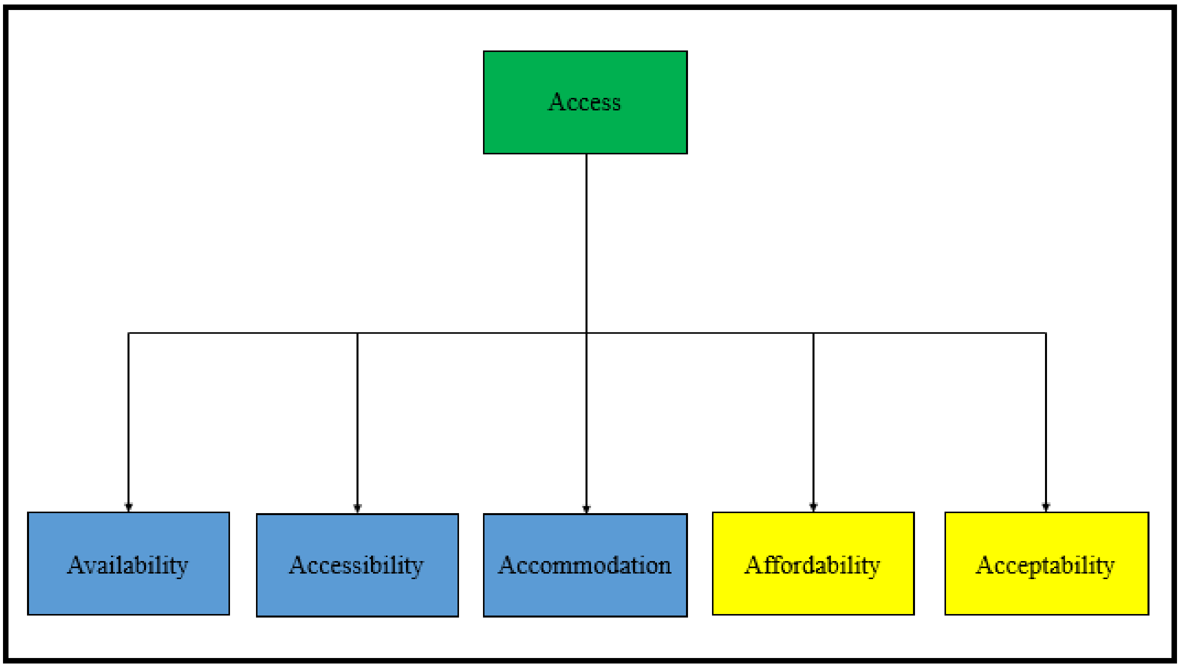


Figure 2-1 Access Features Classification

Source: Penchansky and Thomas, 1981

In addition to the apparent ambiguity for a universal understanding of the concept of access, the term is often referred to indiscriminately, with accessibility, and are both often misinterpreted, poorly defined and poorly measured (Geurs and Wee, 2004). When a measure of access is not simply represented by the presence of a healthcare facility in a region, because the presence of the facility does not ensure it utilisation in relation to the needs and healthcare services the users and healthcare provider value. Penchansky and Thomas (1981) revealed that access was recurrently viewed as a concept that related, in some ways, to consumers' ability or willingness to use healthcare services. This led to the consideration of organisational and financial barriers to healthcare service utilisation. In contrast, Mooney (1983) raised the argument that access was purely a matter of supply; although utilisation was a function of both supply and demand. Equity of access was, however, just a reflection of the supply side consideration, in the instance that equal services are made available to patients who have equal health concern (Goddard and Smith, 2001).

2.1.2 Accessibility

Similarly, 'accessibility' is a term that can be interpreted in many ways. It can be used as an adjective to describe something that is easy to approach, reach, enter, speak with, or use. The origin of the word 'accessibility' can be traced back to the 17th century Latin word

‘Accessibilis’. Hansen (1959) defined the term ‘accessibility’ in scientific fashion as ‘the potential of opportunities for interaction’. Amongst meanings, in transportation practices, accessibility can describe the amount of effort for a person to reach his destination or the sum of activities that are reachable from a certain location. Conferring Vickerman (1974), accessibility combines two elements: the geographic location relative to suitable destination, plus the characteristics of transportation networks linking locations. This definition of accessibility is like the concept of access in that it has several spatial and temporal properties to constrain individuals’ capability/preference to access a specific destination (Witten, Exeter et al., 2003).

Distances (Euclidean, Manathan or Network), dependent travel modes (driving, cycling, public transport, etc.), travel cost and time can be used to measure accessibility. Hence, accessibility is often described in the healthcare literature as a travel impedance between patient location and healthcare service locations (Guagliardo, 2004). In fact, Guagliardo (2004) stated that accessibility and availability were not similar concepts and that accessibility was dependent on the availability of services. Urban areas, for instance, accessibility and availability should be considered simultaneously, where multiple services are commonly available (Guagliardo, 2004). Through healthcare service utilisation, accessibility is often influenced by spatial structures of healthcare service supply and demand, neither of which is distributed uniformly in space (Wang, 2011). Table 2-1 informs the reader about key references in accessibility research, key models and issues of accessibility. Since 1959, the literature shows that various authors (Knox, 1979; McLafferty, 1982; Thouez et al., 1988; Maher, 1994; Geertman and Van Eck, 1995; Brabyn and Skelly, 2002; and Liu, 2008) have developed measures for accessibility research spanning across disciplines.

Table 2-1 Spectrum in Accessibility Research, Issues and Measures of Accessibility

Discipline	Issue	Measure	Reference
Urban planning	Physical planning.	Modified Gravity	Geertman and Van Eck (1995)
	Residential development and accessibility to commercial, industrial, and residential locations.	Gravity	Hansen (1959)
Geography and health	Geographic accessibility to healthcare facility in rural areas.	Gravity	Thouez et al. (1988)
	Distribution and proximity impact on infant mortality.	Ratio	McLafferty (1982)
Public health	Health care in urban diabetic Population.	Travel time and distance	Liu (2008)
	Accessibility to public hospital	Travel time and cost (cost path analysis)	Brabyn and Skelly (2002)
Public policy	Residential mobility and location disadvantage	multi-dimensional	Maher (1994)
	Health care deprivation	Gravity	Knox (1979)

2.1.3 Spatial Accessibility

In a general sense, the term 'spatial accessibility' denotes the physical accessibility that individuals have to a preferred location, or the ease at which individuals in one location can reach another location (Pirie, 1979; Kwan and Weber, 2003). Spatial accessibility refers to the bond between the locations of the supply and the locations of the demand for specific services, while taking account of the transportation infrastructures and travel impedance. In the literature, spatial accessibility (Freeman, 1986; Oppong and Hodgson, 1994; Hewko, 2001; Guagliardo, 2004) and geographical accessibility (McLafferty, 1982; Pooler, 1987; Brabyn and Skelly, 2002; Apparicio et al., 2008) are commonly used in an interchangeable fashion, from the fact that both concepts are location-based and spatially constrained. In fact, Khan (1992) stated that spatial accessibility is explicitly conditioned by the spatial or distance variables (as a barrier or a facilitator of access) and the pattern generated as the main geographic manifestation. In the healthcare geography category, many scholars acknowledge that they use the term ‘spatial accessibility’ to gain the favour and support from the published literature (Khan and Bhardwaj, 1994; Luo and Wang, 2003; Luo, Wang et al., 2004 and Guagliardo, 2004). Spatial accessibility is a serious concern in the provision of both public and private services. Spatial accessibility has mainly been studied and developed in Geography, Mathematics and Social Science but not limited to the disciplines such, as civil engineering, planning, physics, transportation, public health etc. (Figure 2-2) shows several disciplines that study spatial accessibility.

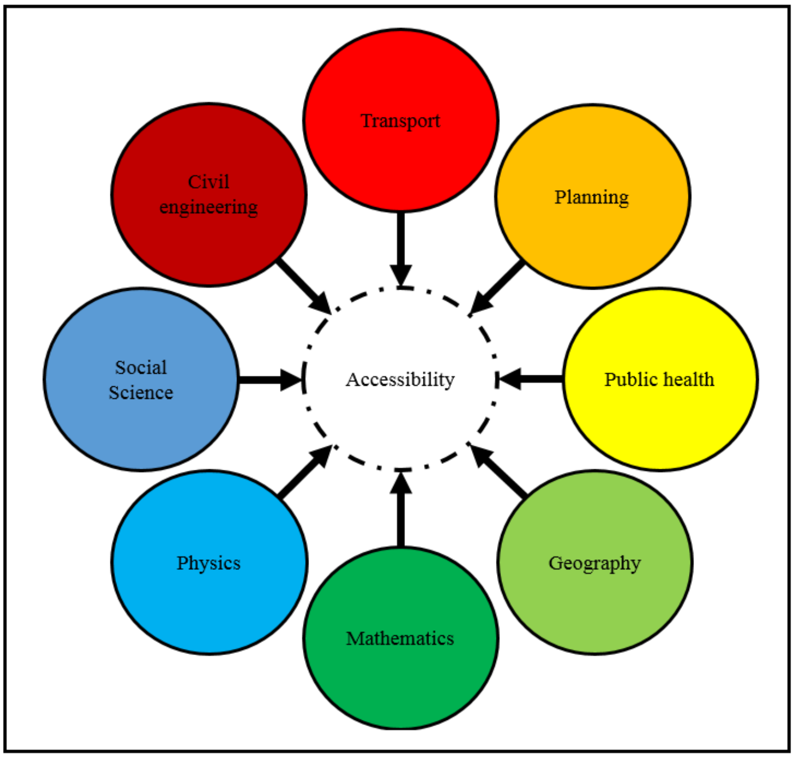


Figure 2-2 Study and Development of the Measures of Spatial Accessibility

Source: Geurs and van Wee, 2004

The population potential, or population over distance, was first discussed by Stewart (1942) as a generalised notion of accessibility. With regards to Stewart’s notion of population potential, in 1959, Hansen conducted empirical research on the topic of residential development patterns. Since then, many empirical studies have been conducted and new concepts have been developed. Moreover, the development of Geographic Information System (GIS) provided a new dimension in the development and application of spatial accessibility measures in many fields of study.

The literature shows that the terms ‘spatial accessibility’ and ‘spatial patterns of accessibility’ can be used interchangeably (Ikporukpo, 1987; Bailey and Phillips, 1990; Hays et al., 1990). However, most scholars use the term ‘spatial accessibility’ to refer to the ability to reach service locations (e.g. healthcare facility) from the potential location of the users (e.g. patient residence) via the transportation network, and the term ‘spatial patterns of accessibility’ to mean the spatial distribution of certain spatial accessibility measures.

2.2 Component of Spatial Accessibility

Geurs and van Wee (2004) described four related components that are used to measure accessibility of locations and a proposed framework to explain their interdependence with spatial accessibility.

A transport component that reveals the disutility that individuals or groups experience in travelling from their origin to destination by means of a specific transport mode, expressed in amount of time, cost and/or effort. This disutility emerges from the relationship between supply and demand. The supply of infrastructure includes its location and characteristics (e.g. maximum travel speed, number of lanes, public transport timetables and travel costs). The demand relates to passenger travel and freight travel.

A land-use component that reveals the spatial configuration of activities at destinations and the demand for those activities. In fact, it consists of (a) the amount, quality and spatial distribution of opportunities supplied at each destination (jobs, health, shops, social and recreational facilities, etc.); (b) the demand for these opportunities at origin locations (e.g. household locations); and (c) the relationship between the supply and demand for opportunities, which may result in competition for activities with restricted capacity, such as job and school vacancies and hospital beds.

A temporal component, which considers the time restrictions of individuals and the availability of activities at different times of the day. The temporal component reflects the time constraints, i.e. the availability of opportunities at different times of the day, and the time available for individuals to participate in certain activity (e.g. work, recreation).

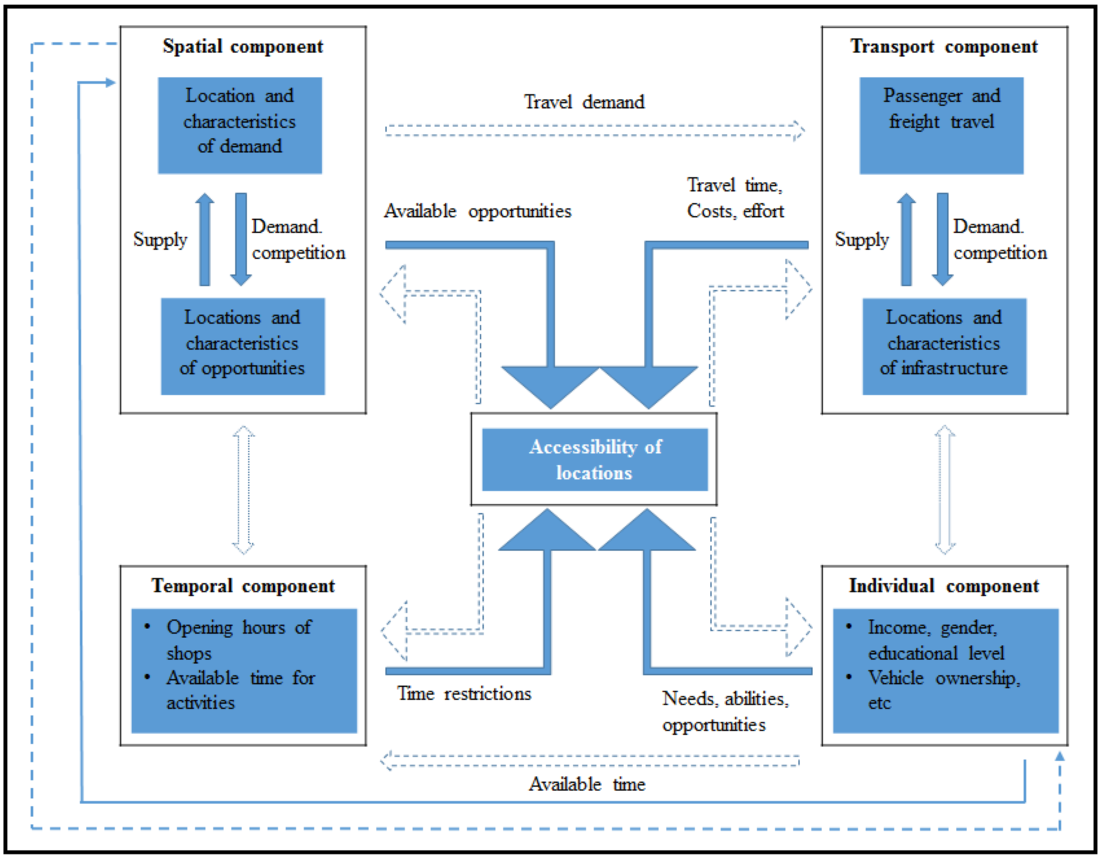


Figure 2-3 Relationship between Spatial Accessibility and its Components

Source: Geurs and Ritsema van Eck, 2001

An individual component that reflects the desires, abilities and opportunities of individuals. These characteristics influence a person's level of access to transport modes (e.g. the ability to drive and borrow/use a car, the ability to walk to a public transport stop) and spatially distributed opportunities (e.g. have the skills or education to qualify for a job near their residential area). Figure 2-4 illustrates the relationship amongst the four components and accessibility of locations.

2.3 Indicators/Measures of Spatial Accessibility

An indicator is a class, set or group of potentially observable phenomena that represents a conceptual definition (Walizer and Wienier, 1978). There have been several attempts to develop indicators and measures to evaluate accessibility to healthcare service. It is very common that the information used in the development of indicators of accessibility to healthcare service overlaps with information used in other social, economic and planning indicators. In fact, indicators are developed based on information which can be used to construct an index. For example, the Index of Multiple Deprivation 2000, also known as IMD2000, was developed by the British Government, based on six indicators of deprivation or domains. The IMD2000 was developed to determine which areas had poor geographical access. These areas were then categorised in terms of eligibility for funding. The indicators of the index included employment, resident income, health and disability, education skills and training, housing and geographical access to services. Straight line distances were calculated between the location of the population and some selected services to measure the geographical accessibility in the IMD2000. Overall, the IMD2000 was used to identify poor accessibility clusters and isolated locations where 29% of the population of England were resident (DETR, 2000).

The infrastructure-based accessibility, activity-based accessibility and utility-based accessibility measures are the three basic perspectives on measuring accessibility identified by Geurs and van Wee (2004). These perspectives are illustrated in Table 2-2 with regards to the component of accessibility described in the previous section. Each perspective is illustrated in terms of the component of spatial accessibility, i.e. transport component, land-use component, temporal component and individual component.

Table 2-2 Perspective on Accessibility Measures and Components

	Transport component	**Land-use component**	**Temporal component**	**Individual component**
Infrastructure-based measures	Travelling speed; vehicle-hours lost in congestion		Peak-hour period, 24-hr period	Trip-based stratification e.g. home-to-work, business
Location-based measures	Travel time and/or costs between locations of activities	Amount and spatial distribution of the demand for and/or supply of opportunities	Travel time and costs may differ, e.g. between hours of the day, between days of week, or season	Stratification of the population (e.g. by income, educational level)
Person-based measures	Travel time between locations of activities	Amount and spatial distribution of supplied opportunities	Temporal constraints and time available for activities	Accessibility is analysed at individual level
Utility-based	Travel costs between locations of activities	Amount and spatial distribution of supplied opportunities	Travel time and costs may differ, e.g. between days of week, or seasons	Utility is derived at the individual or homogeneous population group level

Source: Geurs and van Wee, 2004

2.4 Models for Spatial Accessibility Assessment

A multitude of spatial accessibility measures have been introduced over the last decades. Each measure is custom-made to a specific focus, level of aggregation, situational dataset and computational requirement. The literature sources have shown that, even though spatial accessibility measures can be grouped in a variety of manners (Guy, 1983**;** Church and Marston, 2003)**,** there are three common categories that stand out: cumulative, gravity and utility-based models. Spatial accessibility measures from each category have their own strength and weakness, which are discussed in this section.

One issue that is common to all three categories is aggregation. Spatial accessibility measures are prone to sensitivity loss when results are aggregated by transportation mode (Knox 1980) and zone system scale (Dalvi and Martin, 1976). For instance, when larger zone systems may be easier to work with, spatial accessibility measures tend to assume a greater level of population density and demographic uniformity. These assumptions can lead to biases, in most cases, by providing inaccurate results (Handy and Niemeier, 1997). It is, therefore, important, regardless of the chosen spatial accessibility measure to focus the study on a specific mode, a specific opportunity and a detailed spatial zoning system at the expense of data-intensive processes.

2.4.1 Cumulative Models

The simplest spatial accessibility measures to calculate are cumulative models, also characterised as isochronic or count models. Cumulative models measure the shortest distance that an individual should travel to arrive at the nearest activity opportunity. In other words, they estimate individuals' spatial accessibility to equate the cumulative number of activity opportunities within a specific distance or time frame from his/her location of origin. The travel times and distances are referred to as search-radius that can be calculated either as time travelled on straight-line distances between zones, and network distances to follow the shortest path between zones, or a combination of the two. For walking trips, assuming that travel is not restricted to pedestrian pathways, the best suited calculation is probably the straight-line distance. While, on the other hand, network distance may be ambiguous to define and calculate. However, for vehicular trips, the network distance can be the most realistic calculation, because it uses the road network between the two locations to represent travel times and/or distances. High levels of cumulative model spatial accessibility are illustrated by greater counts of the total number of activity opportunities or lower shortest time travel costs, depending on the specificity of the model under consideration.

Cumulative models are only responsive to two factors; network characteristics and shortest straight-line. For example, some important factors affecting individuals' choice of healthcare provider, like practitioner reputation or quality of care, are not considered in these models. Hence, these models provide a sense of scale of available activity opportunities, and have the benefits of minimal data requirement and straightforward interpretation. However, their relative simplicity is also their most limiting factor.

2.4.2 Gravity Models

Literature sources (Baradaran et al., 2001**;** Pirie, 1979) described gravity models as the most frequently used spatial accessibility measures. These measures share similarities with the transportation gravity models of the four-step planning model. For these measures, individuals' spatial accessibility is calculated as a function of activity opportunity attractiveness, and the travel distance between other zones and the individual's resident zone. The resulting spatial accessibility level is based on zones. There are many ways to describe a zone's activity opportunity attractiveness. The attractiveness can be described in terms of the number of facilities of each industry type, number of employees of each facility, square-footage of facilities, or even a scaled ranking. Like with the cumulative models, travel distances between zones can be calculated using straight-line or network shortest route. However, for gravity models, distances are scaled to "penalise" activity opportunities that are further away. The distances are scaled by an impedance factor that is often predetermined and can be region-, activity-, or trip-specific (Talen and Anselin, 1998). This results in higher gravity spatial accessibility levels; the closer individuals are to more attractive activity opportunities.

Beyond the fact that gravity measures are widely used (El-Geneidy and Levinson, 2006), there are many benefits in using them. These measures are relatively easy to interpret, they are based on widely available data, and require rather straightforward calculations (Baradara et al., 2001; Joseph and Bantock, 1982). Gravity models can also be accustomed to account for individuals' mode choices and travel distances on the mode-specific network (El-Geneidy and Levinson, 2006; Church and Marston, 2003). Despite the wide use of these models, they are not without shortcomings. The main aspects for which these measures fall short are, firstly, that gravity models assume that each destination location is equally attractive to all individuals (Church and Marston, 2003). Secondly, individual traveller behaviour and time constraints are not considered in gravity models (Baradaran et al. 2001). Finally, defining the impedance factor for different types of trips can be a difficult task (El-Geneidy and Levinson, 2006; Talen and Anselin, 1998; Iacono, Krizek and El-Geneidy, 2008).

2.4.3 Utility-based Models

Utility-based measures are, in fact, the most complex out of the three main approaches for measuring spatial accessibility. They are mainly different from the previous two regarding the fact that they incorporate individuals' behaviour and decision-making preferences into the spatial accessibility formulation. There are two ways for calculating individuals' spatial accessibility using these models; either the level of utility (satisfaction) derived from their preferred activity opportunity, or the average of their utilities for all activity opportunities. Models that weight various characteristics of trips, to reach activity opportunities by individuals' perception of importance, are used to calculate this utility. These characteristics are derived from travel survey responses. For example, a basic factor across spatial accessibility models, like the travel distance between an individual's origin zone and activity opportunity zone, can be weighted differently for an elderly person and a teenager to reflect potential differences in perception across age ranges in how vexing traveling long distances is for them. Nevertheless, higher levels of spatial accessibility are reflected by higher individual's calculated utility. Additionally, utility-based models are often included as part of larger micro-simulations that predict individuals' travel patterns in relation to traffic conditions and regional development (Lamondia, 2010).

The fact that individuals' spatial accessibility is calculated based on their preferred activity opportunity, instead of just the nearest one, is the main benefit of utility-based models. These measures acknowledge that just because an activity opportunity is situated nearby does not, necessarily, mean that it contributes to spatial accessibility if the individual does not prefer to go there. Although utility values are unitless abstract numbers, utility-based spatial accessibility measures are not too difficult to interpret. Furthermore, utility models also integrate costs effectively and can be used to translate the spatial accessibility measures into monetary values that are easy to understand and use (Iacono et al., 2008). Because they are model travel choices at the individual level, utility-based spatial accessibility models are more representative measures of the individual's actual choices, as opposed to assuming that everyone has similar preferences and behaves identically (Baradaran et al., 2001; Iacono et al., 2008). These models remove most of the assumptions present in the previous two models. Unfortunately, however, utility-based models have a major disadvantage, which is complex to develop. They require extensive data collection of individuals' travel patterns and opinions, which can be difficult and expensive to obtain (Baradaran et al., 2001).

2.5 Health and Healthcare challenges in South Africa

This section provides an overview of the health sector and healthcare challenges in South Africa based on recent literature. It presents an historical development of the health sector, key figures on government expenditures in the health sector, as well as the challenges and burden of diseases faced by the people of South Africa.

2.5.1 Historical development

In order to understand current health challenges in South Africa it is important to look at its history, because it had a profound effect on the current health of people, as well as the health policy and services (Coovadia *et al.*, 2009). Table2-3 shows some key developments in South Africa's healthcare sector over different periods in history. Early development of the healthcare system in South Africa was mostly centered around the development of a hospital-based system. the hospital-based system was designed to offer basic and specialized public healthcare. During the apartheid era, the healthcare sector was characterized as poorly organized, highly fragmented, and deregulated. Because of a political ideology based on racial segregation, basic healthcare remained out of reach for most of the population for a prolonged period.

The roots of a dysfunctional health system and the collision of the epidemics of communicable and non-communicable diseases in South Africa can be found in policies from periods of the country's history, from colonial subjugation, apartheid dispossession, to the post-apartheid period (Delobelle, 2013). Racial and gender discrimination, the migrant labor system, the destruction of family life, vast income inequalities, and extreme violence have all formed part of South Africa's troubled past, and all have inexorably affected health and health services.

Table 2-3 Historical development in the health sector

Year/period	Key development
17th – 18th centuries	Hospital care was provided by the Dutch East India Company, colonial governments, and Christian missions. Traditional healers, European trained doctors, missionaries, and other health providers offered a mixed range of services.
19th Century	Medically trained doctors became mainstream. Indigenous and traditional healers were marginalized. Orthodox medicine became a professional practice with the training of nurses and doctors. By mid-century, hospitals were present in most major centers. South Africa was hit by epidemics of syphilis, tuberculosis, bubonic plague, yellow fever, typhus, cholera, soil parasites, and malnutrition.
1910 – 1948	The Union of South Africa was established. Health services were fragmented among the four provinces. Poor urban working and living conditions with diseases were caused by overcrowding, poor sanitation, and diets, stress, and social disintegration following the consolidation of racial segregation. Syphilis, tuberculosis, malaria and venereal diseases continued to spread.
1948 – 1994	Apartheid years. Non-communicable diseases rose in white settlements and poverty-related diseases persist in black settlements. Tuberculosis rates and deaths were much higher among Black and Coloured populations groups than among Whites. Health services in Bantustans were systematically underfunded.
1994 - present	Post-apartheid democracy. Today, the public system serves most of the population, but it remains underfunded and understaffed. The wealthiest 20% of the population use the private system and are better served. Diseases of poverty, non-communicable diseases, and HIV/AIDS comprise a huge burden for South Africa.

Source: "The health and health system of South Africa: historical roots of current public health challenges" (PDF). Retrieved 15 September 2019.

2.5.2 Government expenditure

The National Department of Health (DoH) is responsible for policymaking, coordination, and oversight of healthcare services in South Africa, while the nine provincial departments bear the responsibility for service delivery. The DoH derives its mandate from the National Health Act of 2003. The National Health Act states that the department provides a framework for a structured and uniform health system for South Africa. Furthermore, it sets out the responsibilities of the three levels of government in the provision of health services.

Table 2-4 shows that the NDoH and the nine provincial health departments were projected to spend R183 billion in 2017/18. Provincial health departments spend the largest percentage of combined health funding (97.2%), while the NDoH is allocated 2.8 percent of the combined health budget once the grant transfers to provinces are achieved.

Table 2-4 Government expenditure in the health sector, 2017

Department	National	Provincial	% of Total
National Department of health	42 625 700		23,3
…of which transferred to provinces	-37 52 392		-20,5
Combined provincial health		177 767 845	97,2
Eastern Cape		21 707 165	11,9
Free State		9 774 916	5,3
Gauteng		40 207 046	22,0
KwaZulu-Natal		39 440 865	21,6
Limpopo		18 042 777	9,9
Mpumalanga		12 020 037	6,6
Northern Cape		4 433 893	2,4
North West		10 461 340	5,7
Western Cape		21 679 806	11,9
Total health budget	182 873 153		100

Source: Estimates of National Expenditure 2017 and Estimates of Provincial Revenue and Expenditure 2017

2.5.3 Challenges and the burden of disease

The current government's 2014-2019 Medium Term Strategic Framework highlighted in Outcome 2 the promise of a long and healthy life for all South Africans. The DoH is a direct contributor to the realization of this goal. Alongside the vision of the National Development Plan (NDP) of ensuring a long and healthy life for all South African, the DoH is committed to achieving four main outputs: increasing life expectancy, decreasing maternal and child mortality, combating HIV/AIDS and tuberculosis (TB) and strengthening health system effectiveness. These goals ought to be achieved by strengthening the institutional vehicle for the delivery of public healthcare and district hospital services by national legislation (Department of Health, 2019).

The outflow of skilled health practitioners was a trigger to the challenges faced by South Africa's healthcare sector. Between 1989 and 1997, an estimated 250 000 skilled health practitioners left the country for New Zealand, Canada, Australia, the UK and the USA (Padarath *et al.*, 2004). In 2001, there were more than 4 000 vacancies for doctors, as well as an excess of 32 000 vacancies for nurses countrywide (Hall and Erasmus, 2003). This was detrimental to South Africa's healthcare sector. The country's healthcare sector was negatively impacted by the migration of skilled workers toward more developed countries, which was further aggravated by a loss in training investment estimated at US$5 billion alone (Padarath *et al.*, 2003). Human resources loss associated with the migration of healthcare practitioners was driven by several 'push' and 'pull' characteristics that emanated from 'origin' and 'destination' countries respectively. Typical 'push' characteristics at the source of this phenomenon were: low remuneration and salaries, inadequate working conditions, lack of opportunities for professional development, and personal safety (Awases *et al.*, 2003), or external factors to the healthcare system, such as quality of life, social and political security, and education opportunities. 'Pull' factors, on the other hand, included: improved standards of living, working conditions, nurse staffing ratios, and career prospects (Kline, 2003). However, migration of skilled practitioners in the healthcare sector cannot only be attributed to the prospect of higher pay and better work conditions overseas, but also dissatisfaction with the socio-economic climate, and level of crime (Lehmann and Sanders, 2003).

Since 2011, the DoH published a strategic framework to face the human resources crisis in the country. The strategy advocates improved production and retention of healthcare practitioners as critical to a successful outcome, in particular regarding accessibility in rural and remote areas, based on revitalized education, training, and research, including development of

Academic Health Complexes; creating an adequate infrastructure for workforce and service development; improving human resources management; improving workforce flexibility, planning and information; ensuring professional quality care; and implementing sound leadership, governance, and accountability. The framework was determined by epidemiological indicators, which include child and maternal mortality, and by National health policy priorities. It includes refinement of the human resources plan, the reopening of nursing schools and colleges, human resources recruitment and retention, a focus on the training of public healthcare personnel and mid-level practitioners, assessment and review of related grants, and integrating and standardizing community health practitioner categories. The priorities are embedded in the National health policy to comprehensively repair the health system through public healthcare re-engineering and development of a National Health Insurance (NHI) as the primary financing mechanism.

Life expectancy at birth is also a serious concern for the people of South Africa. It was estimated at 61,1 years for males and 67,3 years for females, according to Statistics South Africa in 2018. Infant mortality rate declined from an estimated 53,2 infant deaths per 1 000 live births in 2002 to 36,4 infant deaths per 1 000 live births in 2018. Likewise, the under-five mortality rate declined from 80,1 child deaths per 1 000 live births to 45,0 child deaths per 1 000 live births between 2002 and 2018.

The HIV/AIDS epidemic has had a devastating impact on South Africa. It represents the highest level of HIV infection in sub-Saharan Africa. The total number of persons living with HIV in South Africa increased from an estimated 4,25 million in 2002 to 7,52 million in 2018, according to Statistics South Africa's mid-year population estimates 2018. Approximately 13,1% of the total population was HIV positive in 2018. In 2018, roughly one-fifth of South African women in their reproductive ages (15 – 49 years) were HIV positive.

However, among the youth aged 15 – 24, the HIV occurrence has reduced over time from 6,7% in 2002 to 5,5% in 2018. It is important to note that the number of AIDS-related deaths consistently declined since 2007. It declined from 276 921 in 2007 to 115 167 in 2018. This achievement can be attributed to the increase in access to antiretroviral (ARV) treatment. Access to ARV treatment has changed historical patterns of mortality (Department of Health, 2019), by expending the lifespan of many people in South Africa, who would have otherwise died at an early age. Although the epidemic has stabilized in recent years, the country continues to bear a large share of the burden of disease.

The TB burden is another major challenge for South Africa's healthcare sector. It can be attributed to historical neglect and poor healthcare management systems, intensified by the legacy of fragmented healthcare services. Although a National TB control program was put in place from 1979 to attempt to coordinate healthcare service delivery under the previous healthcare system, it was proven to be inefficient across eighteen different health departments (Edginton, 2000). National TB review conducted in 1996 with support from the World Health Organization (WHO) indicated that despite a theoretical commitment and the availability of an excellent healthcare infrastructure and resources, National and Provincial departments had failed to adequately respond to the TB epidemic (Edginton, 2000).

In March 2000, the DoH signed the Declaration of Amsterdam to stop TB, as one of the 22 high burden TB countries (Department of Health, 2007). The Declaration called for an accelerated expansion of control measures for TB and for increased political commitment and financial resources to reach the targets for global TB control by 2005, which was restated for WHO member states by the World Health Assembly in May 2000 (Lee *et al.*, 2002). Comprehensive programmatic management of patients with TB became national policy, and complete coverage was achieved in all districts of the nine provinces by 2003 (Weyer, 2007). However, despite these efforts, TB incidence increased from 269 per 100 000 in 1996 to 720 per 100 000 in 2006 (Department of Health, 2007). During that period, mortality rates due to TB nearly doubled.

Furthermore, the rise of chronic or Non-Communicable Diseases (NCDs), which include cardiovascular diseases, diabetes, cancer, chronic respiratory disease, and mental illness, affects the quality of life and increases healthcare expenses both at personal and community level (Bradshaw *et al.*, 2011). NCDs affect the workforce and productivity of the population. In South Africa, higher mortality from NCDs was found amongst the poor (Vorster, 2002), and people in disadvantaged communities were more likely to be exposed to defined NCD risk factors, such as second-hand smoke, excessive alcohol use, and indoor air pollution, as well as suffering from asthma (Bradshaw and Steyn, 2001).

Violence and injuries also contribute to the challenges of healthcare in South Africa, with young men aged 15 – 29 years old, excessively involved in violent acts both as victims and perpetrators (Coovadia *et al.*, 2009). Half of all female homicide victims are killed by their intimate male partners, and South Africa has a terrifyingly high rate of female rape (Seedat *et al.*, 2009). Social determinants of violence and injuries include poverty, unemployment, patriarchal notions of masculinity, vulnerabilities within families, exposure to violence during childhood, widespread access to firearms, alcohol, and drug abuse. In turn, these social determinants contribute to the burden of serious health problems, such as HIV and sexually transmitted infections (STI), substance abuse, and common mental disorders, including post-traumatic stress disorder, depression, and suicidal behaviour (Seedat *et al.*, 2009). Therefore, the prevention of violence and injuries remains a national health priority.

Altogether, the above described the constituents for the burden of disease in South Africa. There is a strong need for a broad range of interventions to face this burden of disease. These interventions should include improved access to healthcare and promotion of healthy lifestyles, as well as ensuring that basic needs, such as water, sanitation, and safety are met. In summary, although the restructuring of the healthcare sector post-1994 has achieved substantial improvements in terms of access, health management rationalization and equitable health expenditure, the early gains have gradually eroded by the increasing burden of disease due to HIV/AIDS, weak healthcare systems management, and consistently low health practitioner's morale (Harrison, 2009). The government's challenges are therefore to improve the quality of healthcare service delivery, and to address healthcare management issues nationwide. The decision taken by the government to implement an ambitious process of re-engineering the healthcare sector may prove to be both timely and crucial in this regard.

2.5.4 Inequalities in Access to Healthcare services

Inequality in access to healthcare is an important concern for health policy in South Africa. Because health status influences the human capital acquisition, economic status and the inter-generational transmission of socioeconomic status, access to healthcare plays a role in determining and reinforcing other measures of inequality (Yazbeck, 2009; Wilkinson and Pickett, 2010). In post-apartheid South Africa, the government has emphasized equity and made access to clinics the centrepiece of primary healthcare (Gilson and McIntyre, 2007; Harris *et al.*, 2011; Burger *et al.*, 2012). It is therefore important to understand which members of the population benefit from healthcare services and who is being left behind (Yazbeck, 2009).

Access to healthcare services is particularly prominent in places where policies have historically privileged certain groups over others, leaving behind large gaps in health status that current policy must consider (McLaren *et al.*, 2013). These gaps depend on a complex set of characteristics among demographic factors, spatial components, and institutional constraints.

These factors are particularly important in South Africa because the legacy of apartheid leaves non-whites in remote areas, which are potentially underserved (Harris *et al.*, 2011).

Even when health services are provided free of charge, monetary and time costs of travel to a local clinic represent the price of access to healthcare (McLaren *et al*, 2013). These costs may pose a significant barrier for vulnerable segments of the population, leading to overall poorer health. Even twenty years after the advent of the post-apartheid era, residential location remains largely racially defined and this residential segregation can exacerbate barriers if healthcare facilities are located far from non-White neighbourhoods (Christopher, 2001). Travel costs in South Africa are particularly high relative to other developing countries in Africa and elsewhere, which means that small differences in the distance can translate into large differences in access (Klasen, 1997).

In the literature, several studies have shown that the distance people need to travel to healthcare facilities is a key indicator of the level of access to healthcare services. There are considerable differences in households' proximity to healthcare facilities between rural and urban areas, across provinces and between socio-economic groups in South Africa (Harris *et al.*, 2011). (McLaren *et al*, 2013) investigated the role of distance to the nearest healthcare facility on patterns of healthcare utilization and found that ninety percent of South Africans lived within 7km of the nearest public clinic, and two-third lived less than 2km away. (McLaren *et al*, 2013) also found that 15% of Black African adults lived more than 5km from the nearest facility, in contrast to only 7% of Coloureds and 4% of Whites. McLaren ZM *et al* (2014); Harris *et al.*, (2011), obtained similar finding from an analysis of the 2008 National Income Dynamics Survey (NIDS), where 20% of the lowest income quintile lived more than 5km from the nearest clinic compared with only 5% of the richest quintile.

The likelihood of using a health service is far lower for those living furthest from health facilities (Harris *et al.*, 2011). (Tanser *et al*, 2006) conducted a detailed survey combined with a geographic information system analysis in the Hlabisa sub-district of KwaZulu-Natal and found that households within 30 minutes of a clinic were 10 times more likely to make use of a clinic than households having to travel for 90 – 120 minutes to a clinic. Such inequalities persist even concerning critical healthcare services, where lack of access can often have serious consequences for premature death, such as attended deliveries. (McLaren *et al*, 2013) analyzed the NIDS data and found that children in households that lived more than 2km from the nearest clinic were 8% less likely to have had a doctor or nurse present at birth than those with 2km of a clinic.

2.6 Synthesis of Spatial Accessibility to Medical Services

This section presents a synthesis of recent academic research that was conducted to analyse access to medical health services in the **Western Cape Province** of South Africa. This synthesis provides an indication of the general trend of research on health facilities services and accessibility issues for the Western Cape. This synthesis is based upon three research theses that were completed at the Department of Civil Engineering at the University of Cape Town. A common aspect of the three theses under review was that the authors attempted to evaluate levels of accessibility to medical health services in the Western Cape. They did so by presenting distinct methodological approaches.

Firstly, a thesis that analysed medical facilities' Golden Hour service areas, and their relation to high-accident zones was reviewed. Here the Golden Hour was referred to the first hour after a traumatic injury, when emergency treatment is most likely to be successful. Amongst its objectives, McKune (2013) aimed to determine the service areas for emergency medical facilities and identify service gaps in the Western Cape. He concluded that the high fatality rate observed was due to a lack of road safety measures in the country and that certain programmes were in place to address the issue. The high rate of fatalities was mainly attributed to three factors: the lack of service areas along the route, the high number of fatalities in densely populated areas where there is a combination of slow and fast-moving traffic, and the limited number of overtaking opportunities along certain routes. Upon investigation of the effect of other influential factors on service areas, it was found that 10 of the existing 44 EMS stations in the study area provided absolutely no Golden Hour serviceability to the surrounding areas. In order to improve post road-accident trauma care, McKune (2013) recommended that the location of EMS facilities needed to be optimised to provide more 'Golden Hour' serviceability. Furthermore, that the provision of more infrastructure, in the form of new 'definitive care' medical facilities, new EMS stations and new ambulances, should be considered.

McKune (2013) used an infrastructure-based approach to model spatial accessibility to EMS facilities from the location of recorded fatal accidents. He investigated whether the EMS supply could meet the demand for post road-accident trauma care in the case study area. The transport component of his analysis was the travelling speed of emergency vehicles (ambulances) along the road network and the temporal component was governed by the Golden Hour principals and included a sequence of events that were bound to happen from the time an accident occurred to the arrival of EMS on the scene. The trip-based stratification only considered trips from the scene of an accident to the location of EMS. McKune's research was supplemented by Birungi (2014) who investigated a location-allocation optimisation model for ambulance shelters and hospitals to minimise response time to accident hotspots in the Western Cape. To maximise service coverage of the study area within the Golden Hour, accessibility of the area was analysed to identify potential areas that are service deficient. Birungi's research presented a methodological approach to solving a coverage problem which was applied using scenarios with different strategies. The scenarios were: (1) the expansion with 16 hospitals and 10 ambulances, (2) the relocation of all ambulances, shelters and hospital locations, (3) and relocation of all ambulances, shelters and expansion with 16 hospitals. She compared the results of the scenarios to assess their prospects for improvement of accessibility.

Both researches mentioned above investigated the spatial distribution of EMS services to compute their accessibility measures at the provincial level. Van Cuyck (2015), however, applied a methodology to compute a rural accessibility index to a variety of opportunities, including medical health services at the district municipal level. The said methodology was developed by Vanderschuren et al. (2013). The Cape Winelands District Municipality was the case study for the research. Van Cuyck's (2015) approach was a utility-based perspective where he used a closed-ended questionnaire to survey 74 households within CWDM. The transport component for his study was travel time between locations of activities. The land-use component was the amount and spatial distribution of supplied opportunities, and the individual component was the utility derived at population group level. Subsequently, the primary data from the household survey was computed in ArcGIS, a geographical analysis software, where an Inverse Distance Weighting interpolation tool was used for the various activity opportunities under investigation to create accessibility indices. The subsequent accessibility indices were assigned weightings and summed up to formulate a final rural accessibility index that was used to assess the accessibility deprivation in the CWDM. His research revealed that the CWDM, in general, had relatively good accessibility, most rural settlements and towns along the N1 corridor had moderate to good accessibility and the Drakenstein LMhad the worst accessibility in the CDDM. Although the results of his study were not a true representation of the area, the interpolation rendered was relatively accurate when compared to literature about the area, and in the majority of urban centres accessibility inequality was evident in the lower income areas with increased travel times. His map of the accessibility to medical service showed that settlement/ towns in the North-Western, Western and South-Eastern regions of the CWDM had relatively poor levels of accessibility with the longest travel time amounting up to 150 minutes.

Each research, summarised above, presented a genuine approach to characterise accessibility levels to health services in the Western Cape. Van Cuyck (2015) investigated accessibility issues at the finer level of district municipalities, for various activity opportunities, and developed a rural accessibility index for the region. While McKune (2013) and Birungi (2014) investigated the services area coverage of EMS facilities to road fatalities and accidents at the provincial level and, subsequently, a location-allocation optimisation model for ambulance shelters and hospitals to minimise response time to accident hotspots within the Golden Hour. However, none of these researches considered neither the population distribution, including socio-economic factors with respect to various types of healthcare services, nor the use of different transport modes, nor even the effect of increasing travel distances and time when characterising accessibility to medical health services in the Western Cape. Further research could allow for more complete, rapid and efficient computation and implementation of accessibility indices on a national scale. The methodology for investigation is presented in the following section of this thesis to attempt to fill this knowledge gap and advance understanding in the study of accessibility to healthcare services in the Western Cape.

Chapter 3: Methodology of GIS Based Transport Assessment

The purpose of this chapter is to present an argument that explains how the research approach and methods fit alongside the overall research problem and purpose. The chapter describes the GIS-based research methodology developed for characterising spatial disparities in access to primary healthcare facilities in terms of the spatial distribution of potential users, healthcare facilities and transport infrastructure. This chapter also describes the research approach for identifying local communities for whom spatial accessibility to healthcare facilities is relatively poor. The essential steps of the methodology followed, to achieve the objectives of this study, can be illustrated in the form of a flow diagram, shown in Figure 3-1.

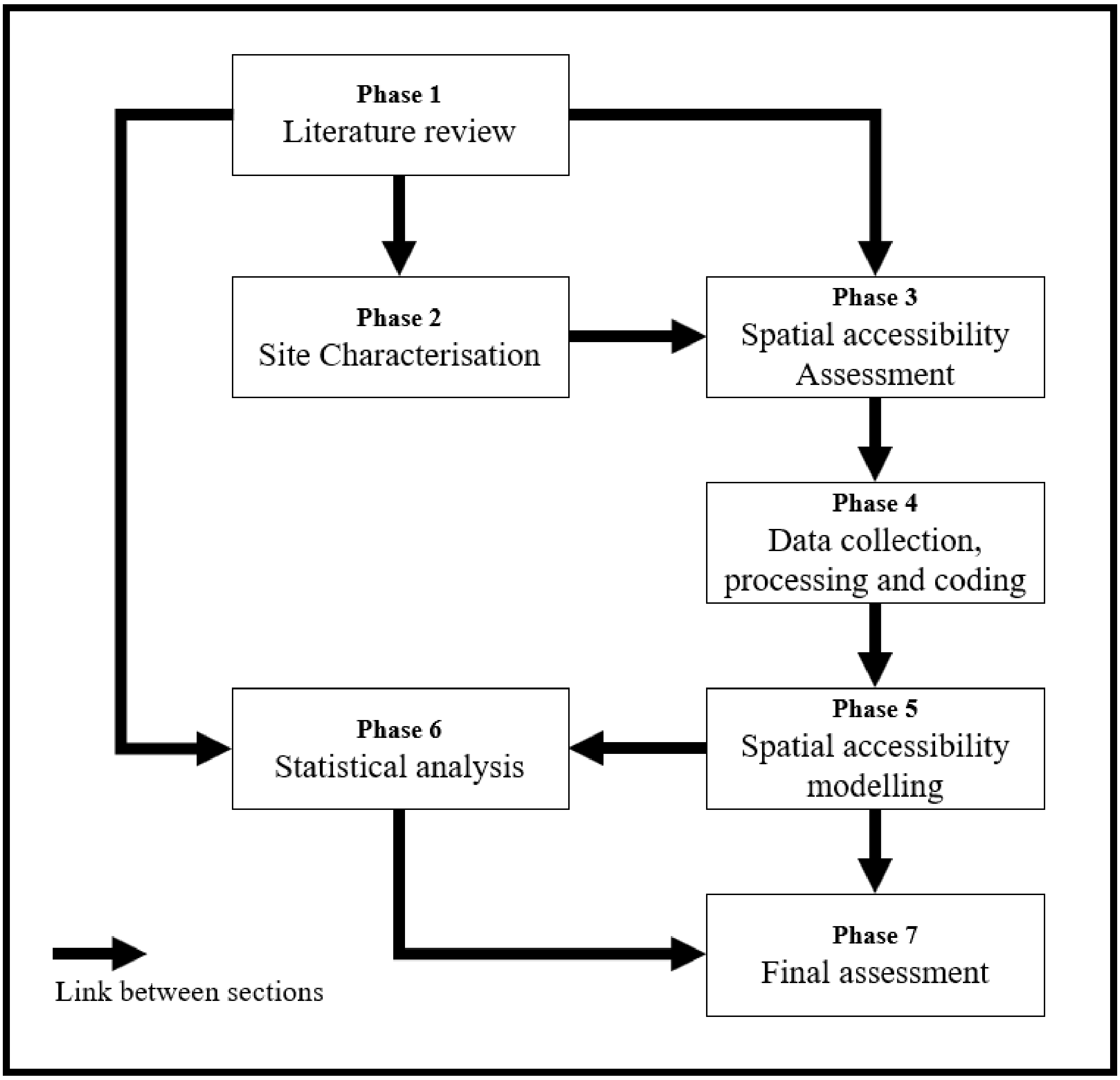


Figure 3-1 Framework of Methodology

In Figure 3-1, each block represents a section of the study under investigation and the arrows indicates that insights were carried to the next section. The literature review provided the theoretical background necessary to develop a method of investigation for this research. It established the relevance of research that was conducted to date. Previous research on the case study area was also reviewed and the methods of assessment for spatial accessibility were derived from the literature. Insights from the spatial accessibility assessment were crucial in determining the relevant means for data collection and processing tools for the case study area. A multitude of spatial accessibility measures were introduced over the past decades and each measure is custom-made to a specific focus, level of aggregation, situational dataset and computational requirement. The availability of data and processing tools made it possible to model spatial accessibility for the case study. A set of Cumulative and gravity models was analysed, statistically compared and considered for the final assessment of spatial accessibility in the case study.

This chapter also provides some clarification of key concepts and definitions of relevant terms used in this thesis and continues with a discussion to justify the claims around the theoretical stance, research design and data collection used for the research. It does so by presenting two sections with a content that relates to the flow diagram in Figure 3-1. The first section covers issues that address the considerations for selecting the spatial accessibility model used. This section assembles the building blocks for the spatial accessibility assessment derived from the literature review and the specifics of the case study. The second section covers all data requirements of the study, data collection and preparation, as well as the development and application of geoprocessing and spatial analytical procedures, and the steps involved in the generation, evaluation, refinement, and final assessment of the outputs.

A breakdown of the methodology followed in this research project can be found in Table 3-1

Table 3-1: Breakdown of Methodology

Phase		Methodology
1	Background research	• Literature pertaining to accessibility indicators was reviewed • Key Performance Indicators (KPIs) were identified from a rural accessibility index framework identified in literature • The need for establishment of a Accessibility Index was identified • Analysis tools were identified
2	Site characterisation	• The study area was described and researched • Various municipal documents were consulted in relation to the study area • Identification of site characteristics and selection of analysis zones
3	Spatial accessibility Assessment	• KPAs and KPIs were used to identify key data requirements • Past studies were reviewed from the literature • Accessibility measures were selected on compatibility with KPAs and KPIs
4	Data collection, processing and coding	• Data collection was conducted • Data processing and coding was completed using a Microsoft Access database • Excel data sets were generated from Microsoft Access database
5	ArcGIS modelling and data analysis	• Excel data sets were converted point data and added to the ArcGIS software • The Inverse Distance Weighting interpolation tool was used to generate AI maps • Variable Search Radii were used to generate AIs for statistical analysis
6	Statistical analysis	• ArcMap was used to generate points within the study area • Values from raster cells were given to the points to create comparable data sets • A *t*-test and p-test was performed on the three different data sets
7	Final assessment	• Results of the various models and analyses were presented • Conclusions were drawn based on results • Recommendations were made about observations and further research

3.1 Spatial Accessibility Assessment Process and Model Formulation

As revealed previously, spatial accessibility measures are more meaningful and accurate when they focus on a specific transport mode, activity opportunity and spatial zoning system. In this study, the case of Cape Winelands District Municipality in the Western Cape Province was considered to quantify and measure individuals' access to primary healthcare services for two specific modes: walking and private vehicle.

To evaluate the region's accessibility, spatial data was collected from a variety of sources and compiled in ArcGIS Desktop. The zone system for CWDM was obtained from the Environmental Systems Research Institute (ESRI). Its associated census demographic database was acquired from Statistics South Africa. Cape Winelands administrative zoning records, road network, point locations of public healthcare facilities and public healthcare facilities footprints were then obtained from the Western Cape Government Department of Transport and Public Works. Finally, a search was conducted on the website, Yellow Pages South Africa, to obtain addresses for private healthcare services in the region. Secondary data on demographics in the case study was acquired from the National Households Travel Survey (NHTS) 2013.

Demographic data and healthcare service addresses were captured in Microsoft Excel Spreadsheet format, to later be used to create the necessary points data for the GIS model. The complete spatial primary healthcare service region dataset was compiled through several steps.

All spatial data was combined and projected to the Transverse Mercator LO 19 South African Coordinated Reference Systems (CRS) to ensure that any spatial calculations were accurate and constant. The result was a conformal projection that does not maintain true directions, with the central meridian placed in the centre of the region of interest to minimise distortion of all spatial properties in the region.

The 2011 Census demographic data was joined to the zone system. Then the zoning data was aggregated into three zoning types required by the accessibility measures. The zoning types were classified as per the Western Cape Government administrative zoning as regional settlements, local towns and hamlets. The land covered by census block groups inside CWDM, that lacked zoning type, were assigned the hamlets zone type.

For measuring and mapping spatial accessibility, as well as identifying disadvantaged locations and communities, spatial characteristics, such as zone areas and inter-zonal distances, were calculated. This required that the polygonal shape of zones was converted to point data first.

TAZs surfaces were converted using the coordinates point of centroid for each zone. Then, distances (in meters) and travel times (in seconds) were calculated from these zone centroids to every other zone centroid, and to the nearest primary healthcare facility. The data was, finally, exported and three accessibility measures were calculated for each zone in the CWDM service region.

3.2 Process and Assessment of Spatial Accessibility Models

This section presents the procedure followed for data collection and sampling, as well as the three accessibility measures that were selected to characterise CWDM individuals' accessibility to primary healthcare. These measures denote frequently used forms of the previously discussed cumulative, gravity and utility-based models. These measures were all computed at the zone level which, in this research, correspond to census block groups. Finally, the spatial accessibility measure results were mapped and compared, and prediction evaluation and environmental justice inequality statistics were also used to compare the distribution of spatial accessibility in the region.

3.2.1 Data Collection and Sampling

The required data was collected using the various sources described previously. Table 3-1 summarised all data requirements with the respective sources that were used to collect them.

Table 3-1 Data Requirements of Study

Data	Sources
Demographic census data	Statistics South Africa
Demographic secondary data	National Households Travel Survey (NHTS, 2013)
CWDM Zones System	Environmental Systems Research Institute (ESRI)
Transportation networks	WCG Department of Transport and Public Works, Open Street maps (Open source)
Public healthcare services	WCG Department of Transport and Public Works
Private healthcare services	Yellow Pages South Africa
Primary healthcare facilities square footage	Google Earth

Assuming 0,77 physicians per 1 000 people in South Africa from the World Development Indicators Database (2017), and a population of 787 490 people in CWDM, the estimated total number of physicians was 606 doctors. It was not feasible in terms of the research purposes to search and find all private healthcare services in CWDM. The large study area and limited data sampling methods only required that a limited number of private healthcare services be selected. The samples were randomly drawn from a spatial frame covering the entire CWDM. (Cochran, 1977) explains that, compared to a complete enumeration, sampling based on statistics creates benefits that lead to a short survey period, reduced costs, greater scope and a loss of accuracy that is deemed negligible. Hence, the next step was to calculate the minimum sample size (number of private healthcare services) required to carry on the research.

Confidence level and accepted Margin of Error (MoE) were the statistical tools used to determine the required minimum sample size for private healthcare services for CWDM. The calculated minimum sample size represents the minimum number of private healthcare services required for the online search. For a confidence level of 95%, with a margin of error set at 5%, the minimum of private healthcare to search for online was calculated to be 14, using equation:

$$n = \frac{Z^2 p(1-p)}{a^2} \tag{1}$$

Where:
n represents the calculated minimum sample size,
Z represents the level of confidence value, a value of 1,96,
p represents the probability, a value of 0,5 was used, and
a represents the margin of error, a value of 0,05 was used.

3.2.2 Spatial Accessibility Calculation Process

Seven steps were used to describe the process of calculating spatial accessibility for this study. This process was used across software environments, including ArcGIS Desktop, Visual Basic of Applications, Microsoft Excel and the internet for the research outcomes. It is essential to understand that the flow through the steps is not, necessarily, performed in the order specified below. Certain steps can be performed as pre-processes or in a different order to the suggested one. However, all steps must be considered, to some extent, to obtain a comprehensive, complete and effective calculation solution for large source datasets. The steps are:

- Import the network,
- Add a spatial index,

- Connect points to the network,
- Build topology in the network,
- Generalise the network,
- Perform network search, and
- Export the results.

Import the Network

A network, when distributed from the network producers, is often delivered in an unstructured format. In this case, unstructured meant that no spatial index or topological connections between objects were included. Selecting parts of the geometry and changing attributes with ArcGIS Desktop was a necessary task because of the format in which Network data was the delivered.

The demands on the attributes on the network increase when the spatial accessibility analysis application uses advanced functions, such as one-way roads and turning restrictions. For spatial accessibility measures that use time, the network needs to contain information about the travelling speed on the road segments. This is usually given by assigning a class to each road segment and a description of each class with the delivery, so that it is up to the user to allocate a speed to each network segment class.

Add a Spatial Index

The network imported in the previous step required to be complemented with a spatial index. As with any index, the spatial index is a way of structuring data for efficient retrieval at later stages of the study. This means that the actual dataset was sorted in a way to make fast searches possible within the dataset. This was performed by building a separate data structure with the purpose of pointing at an already existing dataset. In object-oriented programming, a class is an extensible program-code (template) for creating object, providing initial for state (member variables) and implementations of behaviour (member functions or methods) (Bruce 2002).

Connect Points to the Network

To create network datasets, edge and junction elements are created from source features. Ensuring that edges and junctions are formed correctly is important for accurate network analysis results (ESRI 2017). Connectivity in a network dataset is based on geometric coincidences of line endpoints, line vertices and points, as illustrated in Figure 3-2. The connectivity rules were applied to meet the requirement of the network dataset for analysis.

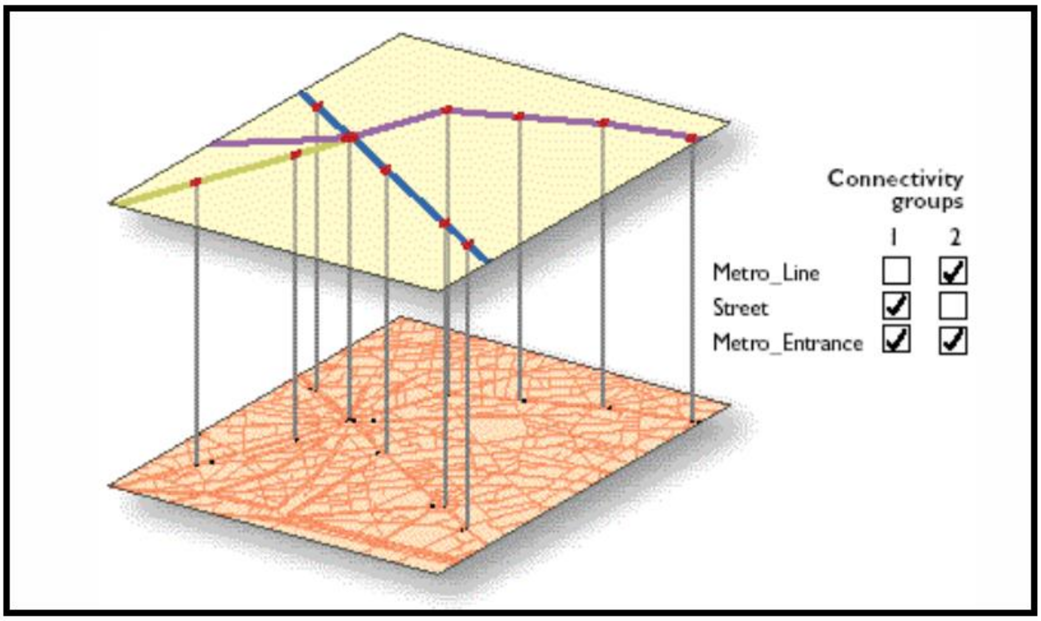


Figure 3-2 Illustration of Network Connectivity in ArcGIS Environment

Source:(ESRI 2017)

Build Graph Structure from the Network

A graph structure was built from the unstructured network. The graph structure consists of nodes and edges. Each node knows what edges are connected to it. Each edge knows what nodes are connected to the ends of the edge. An adjacency matrix was used for sorting these connections.

It is important to use an effective structure to describe the graph. If the size of the graph is minimised, larger geographic areas can be held in the internal memory, at the same time, and this leads to less reading and writing to a secondary memory during a calculation that covers a large geographic area (Dahlgren, 2008).

Generalise the Network

This step begins when the source data is a graph with connected points. The network, supposedly, contains unnecessary information that can be removed before proceeding with the computations. Figure 3-3 shows an illustration of an original network before the generalisation, and Figure 3-4 shows the same network after dangling and internal nodes were removed.

Instead of letting the geometry of network describe the distances between the nodes it is more convenient to remove all internal nodes and store the distance as an attribute of the edges. Note that for time values a valid speed table must be available at this stage.

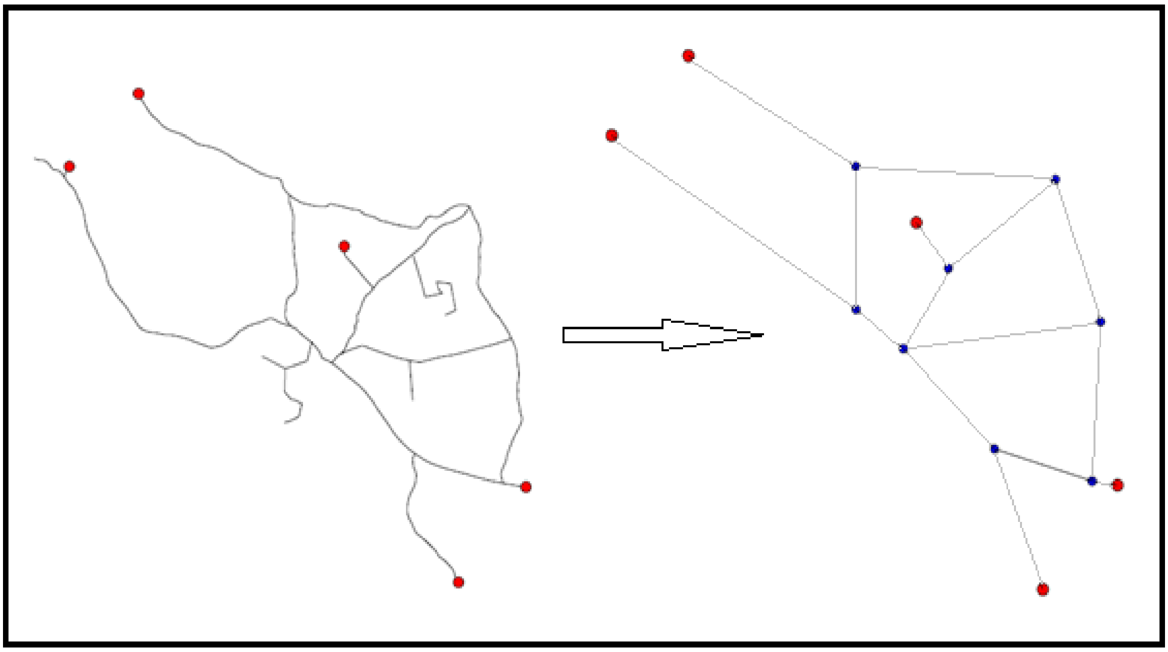


Figure 3-3 A Network Before and After Generalisation

Perform Network Search

Network search algorithms are often divided into two groups, Depth First Search (DFS) and Breadth First Search (BFS). DFS algorithms start the search at a root node or an arbitrary node and explore as far as possible along each branch before backtracking while BFS algorithms start at a root node and explore all of the neighbour nodes at the present depth prior to moving on to the nodes at the next depth level. When a fast solution is needed to a distance calculation between two points, the DFS algorithms are very convenient. These algorithms are commonly used in navigation. When using a DFS algorithm it is common to be satisfied with an approximate solution to obtain short calculation times.

BFS, on the other hand, like the Dijkstra's algorithm of 159, are more frequently used in spatial accessibility analysis, since it is more common to have calculations between many start points and the unknown closest target point. This fits the behaviour of the BFS algorithm. The BFS gives broadly correct answers and is generally slower to perform than DFS. Modifications, leading to improvements in the Dijkstra's algorithm, have recently been developed. Some of these developments are summarised and evaluated by Meyer in 2003 (Meyer, Sanders and Sibeyn, 2003).

When the points are connected to the network and a graph structure is built, the spatial index is no longer needed. Since the following network calculations were memory consuming, it was rational to remove the structures for spatial indexation from the computer's internal memory (Dahlgren, 2008).

Export the Results

The results, after network search, were stored in the graph structure as attributes in the start nodes. The values were exported to a results file or database in a format that is convenient for the user to analyse. One way of performing this was to add the spatial accessibility values to the start point dataset in the attribute table. Giving the accessibility as an attribute to the spatial object start points made it convenient to analyse the result, using visualisation in thematic maps, for example.

3.2.3 Inter-zonal Travel Time and Distance Calculations

Inter-zonal distances and travel time were calculated by means of Origin-Destination Matrices (OD matrices) in Microsoft Excel Spreadsheets. Google facilitates Google Maps Distance Matrix API for limited usage. The Distance Matrix API was set up as a function with Visual Basic for Applications (VBA), the programming language of Excel. Finally, the VBA function could run over the set of OD matrices and iterations were made to return Google Maps distances and travel times, respectively. The limitation of this process was that Google Inc. limits the number of free queries to 100 elements per query, 100 elements per 10 seconds, and 2 500 elements per 24-hour period.

3.2.4 Minimum Travel Time Measure

The Minimum Travel Time measure is a common cumulative model that is best at describing, with minimal data requirements, travellers' residential location relative to primary healthcare facility locations. As stated, this measure defines spatial accessibility to the nearest primary healthcare facility k:

$$AMTT, i = min\ d_{ik} \tag{2}$$

Where:

AMTT,i represents the calculated accessibility index for TAZ i, and
Min d_{ik} represents the cost of travel between TAZ i and facility k.

To quantify the cost of travel, straight-line distances, travel times, as well as network distances and travel times, were used. It is important to recognise that this measure was not based on traveller's preferred healthcare facilities, but simply the nearest ones to the centroid of the zone in which individual travellers reside. Lower values from this measure (i.e. shorter distances and travel times) correspond to higher levels of accessibility.

3.2.5 Primary Healthcare Gravity Measure

The second accessibility measure, introduced by Knox (Knox 1980), took the form of a traditional gravity model. In the Primary Healthcare Gravity measure, all primary healthcare facilities were evaluated in relation to each zone. Spatial accessibility was proportional to the attractiveness of each facility, as well as inversely proportional to the distances and time travel times that travellers must travel to each facility. The resulting measure was calculated as follows:

$$APHG, i = \sum_{k=1}^{N} \left(\frac{Sk}{{d_{ik}}^{\propto}} \right) \tag{3}$$

Where:

APHG, i represents the calculated accessibility index for TAZ i,
Sk represents the attractiveness of the healthcare facility k,
d_{ik} represents the cost of travel between TAZ i and facility k, and
α represents the distance decay function.

Spatial accessibility from each zone i was calculated by summing gravity values for each facility k (k=1,2,…,N). These gravity values were estimated by scaling the square footage, Sk, of each facility k as an indicator of the attractiveness or quality of the location by the distance/travel time d_{ik} between zone i and facility k (in meters/seconds from the centroid of each zone to the healthcare facility). The amount by which facilities were penalised by distance was controlled by the distance decay function α. A value of 1,285 was assumed for α, the recommended standard for home-based other trips (Martin et al. 1998). In this measure, higher values of APHG,i (i.e. more closer and attractive facilities) correspond to higher values of spatial accessibility for zone i.

3.2.6 Two-step Cluster Primary Healthcare Gravity Measure

The Two-step Cluster Primary Healthcare Gravity measure considered traveller’s access to primary healthcare facilities in relation to the facilities overall availability for the entire population (Luo, Wei and Qi, 2009). This measure recognised that facilities that serve too large a population may not be preferred destinations because it becomes difficult to schedule desired appointment times or receive personal service. Therefore, an additional component was included in this gravity measure that reduced the spatial accessibility score for facilities located in the most populated areas of the region. Because the measure also includes the square footage of each hospital, large hospitals, that can handle more patients, are less affected by this component than those that are smaller but are expected to serve as many patients. This measure took the form:

$$ATSCPHG, i = \sum_{k=1}^{N} \left(\frac{Sk \times {d_{ik}}^{-\propto}}{\sum_{j=1}^{M} P_j \times {d_{jk}}^{-\propto}} \right) \quad (4)$$

Where:

ATCPHG, i represents the calculated accessibility index for TAZ i,
Sk represents the attractiveness of the healthcare facility k,
d_{ik} represents the cost of travel between TAZ i and facility k,
α represents the distance decay function,
P_j represents the population size of TAZ j, and
d_{jk} represents the cost of travel between TAZ j and facility k.

Just like the previous measure, spatial accessibility from each zone i was calculated by summing gravity values for each primary healthcare facility k (k=1,2,…,N). In this measure, however, gravity values were composed of two parts. The numerator, or base measure of facility attractiveness tempered by travel distance/travel time, was identical to the basic gravity model measure. The denominator, which described each facility's availability relative to the region's population, was represented by the total population size, P, of each region zone j (an indicator of the level of demand) and the distance/travel time, d_{jk}, between facility k and zone j (in meters/seconds from the centroid of each zone in which the primary healthcare facility k was located). The denominator was summed for each region zone j (j=1, 2,…, M). the recommended value of 1,285 for home-based trios was also used for α (Martin et al. 1998). Again, higher values (i.e. with closer and more attractive facilities) correspond to higher levels of spatial accessibility.

3.2.7 Spatial Accessibility Maps and Index Calculation

A Raster Interpolation toolset was used to compute accessibility indices and generate accessibility maps in ArcGIS. Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data.

The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics. The basis of interpolation implies that the values of points close to sampled points are more likely to be similar than those that are farther apart.

The Inverse Distance Weighting (IDW) spatial analyst tool in ArcMap was used to interpolate from the results to create raster surfaces. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance and the surface being interpolated should be that of a locationally dependent variable. This method assumes that the variable being mapped decreases in influence with distance from its sampled location.

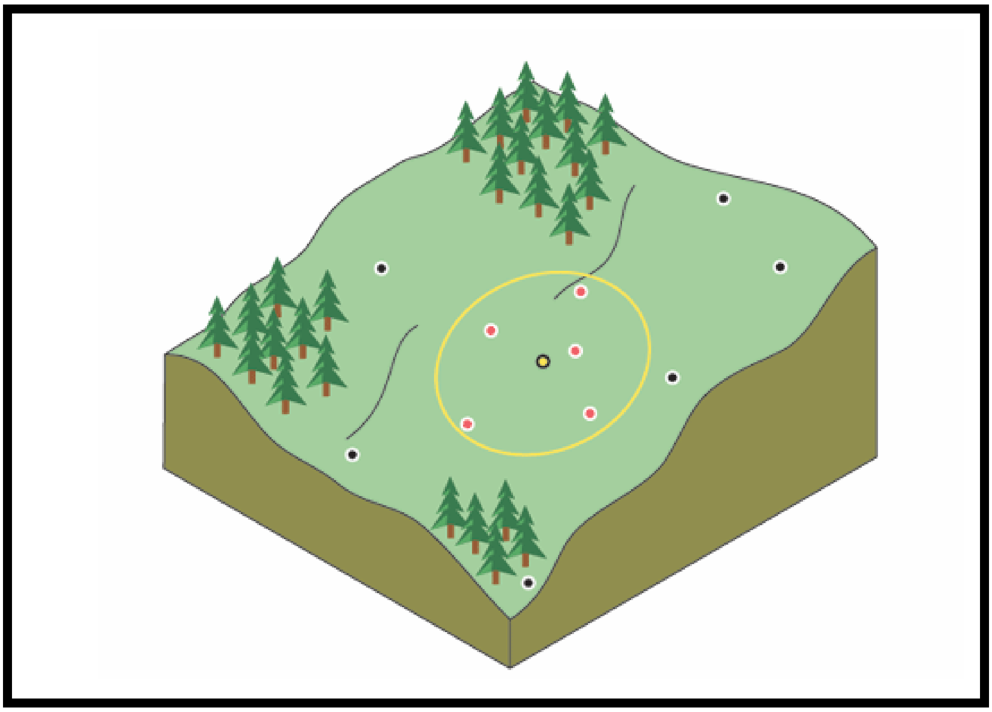


Figure 3-4 IDW Neighbourhood for Selected Point

Source:(ESRI 2017)

IDW relies mainly on the inverse of the distance raised to a mathematical power. The Power parameter allows to control the significance of known points on the interpolated values based on their distance from the output point. It is a positive, real number, with a default value of 2.

The raster surfaces were generated with specified 100m2 raster cells. With a variable search radius, these raster cells were assigned a calculated value from the interpolation (see Equations 5, 6 and 7) of the 12 closest data points (Johnston, 2004).

$$Z(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i) \qquad \lambda_i = d_{i0}^{-p} / \sum_{i=1}^{N} d_{i0}^{-p} \qquad \sum_{i=0}^{N} \lambda_i = 1 \qquad (5), (6), (7)$$

Where:

$Z(s_0)$ represents the predicted value of location s_0,
N represents the number of sample points measured that surround the predicted sample point,
λ_i represents the weight assigned to each point,
$Z(s_i)$ represents the actual value observed at location i,
d_{i0} represents the distance between,
s_0 the prediction location, and
s_i the measured location.
p represents the factor by which the weighting is reduced as the distance becomes larger.
For this project, p was set to the default value of 2.

3.2.8 Statistical Comparison of Spatial Accessibility Measures

In response to the variety of travel demand methods introduced over the past decade, researchers have developed several methods for evaluating a model's ability to match current travel patterns. Statistics have been used to examine how effective different prediction measures are at describing the same travel situation. At this stage, the three spatial accessibility measures, presented previously, were evaluated to determine whether they are comparable and/or interchangeable. This was completed using two distinct approaches. First, the spatial accessibility results were mapped, and spatial distributions were compared. The maps were generated using the software ArcMap from ESRI. Second, evaluation statistics were used to test how similar each measure is to the others and to describe how each measure distributed spatial accessibility across zones.

T-tests were performed for the second approach, the test results were all based on T-values. T-values are commonly referred by statisticians as test statistics. A test statistic is a standardized value that is calculated from sample data during a hypothesis test. Hypothesis tests are used to test the validity of a claim (null hypothesis) that is made about the population. The calculations used to obtain T-values compares the spatial accessibility sample means to the null hypothesis and incorporates both the sample size and the variability in the data for the three measures of accessibility that were used for this research. A T-values of 0 indicates that the sample data exactly equal the null hypothesis. As the difference between the sample data and the null hypothesis increases, the absolute value of the T-value increases too. Hence, T-tests were used to indicate and compare the level of similarity between each measure of spatial accessibility under investigation.

To Calculate T-values, pairs of independent n sample data sets (X1 and X2) had to be considered and drawn from the distribution of spatial accessibility values. The basic procedure consisted of three steps:

- develop the null hypothesis. For a two-sample test, the null hypothesis was H_0:
  $$\mu X1 = \mu X2 \tag{8}$$
- Calculate the T-test statistic and find the critical value β from a given confidence interval
- If |T| > β, reject the hypothesis. Otherwise, accept the hypothesis.

For two samples of equal size n, the t-variable is defined by:

$$T = \frac{(\overline{X1} - \overline{X2})}{Sd/\sqrt{n}} \tag{9}$$

Where Sd is the combined sample variance given by:

$$Sd = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(\widetilde{X1\iota} - \widetilde{X2\iota}\right)^2} \tag{10}$$

$$\widetilde{X\iota} = Xi - \bar{X} \tag{11}$$

$\bar{X}$ is the mean of data set Xi

Like T-values, P-values were also calculated to compare the spatial accessibility sample means to the null hypothesis and incorporated both the sample size and the variability in the data for the three measures of accessibility that are used for this research. In general, all hypothesis tests eventually use a P-value to evaluate the strength of the evidence (what the data are telling about the population). The P-value is a number between 0 and 1 that is interpreted in the following manner:

- For P-Value ≤ 0,05, the null hypothesis is rejected. This indicates strong evidence against the null hypothesis.
- For P-value > 0,05, the null hypothesis fails to be rejected. This indicates weak evidence against the null hypothesis.
- For P-values very close to the 0,05, it could go either way. It is considered to be marginal and should always be reported for the readers to draw their own conclusions.

Chapter 4: Case Study of Cape Winelands District Municipality

This section describes the study area and the datasets used to conduct the study on spatial accessibility to healthcare facilities by local communities. First, the location and land use of the study area, then the characteristics of the population, the health care facilities and the road transportation network in the study area are discussed.

4.1 Location, Localities and Land Use of the Study Area

The case study area is confined to the Cape Winelands District Municipality (CWDM), a Category C Municipality in the Western Cape Province, South Africa. As shown in Figure 4-1, the Western Cape Province comprises of 5 (five) District Municipalities (DM), including the Cape Winelands. CWDM is located next to the Cape Metropolitan area and was formerly known as 'Boland District Municipality'.

The CWDM is a landlocked area between the West Coast and Overberg coastal districts. The area is one of the 'pearls' of South Africa's rural and small-town sub-regions, contrasting with a relatively high and diverse level of development. It is a superb wine-producing area and, indeed, the best known in South Africa. The magnificent mountain ranges around Stellenbosch and Franschhoek provide ideal microclimates for the vines.

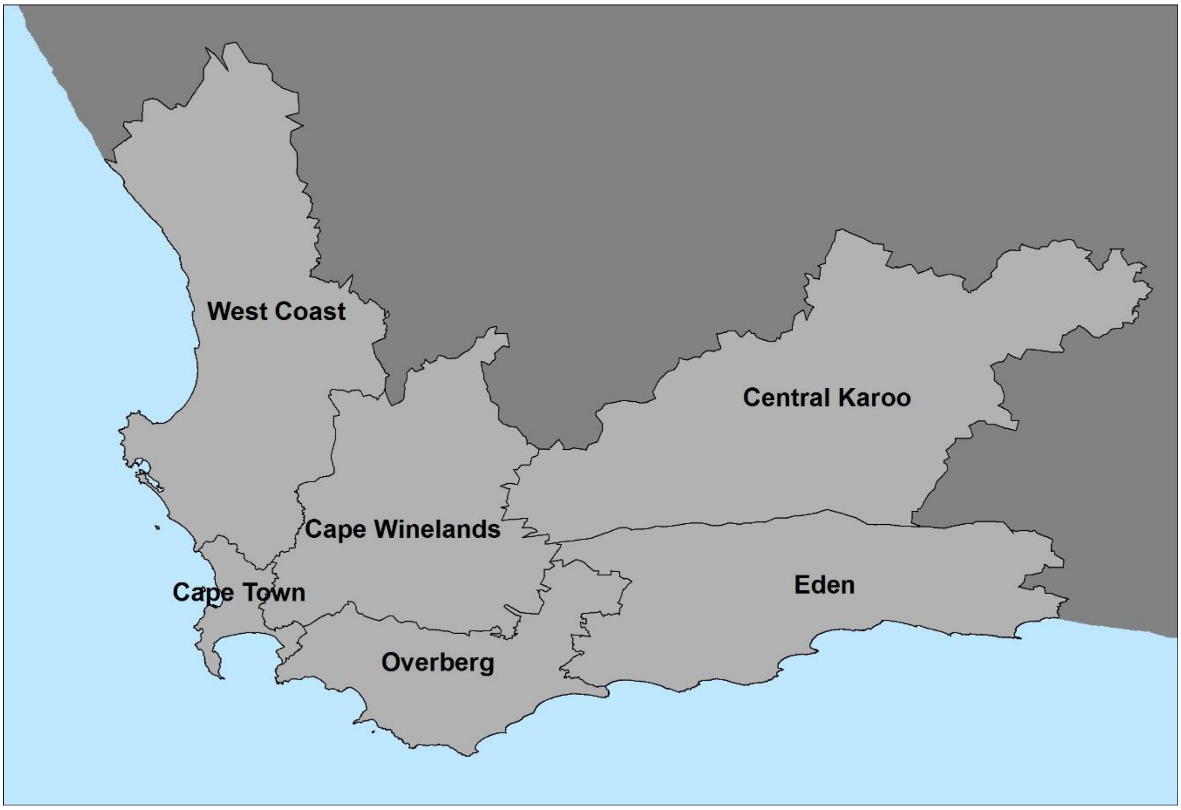


Figure 4-1 Location of the CWDM with respect to the Western Cape Province

The topography of the Wineland's soils varies substantially, ranging from shallow, rocky soils on steep slopes and plateaus, to reddish-brown soils along mountain foothills - the predominant soil type of the Cape Winelands. This landscape is characterised by very old geological formations that are, today, still clearly visible due to sustained tectonic uplift and subsequent erosion, resulting in steep, folded mountains that roughly parallel the coast, with younger deposits found in the high laying inland areas. The oldest rocks are the Malmesbury group (pre-Cambrian Namibian Epoch, 980-830 Ma) of shale, phyllite, schist and greywacke, that occur in pockets as foothills and lower lying undulating hills around Stellenbosch and Somerset West, and also form a prominent range of high hills (Tygerberg) around and north of Durbanville.

These inland vineyards benefit from a typical Mediterranean climate but are cooler than areas at the same latitude in the Northern Hemisphere. This is, predominantly, due to the influence of the nearby oceans. The cold Benguela current from the South Pole flows northwards along the western coast (Atlantic Ocean) and the warmer Mozambique current from the equator (Indian Ocean) follows the south coast in a westerly direction; the two currents or oceans meeting each other between Cape Agulhas and Cape Point. The cooling effect of prevailing winds and breezes, from these oceans on nearby land, have been scientifically studied and verified.

An old Cape saying goes that "a vineyard that can see the sea, is a good vineyard". This seems to be largely true in view of the outstanding varietal characters that are obtained in such vineyards, especially in the case of terroir sensitive cultivars like Sauvignon Blanc, Sémillon, Shiraz and Pinot Noir. Stellenbosch, Franschhoek, Paarl, Tulbagh and Wellington form the backbone of the Cape Winelands – their wine routes representing hundreds of wine and grape producers. These valleys are the largest winemaking region in the country with grape cultivation that dates to the 1600s.

The CWDM comprises of five LMs, namely Breede Valley, Drakenstein, Langeberg, Stellenbosch and Witzenberg, as shown in Figure 4-2. The Breede Valley LM is centrally located and is the second largest LM. The municipality covers a total area of 3 833 square kilometres, which includes a section of the Breede River Valley around the town of Worcester and stretches up to the Hex River Valley to the edge of the Karoo. It abuts Witzenberg Municipality to the north, which is the largest LM covering 10 753 square kilometres, including Tulbagh Valley, the Warm Bokkeveld, the Koue Bokkeveld and Ceres Karoo.

Figure 4-2 Local District Municipalities with respect to the CWDM

Witzenberg Municipality stretches from the Groot Winterhoek Mountains in the west and the Hex River Mountains in the South as far as the Nothern Cape Province border in the north and east. Drakenstein and Stellenbosch LMs are located in the western side of the CWDM and are mostly urban LMs which contribute significantly to the economic growth of the CWDM. The Drakenstein LM covers a total area of 1 538 square kilometres in the valley of the Berg River to the west of the Boland Mountain ranges. The principal town and location headquarter is Paarl, situated in the south of the municipality. Stellenbosch LM on the other hand, covers 831 square kilometres around the towns of Stellenbosch and Franschhoek. Finally, the Langeberg LM covers a land of 4 518 square kilometres in the Breede River Valley and the west end of the Little Karoo. The Langeberg Mountains run from northwest to southeast through the centre of the municipality, and the Breede River flows in the same direction south of the Langeberg. The Riviersonderend Mountains and the Koega Mountains, respectively, from the southern and northern boundary of the municipality.

The Cape Winelands Spatial Development Framework (CWSDF) document highlights the following areas as having high development potential:

- Breede Valley Municipality around Worcester;
- Areas of Drakenstein Municipality around Paarl; and
- Areas of Stellenbosch Municipality surrounding Stellenbosch.

To understand the hierarchy of urban settlement in the region, as well as the functional relationships between them, the existing settlements can be grouped into a number of categories related to their size and their level of service.

Paarl, Worcester and Stellenbosch are regarded as the core regional settlement as they have the largest populations and offer the greatest number of non-residential functions. These towns draw people from afar, due to the presence of, amongst other things, tertiary health facilities and tertiary education institutions.

Within their local town clusters and within their hinterland, local towns are the most important due to their population size and range, variety and number of non-residential functions. Wolseley, Ceres, Franschhoek, Robertson, Wellington, Rawsonville and De Doorns are all identified as local towns.

Rural towns are the next level of the settlement hierarchy. These towns perform as key agricultural and social support centres. They are linked to regional and local towns creating the functional cluster. The following are rural towns:

- Saron, Tulbagh and Gouda (linked to Wolseley),
- Prince Alfred Hamlet (linked to Ceres);
- Bonnievale, Ashton, Montagu and McGregor (linked to Robertson)
- Klapmuts, Jamestown, Kylemore and Pniel (linked to Stellenbosch); and
- Touwsrivier (linked to Worcester).

Hamlets are the last level of settlement categorized and are, typically, comprised of a cluster of homesteads which serve as minor service points. They have limited capacity to grow, given numerous guidelines which protect agricultural land and the cultural landscape. Table 4-1 lists the hamlets in relation to the larger regional and local towns they associate with.

Table 4-1 Settlement Hierarchy (CWSDF 2010)

Regional Settlements or Local Towns	Hamlets
Tulbagh	Hermon, Voelvlei Dam, Tulbagh Way, Romansrivier
Franschhoek	Groenendal, La Motte, Wemmershoek, Groot Drakenstein
Ceres	Op-die Berg
Wellington	Windmeul, Nuwedrift, Bainskloof
Stellenbosch	Johannesdal, Lynedoch, Vlottenburg, Jamestown, Kylemore, Simondium, Koelenhof
De Doorns	De Wet, Sandhills, Orchard, Matroosberg
Worcester/ Rawsonville	Kwaggakloof Dam, Moordkuil, Nuy, Brandvlei, Hammamskloof

4.2 Demographics of the Study Area

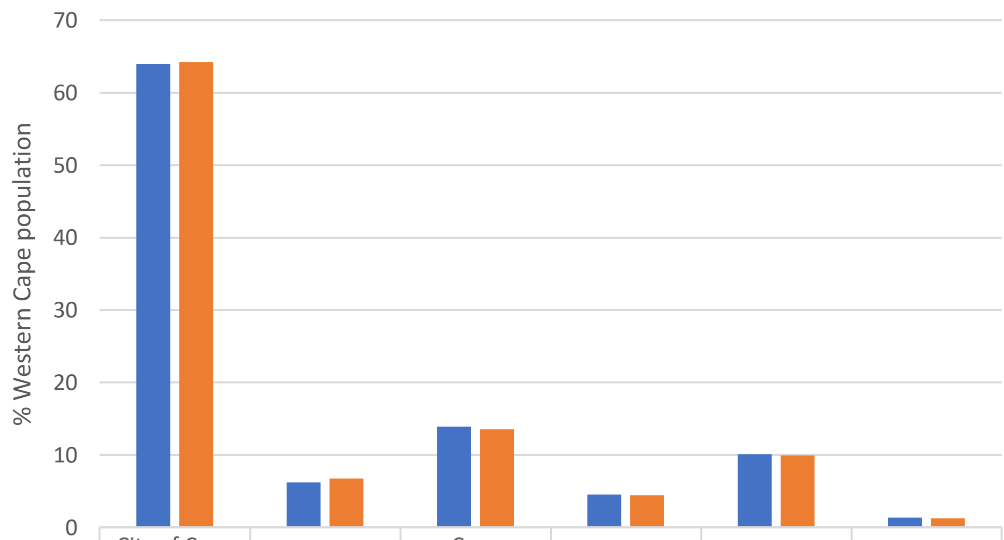
This section outlines certain factors affecting the demography of the Western Cape and, more specifically, that of the CWDM. Demographic change brings about a variety of challenges and opportunities for planners and decision makers which can guide funding priorities. In a municipal service delivery environment, demographic characteristics determines the extent and quantum of services to be delivered. Population Figures help to target plans and budget priorities more accurately and reduce the occurrence of fragmented and unfocused planning within a context of limited resource availability.

According to South African Treasury (2013), the factors influencing the demographic fabric of the Western Cape include economic conditions, the burden of disease, healthcare, fertility levels, crime, services level and development, generally. In other words, the effective functioning of the healthcare system, lower accident rates and good sanitation levels passively influences population growth. While, on the other hand, high mortality, reduced fertility, increased burden of disease and poor service delivery, could contribute to negative population growth.

Each LM that make up the CWDM has a specific demographic profile. These profiles are categorised in terms of population density and distribution, employment levels, income level, and car ownership.

4.2.1 Population Size

Population size provides an indication of the volume of demand for government services in a particular geographical space. It also serves as a planning measure to assist budget planners in matching available resources to the relative demand for services. Figure 4-3 depicts the regional composition of the total population across the Western Cape Province.



	City of Cape Town	West Coast	Cape Winelands	Overberg	Eden	Central Laroo
2001	63,9	6,2	13,9	4,5	10,1	1,3
2011	64,2	6,7	13,5	4,4	9,9	1,2

Figure 4-3 Population Distribution between 2001 and 2011 in the Western Cape

Source: Statssa

Almost two thirds of the Western Cape population were accounted for by the City of Cape Town, in both 2001 and 2011, with 63,9% in 2001 and 64,2% in 2011. Cape Winelands District remained the largest district outside of the metro in the Western Cape, as it accounted for 13,5% of the total population in 2011. It was followed by Eden at 9,9% of the total population in 2011. West Coast was home to 6,7% of the population and, finally, Central Karoo which accounted for the remaining 1,3%. No significant shifts were evident in the population distribution across the districts between the two last Censuses.

Figure 4-4 depicts Cape Winelands District population numbers distributed across its LMs from the Census 2001 and Census 2011. Both 2001 and 2011 Census highlight Drakenstein as the most populated municipality of CWDM. The population of Drakenstein grew from 194 416 in 2001 to 251 262 in 2011. The 2011 Census revealed that the next most populated municipalities were Breede Valley at 166 825 and Stellenbosch at 155 733 people, whereas the least populated municipalities within the region were Witzenberg at 115 946 and Langeberg at 97 724.

The population of CWDM grew at an annual average rate of 2,0% from 2001 to 2011. The annual average growth rate of the Witzenberg LMwas the highest at 2,8% and was followed by Stellenbosch and Drakenstein LMs, respectively, at 2,4% and 2,3%. Langeberg and Breede Valley recorded a relatively low annual average growth rate of 1,7% and 1,2%, respectively.

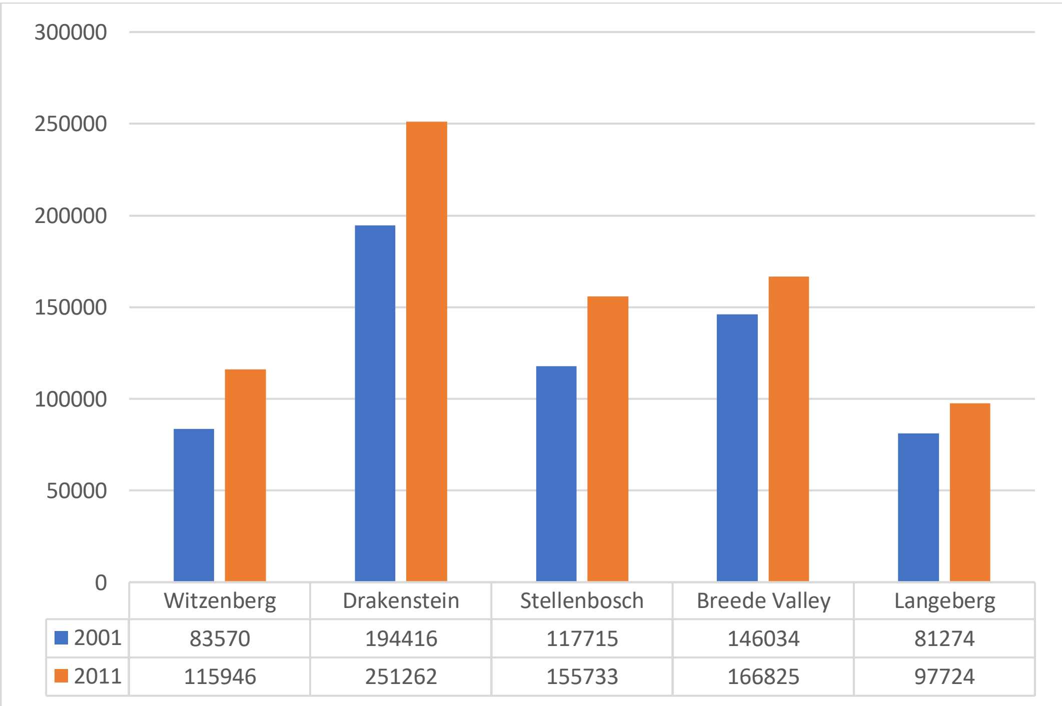


Figure 4-4 Cape Winelands District Municipality Population Numbers

Source: Statssa

As depicted in Figure 4-6, the Drakenstein LMaccounted for almost a third of CWDM population in both 2001 and 2011, with 31,2% in 2001 and 31,9% in 2011. Breede Valley remained the second largest LMas it was home to 21,2% of the total population in 2011, followed by Stellenbosch at 19,8%, Witzenberg at 14,7% and, lastly, Langeberg at 12,4%. For the CWDM, as well, no significant shifts were evident in the population distribution across the LMs between the two last Censuses.

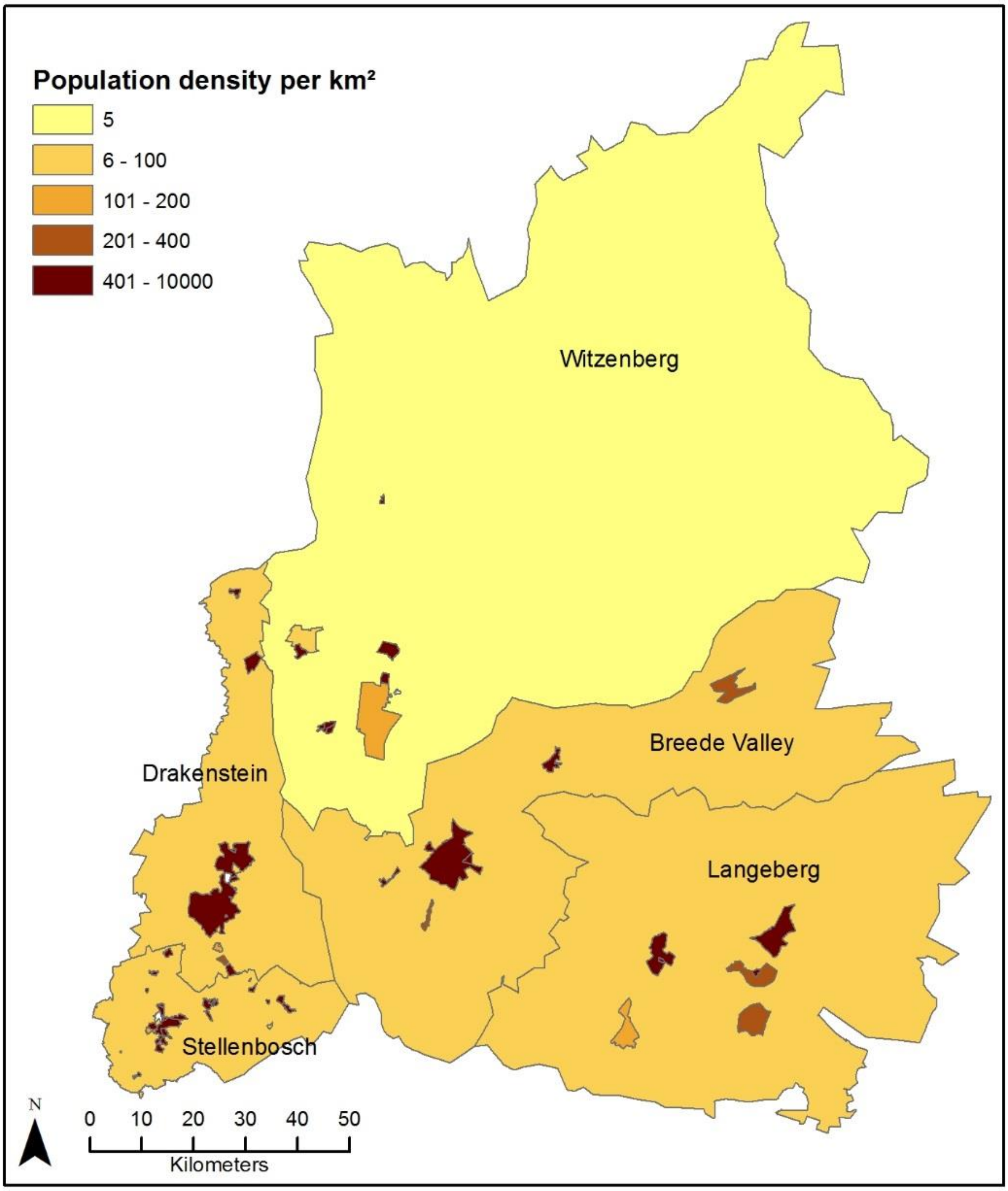


Figure 4-5 CWDM Population Distribution

Source: Census 2011

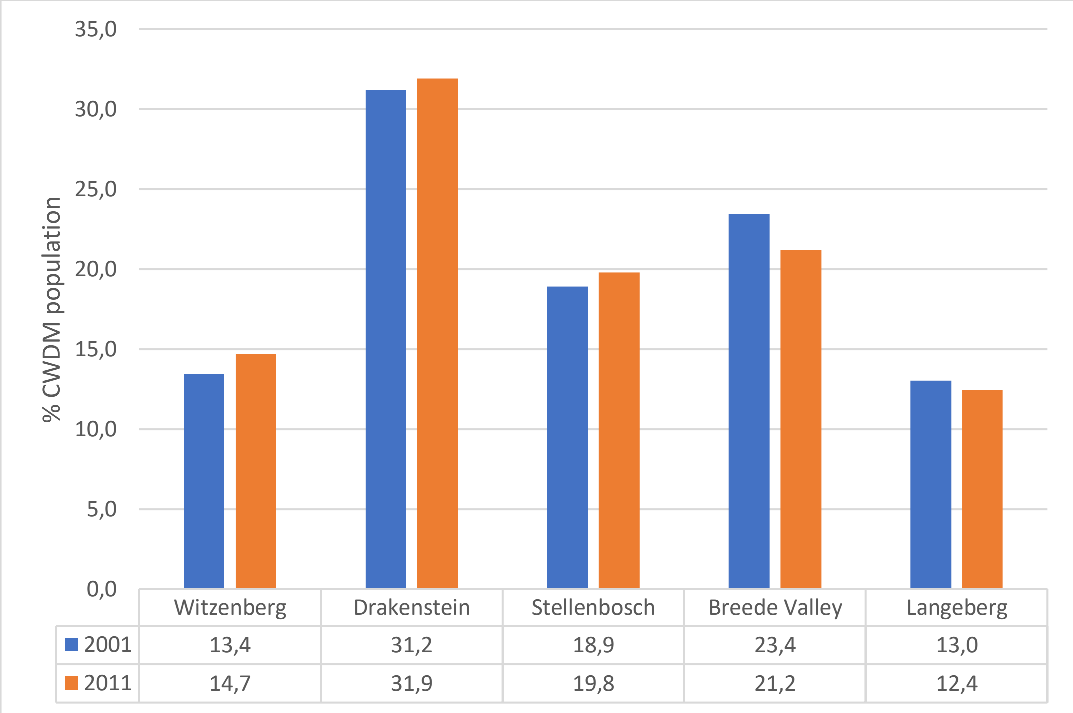


Figure 4-6 Population Distribution between 2001 and 2011 in the CWDM

Source: Statssa

4.2.2 Gender and Age Distribution

In 2001, Census revealed that 51,1% of the population in CWDM was female and 48,9% was male (Figure 4-6). The 2011 Census (Figure 4-7) estimates that 50,7% of the population in CWDM was female and 49,3% male. For CWDM, the gender ratio in 2001 was 95,9 males per 100 females and increased to 97,2 males per 100 females in 2011. The male population increased by 26% from 308 124 males in 2001 to 388 214 males in 2011, whilst the female population increased by 24,2% from 321 366 people in 2001 to 399 278 people in 2011.

Statistics of the age distribution of the population can assist in directing resources more appropriately toward the related age groups. The different age cohort is grouped into three main categories: children (0 – 14 years); economically active population (15 – 64 years); and persons aged 65 years and older. The age distribution statistics across CWDM provides insights into the age groups, where the bulk of the population is located. In 2011, CWDM population composition was as follows: 25,8% (203 475 persons) children, 69% (543 601 persons) economically active and 5,1% (40 417 persons) aged 65 years and older

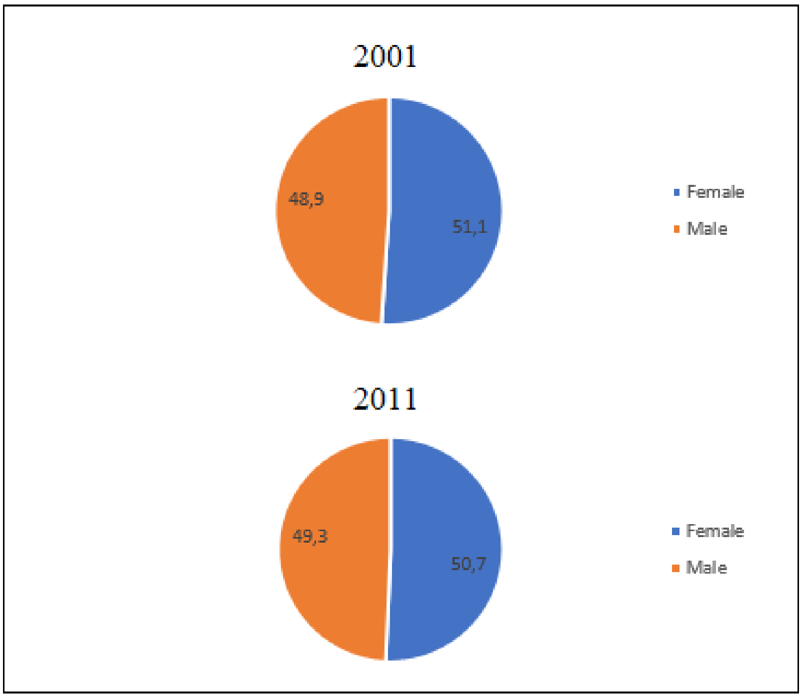


Figure 4-7 CWDM Gender Distribution 201 and 2011

Source: Statssa

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Persons aged 15 – 34 years are defined as youth. They accounted for 36,8% (289 623 persons) of the population in 2011. The youth, together with the children, represent 62,6% (493 098 persons) of the CWDM population. The annual growth rate for children and economically active population was 0,9%, respectively, between 2001 and 2011. A growth of 10,3% was recorded for persons aged 65 years and older over the same period.

On the other hand, the child dependency ration decreased from 43,1% in 2001 to 37,4% in 2011. However, the age dependency ration increased from 6,9% to 7,4% over the same period.

4.2.3 Population Groups

One needs to consider the particular relevance of the historical and emerging South African context, for how municipal services are packaged, in order to improve the socio-economic realities. Migration patterns, in turn, have implications for current and future demand for municipal services. Furthermore, population disaggregation provides insights into the service levels of the various racial groups to the employment opportunities and government services. These dynamics hold implications for the government planning, including the delivery of health, education, housing and basic services.

Table 4-2 Cape Winelands District Population Groups, 2001 and 2011

Population Group	Population for 2001	Percentage Distribution of Population 2001	Population for 2011	Percentage Distribution of Population 2011	Average Annual Growth Percentage
African	124 975	19,90%	186 472	23,90%	6,90%
Coloured	408 764	64,90%	489 189	62,70%	3,00%
Indian or Asian	1542	0,20%	3 153	0,40%	12,70%
White	94 208	15,00%	101 491	13,00%	1,20%
Total	629 489	100%	780 305	100%	3,60%

Source: Statssa

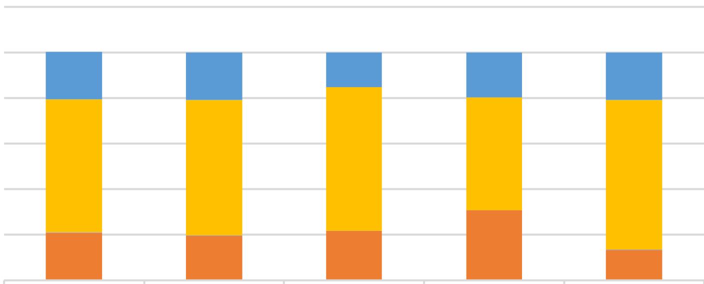
Table 4-2 shows the Cape Winelands disaggregated population per racial group. In 2001, the Coloured racial group accounted for the majority of the population, with 64,9% of the total population, followed by the African racial group and White racial group, at 19,9% and 15%, respectively.

The Coloured racial group remained the largest population group at 62,7% of the total population in 2011. The African and White racial population groups retained their positions as the 2nd and 3rd largest population groups as they, respectively, accounted for 23,9% and 13% of the total population in 2011.

The India/Asian racial group accounted for less than 1% of the total population in 2001 and 2011.

Figure 4-8 and Figure 4-9, respectively, illustrate the racial group distribution of the total population in the CWDM in Census 2001 and Census 2011. The racial groups were uniformly distributed across the Cape Winelands Municipalities, with all municipalities having a predominantly Coloured population, whilst Africans are proportionately the second most populous racial group in all municipalities, followed by Whites and Indian/Asians.

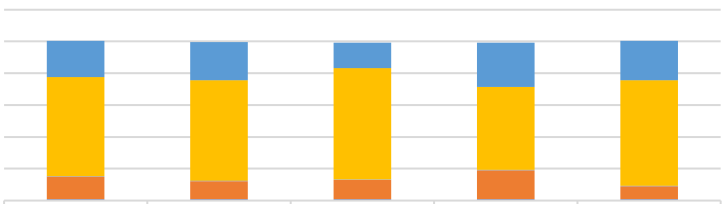
Drakensberg, Stellenbosch and Langeberg Municipalities experienced notable shifts in the racial distribution of its population, especially amongst the Whites/African Black population groups.



	Drakenstein	Breede Valley	Langeberg	Stellenbosch	Witzenberg
African	21%	20,80%	15,10%	19,60%	20,90%
Coloured	58%	59,40%	63,10%	49,40%	65,50%
Indian/Asian	0,30%	0,30%	0%	0,20%	0,20%
White	21%	19,50%	21,70%	30,70%	13,40%
Other					

Figure 4-8 Cape Winelands District Racial Group Distribution 2001

Source: Statssa



	Drakenstein	Breede Valley	Langeberg	Stellenbosch	Witzenberg
African	23,00%	24,00%	16,00%	28,00%	25,00%
Coloured	62,00%	63,00%	70,00%	52,00%	66,00%
Indian/Asian	0,40%	0,60%	0,30%	0,40%	0,40%
White	14,00%	11,00%	12,00%	18,00%	8,00%
Other	1,00%	1,00%	1,00%	1,00%	1,00%

Figure 4-9 Cape Winelands District Racial Group Distribution 2011

Source: Statssa

4.3 Development and Well-being in CWDM

This section provides an insight into the employment and average household income levels in the Cape Winelands region, as well as household goods ownership. These factors are indicators of the development levels and well-being in the Cape Winelands District Municipality.

4.3.1 Labour Force and Employment

Statistics South Africa uses the following definition of Unemployment as its official definition. “The unemployed are those people within the economically active population who:

(a) did not work during the seven days prior to the interview, (b) want to work and are available to start work within a week of the interview, and (c) have taken active steps to look for work or to start some form of self-employment in the four weeks prior to the interview."

The participation in the labour market in CWDM can be influenced by many factors, such as disability, early retirement choices, long-term illness, study choices, or even feelings of discouragement from those participating. Participation levels have a direct impact on the labour force statistics e.g. high levels of labour force participation with few employment opportunities is easily evident in a high unemployment rate, while low levels of participation with few employment opportunities results in a lower unemployment rate. The differences in participation levels, as a result of discouragement, people who want to work but have given up hope in finding employment and, therefore, are not taking active steps to look for work, is what is typically captured as the difference between South Africa's official versus the broad/expanded unemployment definition.

Table 4-3 Working Age Population and Labour Force Details, CWDM, 2001 and 2011

Census Year	Labour Force	Employed	Unemployed	Unemployment Rate (percentage)
2011	337 252	289 765	47 487	14,1
2001	284 807	221 090	63 717	22,4

Source: Statssa

For the 2001 to 2011 period, statistics show a growth of the labour market where new entrants were accommodated in the Cape Winelands District. The Unemployment was reduced from 22,4% in 2001 to 14,1% in 2011. The labour force number grew, over this period, by a factor of 52 445 new entrants. Figure 4-10 shows how employment status varies in the LMs of CWDM. The unemployment rate in the Cape Winelands region was the lowest in Witzenberg Municipality, with a value of 5,2%, followed by Langeberg Municipality at 6,9%. Drakenstein Municipality had the highest unemployment rate in the region, at 10,7%, followed by Stellenbosch and Breede Valley at 9,0% and 8,8%, respectively.

Figure 4-10 also depicts the percentage of not economically active individuals in the Cape Winelands region. Over a third of the population in CWDM was considered not economically active.

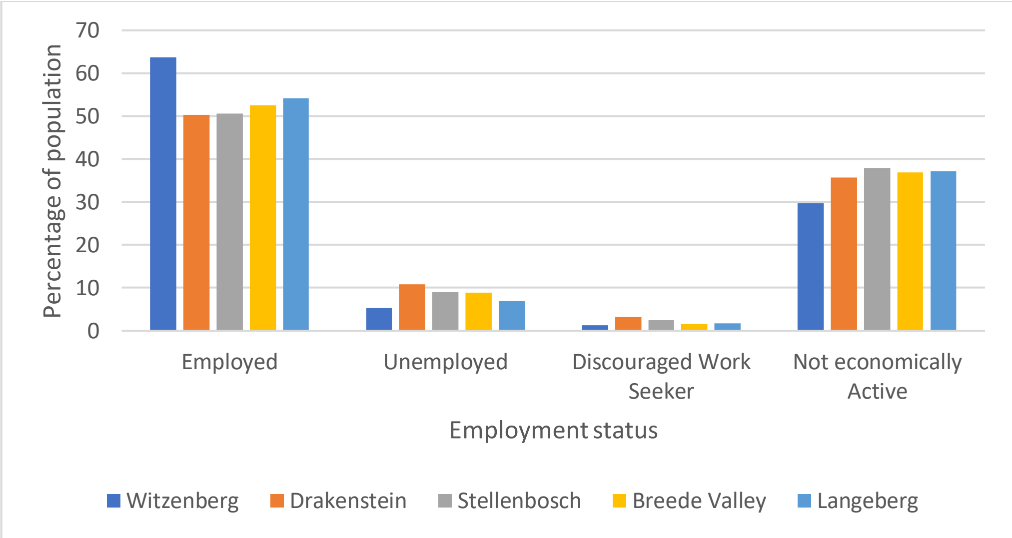


Figure 4-10 Employment Status, Cape Winelands District Municipal Area, 2011

Source: Statssa

At 37,9%, Stellenbosch LM holds the highest percentage of its residents falling in the not economically active category of the CWDM labour force. It was followed by Langeberg and Breede Valley, with a not economically active population of 37,1% and 36,9%, respectively, where 35,7% of the Drakenstein population falls under that category and 29,6% under Wittenberg.

4.3.2 Average Household Income

Household income is a measure of the combined incomes of all people sharing a household or place of residence. It includes every form of income, e.g. salaries, wages; and retirement income.

Average household income can be used as an indicator for the monetary well-being of the Cape Winelands residents. It is a good indicator of standard of living, because it includes disposable income and acknowledges that people sharing accommodation benefit from pooling some of their living costs. Table 4-4 indicates the percentage of the population within income brackets for each LM in the Cape Winelands region.

Stellenbosch LM had the highest percentage of residents with no income, at 20,6%. It was followed by Drakenstein LM with 13,0% of the residents that have no income. Breede Valley LM, Langeberg LM and Witzenberg LM, respectively, had 12,0%, 9,7% and 6,4% of their residents that have no income.

Table 4-4 Average Household Income Distribution in CWDM, 2011

Income	Witzenberg	Drakenstein	Stellenbosch	Breede Valley	Langeberg
	Percentage				
None income	6,4%	13,0%	20,6%	12,0%	9,7%
R1 - R4 800	1,9%	1,7%	2,1%	1,7%	2,3%
R4 801 - R9 600	4,0%	3,1%	3,5%	2,9%	4,4%
R9 601 - R19 600	18,5%	10,7%	10,2%	14,9%	15,5%
R19 601 - R38 200	25,8%	17,2%	16,5%	22,2%	24,9%
R38 201 - R76 400	20,9%	18,4%	15,5%	19,0%	20,0%
R76 401 - R153 800	10,4%	13,9%	11,5%	12,6%	11,0%
R153 801 - R307 600	6,8%	11,0%	8,5%	8,5%	7,3%
R307 600 - R614 400	3,9%	7,4%	6,6%	4,7%	3,6%
R614 001 - R1 228 800	0,9%	2,5%	3,3%	1,0%	0,8%
R1 228 800 - R2 457 600	0,3%	0,7%	1,0%	0,3%	0,2%
R2 457 601+	0,2%	0,4%	0,7%	0,2%	0,2%

Source: Statssa

Witzenberg LM residents, at 24,4%, had an average household income ranging between R1 – R19 600, whereas 22,2% and 19,5% of the population, for Langeberg LM and Breede Valley, respectively, fell under that income bracket. Furthermore, 15,8% and 15,5% of the population of Stellenbosch and Drakenstein LMs fell under that income bracket.

Most residents of CWDM had an average household income ranging between R19 601 – R153 800 with 57,1% for Witzenberg LM, 55,9% for Langeberg LM, 53,8% for Breede Valley LM, 49,5% for Drakensberg LM and 43,5% for Stellenbosch LM.

Drakenstein LM had the highest percentage of residents with over R153 801 average household income, at 22%. It was followed by Stellenbosch LM with 20,1% of its residents, while, 14,7% of the residents in Breede Valley had over R153 801 average household income, and 12,1% for both Langeberg LM and Witzenberg LM.

4.3.3 Households Goods and Motorcar Ownership

Table 4-5 provides key households items status ownership with percentage across CWDM. The ownership status of these items reflects an indication of the standard of living within the households.

Table 4-5 Household Goods Ownership Status, 2011

Item	Witzenberg		Drakenstein		Stellenbosch		Breede Valley		Langeberg	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Cell phone	81,1%	18,9%	86,7%	13,3%	89,2%	10,8%	82,3%	17,7%	80,5%	19,5%
Computer	17,4%	82,6%	33,0%	67,0%	37,7%	62,3%	22,8%	77,2%	24,2%	75,8%
Television	74,9%	25,1%	88,2%	11,8%	83,0%	17,0%	82,0%	18,0%	82,5%	17,5%
Satellite Television	33,8%	66,2%	28,6%	71,4%	29,7%	70,3%	25,7%	74,3%	27,0%	73,0%
Radio	53,3%	46,7%	71,1%	28,9%	67,6%	32,4%	64,5%	35,5%	65,1%	34,9%
Landline/Telephone	16,3%	83,7%	28,2%	71,8%	25,9%	74,1%	20,9%	79,1%	22,1%	77,9%
Motor Car	71,6%	28,4%	44,0%	56,0%	43,5%	56,5%	32,7%	67,3%	35,1%	64,9%
Refrigerator	70,3%	29,7%	84,8%	15,2%	81,1%	18,9%	75,1%	24,9%	78,3%	21,7%
Electric/Gas-Stove	87,4%	12,6%	91,0%	9,0%	89,6%	10,4%	87,5%	12,5%	90,8%	9,2%

Source: Statssa

Motorcar ownership can contribute to changes in employment distribution, shopping patterns, social interactions, manufacturing priorities and city planning. Figure 4-11 provides vehicle ownership status of households with percentages across the CWDM. Witzenberg LM had the highest levels of ownership of vehicles (71,6%), while Drakenstein LM and Stellenbosch LM reported the least, at 56% and 56,5%, respectively. Breede Valley LM reported 67,3% and Langeberg LM 64,9%.

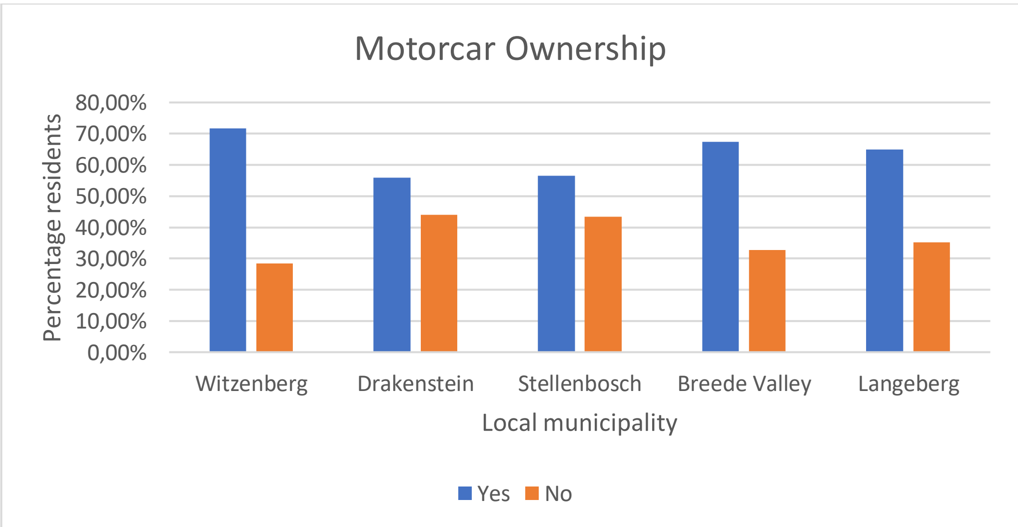


Figure 4-11 Households who own and use at Least one Type of Vehicle in CWDM, 2011

Source: Statssa

4.4 Healthcare Facilities

Healthcare facilities, and their characteristics, represent the supply of healthcare in CWDM. The sources used to identify the various healthcare facilities within CWDM were the Western Cape Government and SA Yellow online directories. There are a number of different public and private healthcare facilities and hospitals in the region. Altogether, 196 healthcare facilities were identified (Table 4-5). Some of these services, like Centre for Disease Control and Emergency Medical Services are public funded, while other services, like Pharmacy and Ophthalmologists, are private funded.

Table 4-5 Available Healthcare Facilities within the Study Area

Facility Type	Number of Services	Funding
Centre for Disease Control	6	Public
Dental Medical Health Clinics & Hospitals	31	Public & private
District Hospital	4	Public
Emergency Medical Services	12	Public
EMS Disaster Management Centre	1	Public
Eye Hospitals & Ophthalmologists	2	Private
Forensic Pathology Laboratory	4	Public
Gynaecology & Obstetrics	7	Private
Medical Health Clinics & Hospitals	56	Public & private
Medical Practitioners – General Practice	24	Private
Medical Practitioners – Pathology	4	Private
Medical Practitioners – Psychiatry	6	Private
Nephrologists & Renal Care Centres	1	Public
Nursing College	3	Private
Pharmacies & Medicine Depots	20	Private
Psychologists – Registered	4	Private
Regional Hospital	2	Public
Satellite Medical Health Clinics & Hospitals	6	Public & private
Sub-D strict Office	1	public
TB Hospital	1	Public
Urologists & Urology hospitals	1	Public
Total	**196**	**-**

Seven types of primary healthcare services are selected in this study. These types included dental health clinics, EMS, medical health clinics, medical practitioners GP, pharmacies, district and regional hospitals. It is assumed that for primary healthcare, people go to the nearest pharmacy to get basic medicine more often than they go to a GP clinic to get check-ups, medical examinations, consultation and prescriptions, and that dental services are another important form of primary healthcare.

Table 4-6 Available Primary Healthcare Facilities within the Study Area

Facility Type	Total Count of Facility Type (n=149)
Dental Medical Health Clinics & Hospitals	31
District Hospital	4
Emergency Medical Services	12
Medical Health Clinics & Hospitals	56
Medical Practitioners – General Practice	24
Pharmacies & Medicine Depots	20
Regional Hospital	2

There are 149 healthcare facilities for the seven primary healthcare services selected for this study. Most of these facilities are located in the local towns. Paarl has the largest number of primary healthcare services (n=49), followed by Stellenbosch (n=39). Wellington has (n=13), Franshhoek (n=7), Ceres (n=6), Worcester (n=3) and Tulbagh (n=2), respectively. The rest of the healthcare facilities are distributed in the Hamlets. Amongst the 66 localities within CWDM, only 26 localities have healthcare facilities. Table 4-7 shows the count of healthcare facilities in the local towns.

Table 4-7 Available Primary Healthcare Facilities within the Study Area by Local Towns

Local Towns	Count of Primary Care Facility types							
	Dental Medical Health Clinics & Hospitals	District Hospital	Emergency Medical Services	Medical Health Clinics & Hospitals	Medical Practitioners – General Practice	Pharmacies & Medicine Depots	Regional Hospital	Grand Total
Ceres		1	1	4				6
Franschhoek	2			2	2	1		7
Paarl	11		1	17	11	8	1	49
Stellenbosch	15	1	1	8	6	8		39
Tulbagh			1	1				2
Wellington	2		1	2	5	3		13
Worcester			1	1			1	3
Total	**30**	**2**	**6**	**35**	**24**	**20**	**2**	**119**

Figure 4-12 shows the geographic locations of primary healthcare facilities within the study area. These locations depict a geographic distribution in the region from which the localities with the most concentration of healthcare is supplied in the region. The highest concentration of these facilities is found in the Drakenstein LMwith a total number of 63. Stellenbosch Municipality has the second highest concentration of primary health care facilities with 48. Langeberg, Witzenberg and Breede Valley have 10, 9 and 7 primary healthcare facilities, respectively.

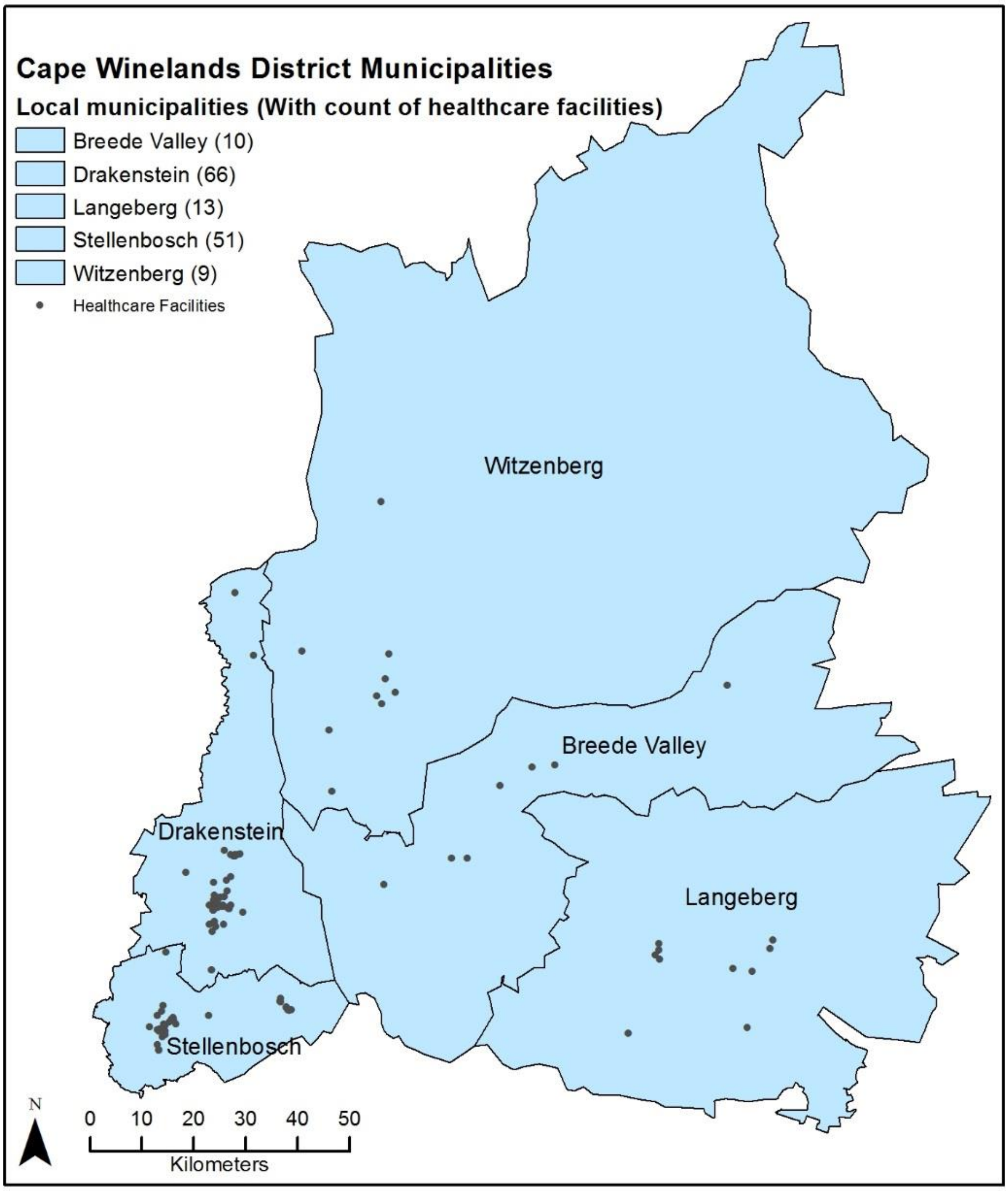


Figure 4-12 Distribution of Primary Healthcare Facilities within the Study Area

4.5 Road Transportation Network

The distribution of the road network is uneven in the study area (Figure 4-13). The northern part of CWDM is mainly rural, with only a few small towns and fewer roads than its southern part. The N1 National Road enters the CWDM near Paarl in the Drakenstein Local Municipality, going through Worcester and exits after De Doorns and Touws River. In contrast, the Southern West part of the CWDM is well populated, has larger towns and many roads. The roads have different speed limits and different traffic conditions throughout the day. There are Trunk roads, National roads, Main roads, Divisional roads and Minor roads. The speed limits for the roads transportation network are listed in Table 4-8. Altogether, there were approximately 4 900 km of roads within the study area, with an average road density of 22,8 km roads per $km^{2.}$

Table 4-8 Speed Limits for the Road Network

Road Types	Speed Limits (km/hr)	Road Length (km)
Divisional	60	1 418,9
Main	60	975,2
Minor	60	1 934,6
National	120	169,4
Trunk	120	387,4

An illustration of the road network in CWDM can be found in Figure 4-13.

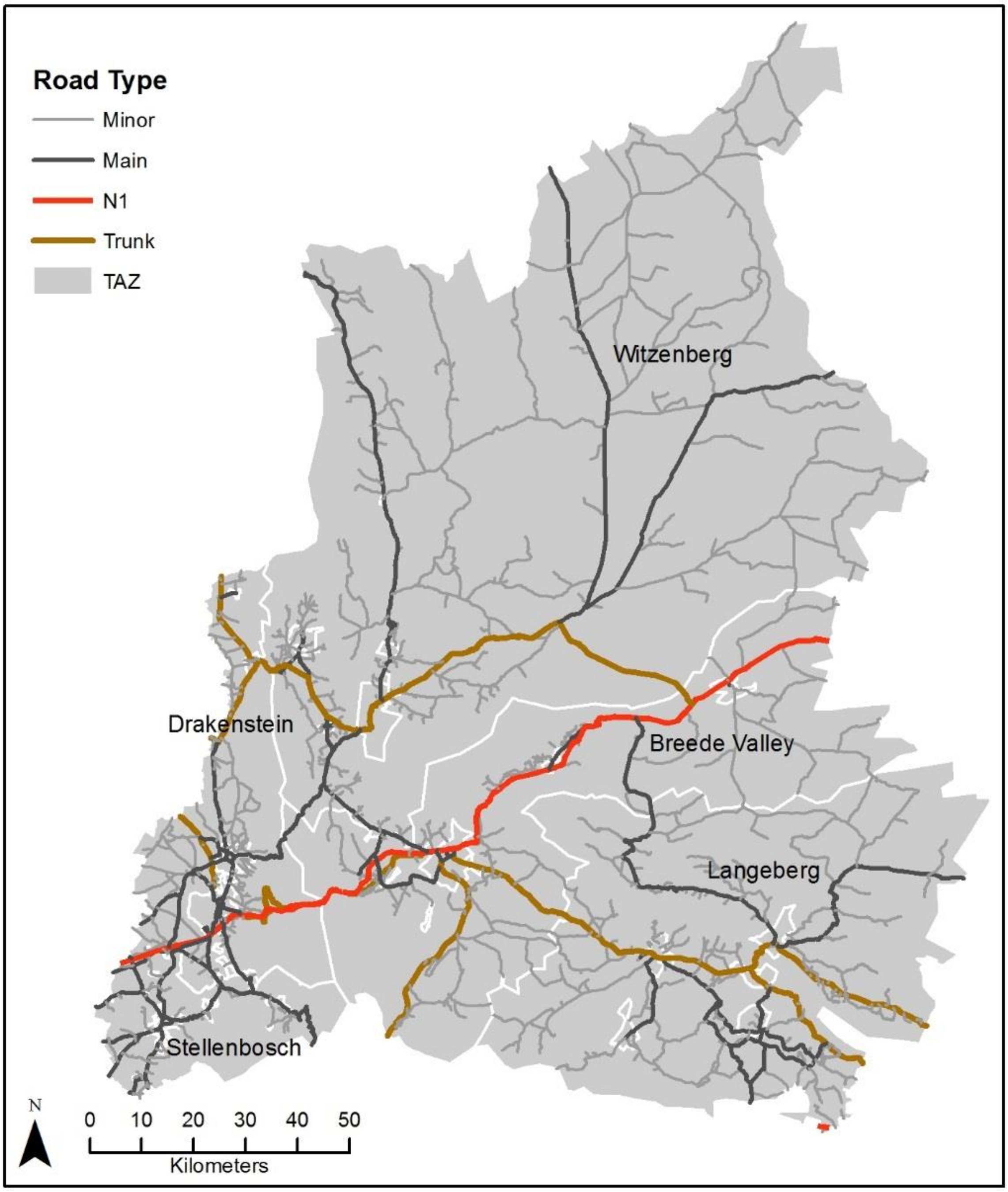


Figure 4-13 CWDM Transportation Network

Chapter 5: Spatial Accessibility for Local Communities

The purpose of this chapter is to present key results from the analysis of spatial accessibility to healthcare in the CWDM. It also presents findings that identify disadvantaged local communities in the study area.

5.1 Travel Distance as Accessibility Indicator to Healthcare Facilities

The spatial accessibility to healthcare was characterised within zones of specified travel distances. This was done in terms of the shortest road network distance from the locations of potential users at Traffic Analysis Zones (TAZ) level to healthcare facilities, as well as the respective population and their relevant socio-economic characteristics.

Travel distance to nearest healthcare facilities in Cape Winelands, regardless of facility type, was measured with the road network using the Near Facility tool in ArcGIS. The procedure was described in the methodology section and TAZ centroids were used as proxies of local communities. Figure 5-1 displays the distribution of TAZs grouped into shortest travel distances to the closest healthcare facility. It shows the relative portion of each factor to the total number of TAZs. The most significant factor in the data was that 66% of TAZs (n=40) were located within 2,5 km to their nearest healthcare facility.

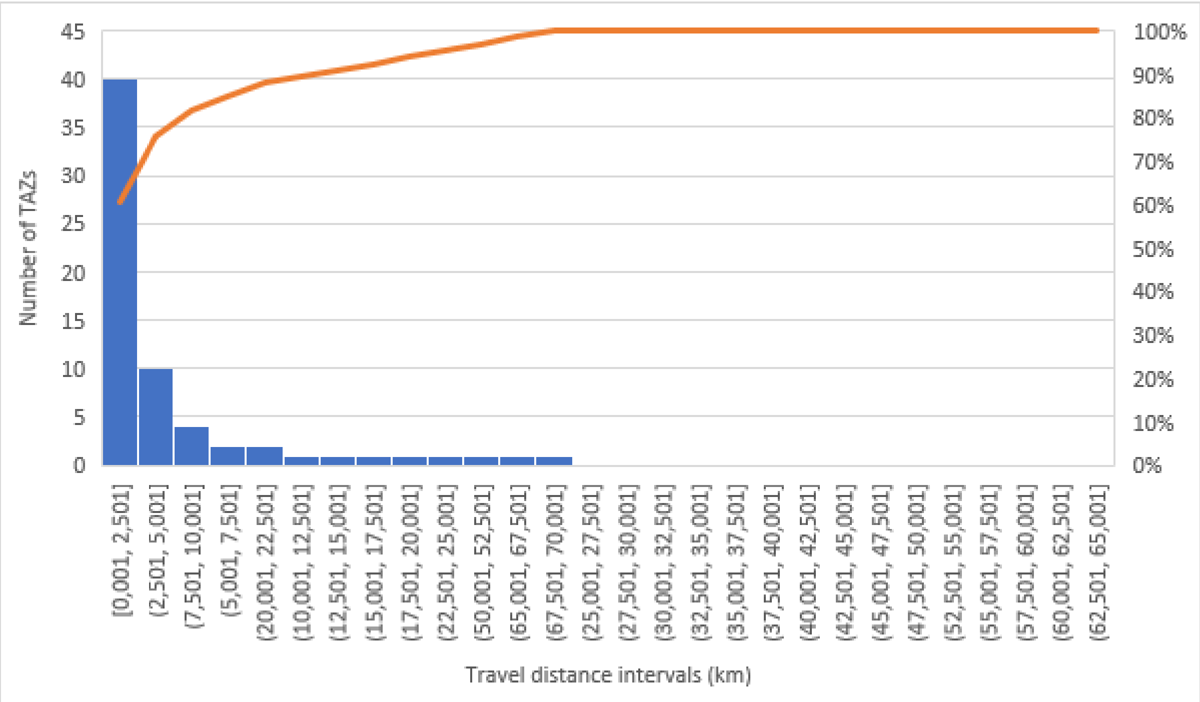


Figure 5-1 Distribution of TAZs by Distance to Nearest Healthcare Facility

Travel distance to nearest healthcare facilities in Cape Winelands, categorised by facility type, was measured with the road network using the Google Maps Distance Matrix API. The procedure was described in the methodology section and TAZ centroids were used as proxies of local communities. Figure 5-2 displays the variation in travel distances to healthcare facilities from the TAZs in the study area. Important statistics, such as minimum, maximum and average travel distances, as well as the standard deviation are displayed.

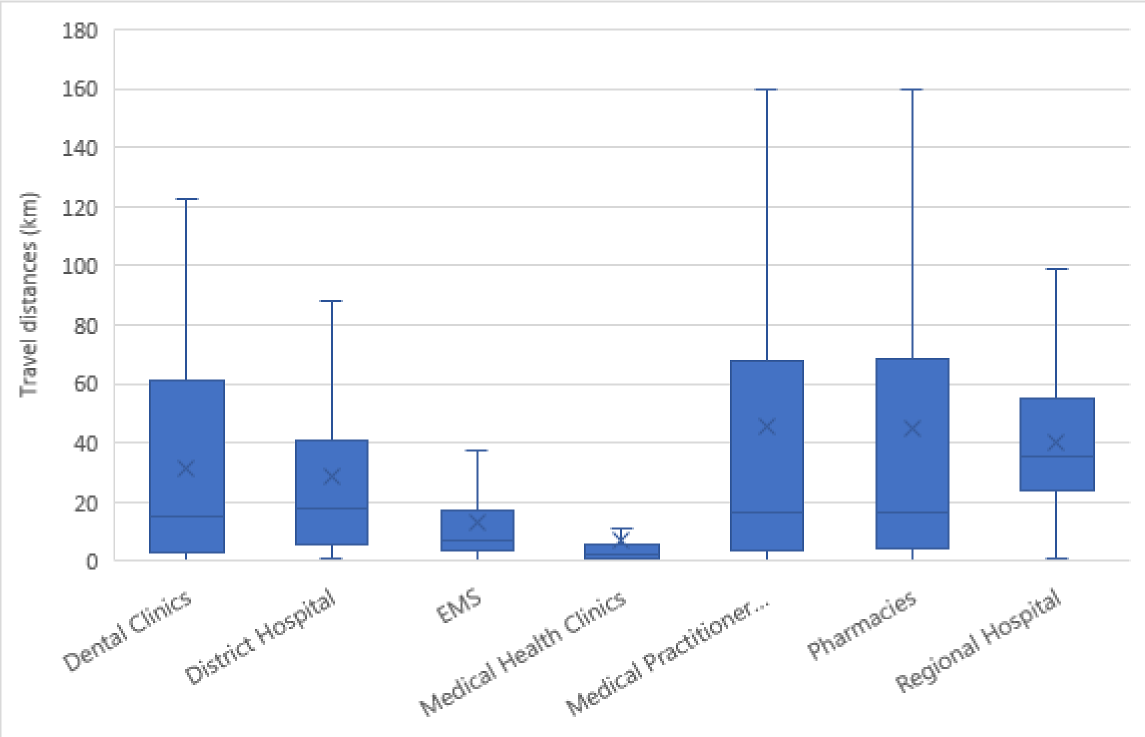


Figure 5-2 Travel Distances to Healthcare Facilities from TAZs

It is clear that medical health clinics were the most spatially accessible healthcare facility type in the CWDM since none were located further than 12 km from any TAZs. The second most accessible healthcare facility type in the CWDM were emergency medical services, with an observed maximum distance of 37 km from the furthest TAZ.

At some locations, residents had to travel 50 km, and in some cases, even more than 100 km, to access the nearest dental health clinic or a pharmacy. On average, the residents of Cape Winelands were required to travel approximately 30 km (31 292,5 m and 28 615,5 m) to a dental health clinic and to a district hospital. The calculated average distance from TAZs was almost 13 km (1 2971,1 m) to an emergency medical station, over 5 km (6 998,8 m) to a medical health clinic and hospital, over 45 km (45 430,8 m) to a medical practitioner/GP, almost 45 km (44 903,2 m) to a pharmacy and just under 40 km (39 995,6 m) to a regional hospital.

A proximity analysis of healthcare facilities filtered by categories was conducted. Figure 5-3 shows the distribution of TAZs located within a specified range to the categories of healthcare facilities under investigation. It was found that 27% was the largest amount of TAZs (n=18) that were located within 1 km to the nearest Healthcare facility of a single type. This was the medical health clinics category. Then, 8% of the TAZs (n=5) were located within 1 km to the nearest EMS. The proximity analysis revealed that only 6% of the TAZs (n=4) were located within 1 km to the nearest dental health clinics. These four TAZs (Brandwacht, Dalsig, Jamestown and Idasvallei) are all within the Stellenbosch local municipality. Another 6% of TAZs (n=4) were located within 1 km to the nearest medical practitioners/GPs. 3% of TAZs (n=2) were located within 1 km to the nearest pharmacies, namely Paarl and Robertsvlei, respectively located in the Drakenstein and Stellenbosch LMs. Only 1 TAZ, Worcester, in the Breede Valley LMwas located within 1 km to the nearest regional hospitals. Lastly, there were no TAZs (n=0) located within 1 km to any district hospitals.

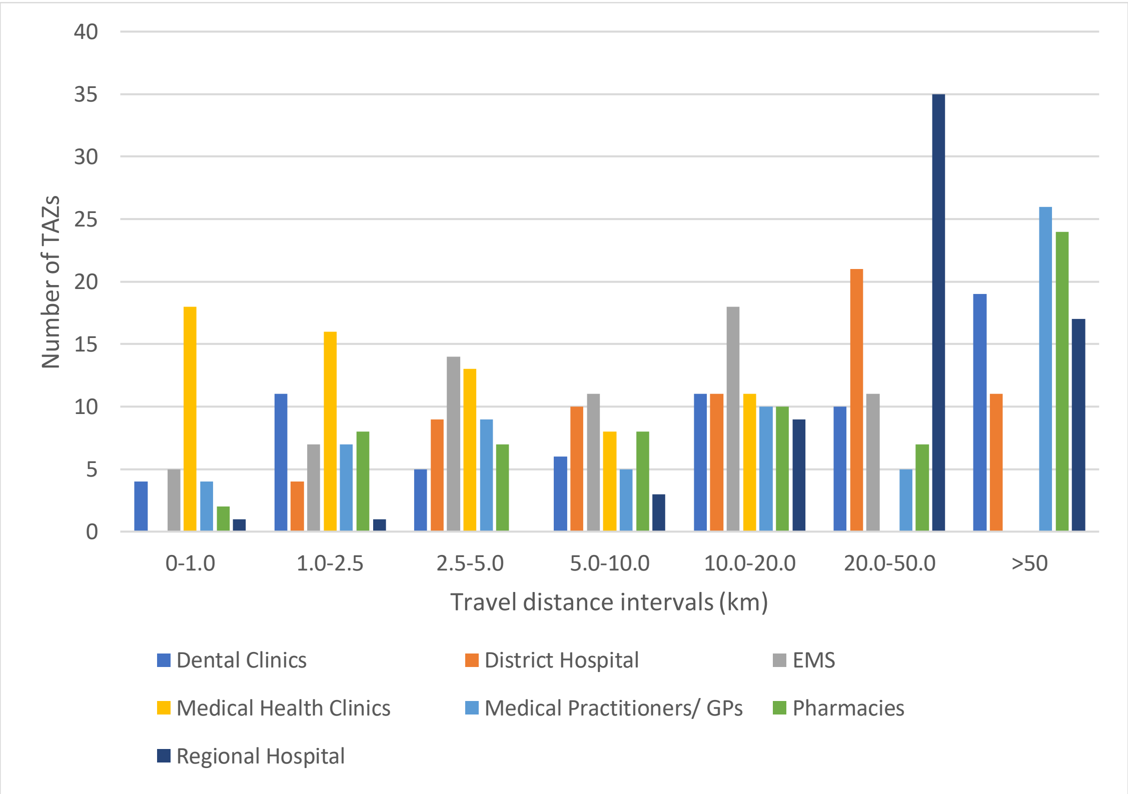


Figure 5-3 Number of TAZs within Specified Range to Healthcare Facilities

Likewise, results were obtained for the number of TAZs located more than 50 km to the categories of Healthcare facilities under investigation. As an indication of good service coverage for medical health clinics and EMS, no TAZs were located beyond the said distance. However, it was found that 39% was the largest amount of TAZs (n=26) that were located more than 50 km to the nearest Healthcare facility of a single type. This was the case for medical practitioners/ GPs. Then, 36% of the TAZs (n=24) were located more than 50 km to the nearest pharmacies. The proximity analysis also revealed that 29% of TAZs (n=19) were located more than 50 km to the nearest dental health clinics. Lastly, 26% of TAZs (n=17) were located more than 50 km to the nearest regional hospitals.

A frequency distribution of the CWDM population over the distance to nearest healthcare facilities was conducted. TAZs were used as proxies of local communities and population data was obtained from the Census 2011. The analysis revealed the portion of the CWDM population that was able to reach healthcare facilities at specific range. The results are shown under Figure 5-4. At any given distance, the analysis revealed that medical health clinics were accessible by the largest portion of the population, in comparison to the other healthcare facility types. In fact, all residents in the CWDM were able to access a medical clinic within 20 km. Another interesting result was that all residents in the CWDM could access an EMS within 50 km.

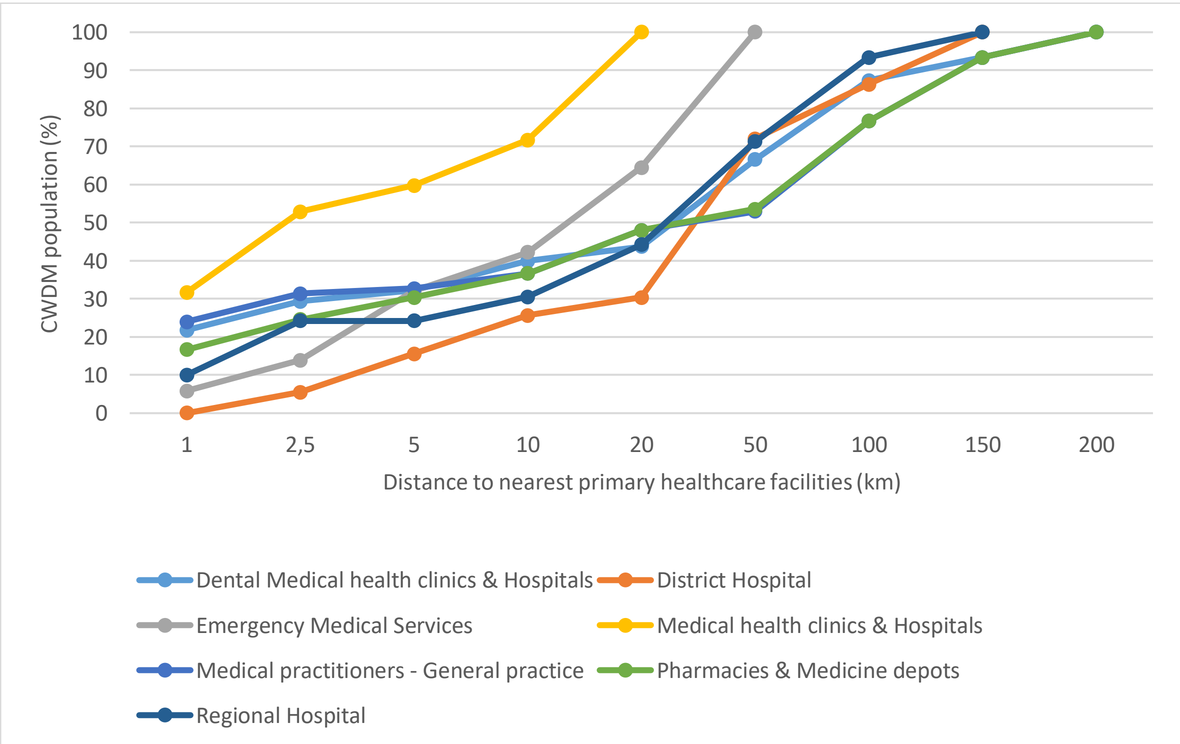


Figure 5-4 CWDM Residents within Specified Range to Healthcare Facilities

Medical clinics were the closest facility type, accessible to most of the population. At the 5 km range, Figure 5-4 shows that 60% of the CWDM population could access a medical health clinic. They were followed by medical practitioners/GPs, dental clinics, EMS and pharmacies with slightly more than 30% of the total population, located within the 5 km range. Whereas, regional hospitals and district hospitals were accessible to almost 25% and 15% of the total population respectively within the 5 km range.

For the CWDM, the numbers of residents that did not own a private vehicle and that were located within or beyond the 5 km range to their nearest healthcare facilities were also calculated. Car ownership levels were obtained from the Census 2011 and used as proxies. Percentages of the CWDM population without a car and falling within or beyond 5 km to their nearest healthcare facility are illustrated under Figure 5-5

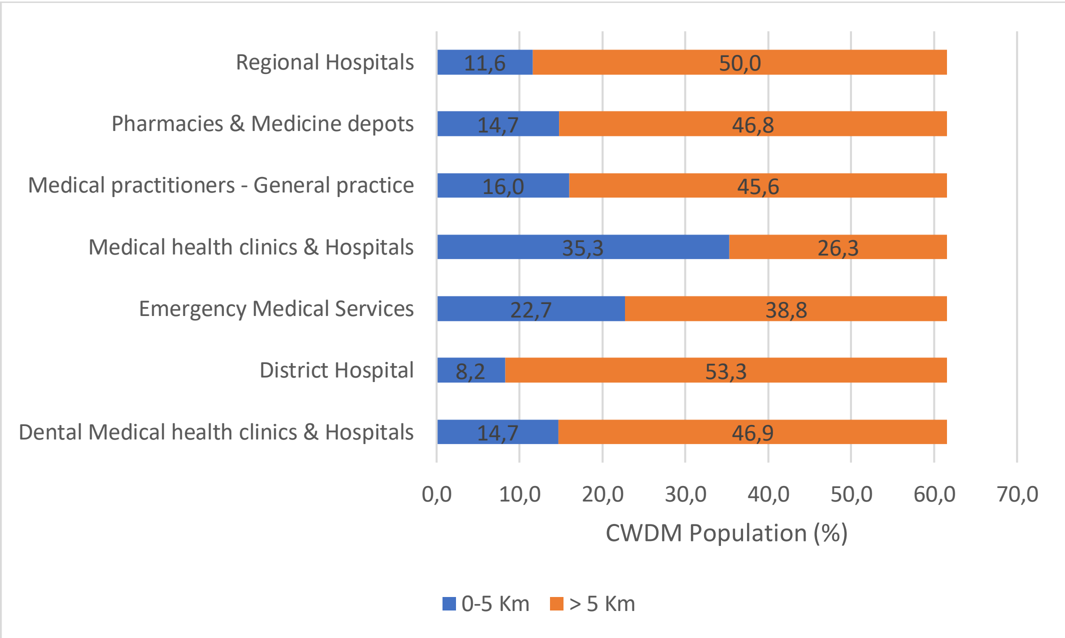


Figure 5-5 CWDM Residents without Car per Distance to Nearest Healthcare Facilities

Figure 5-5 shows that a large proportion of the CWDM population did not own a car and were located further than 5 km to their nearest healthcare facilities. District hospitals, with 53% (n=418,768), had the largest number of residents falling under that category. It was 50% (n=393,559) of the population for regional hospitals, 46,9% (n=369,332) for dental clinics, 46,8% (n=368,545) for pharmacies, 45,6% (n=359,095) for medical practitioners/GPs, 38,8% (n=305,546) for EMS and 26,3% (n=2 017,110) for medical clinics.

5.2 Travel Time as Accessibility Indicator to Healthcare Facilities

The spatial accessibility to healthcare was characterized within zones of specified travel times for two modes (Walking & Private Vehicle). This was done in terms of the shortest travel time from the locations of potential users at traffic analysis zones (TAZ) level to healthcare facilities, as well as the respective population and their relevant socio-economic characteristics.

5.2.1 Walking Time to Healthcare Facilities

Walking time to nearest healthcare facilities in Cape Winelands, regardless of facility type, was measured with the road network using the Near Facility tool in ArcGIS. The procedure was described in the methodology section and TAZs centroids were used as proxies of local communities. Figure 5-6 displays the distribution of TAZs grouped into shortest walking time to the closest healthcare facility. It shows the relative portion of each factor to the total number of TAZs. The most significant factor in the data was that 65% of TAZs (n=39) were located within 30 minutes of walking time to their nearest healthcare facility.

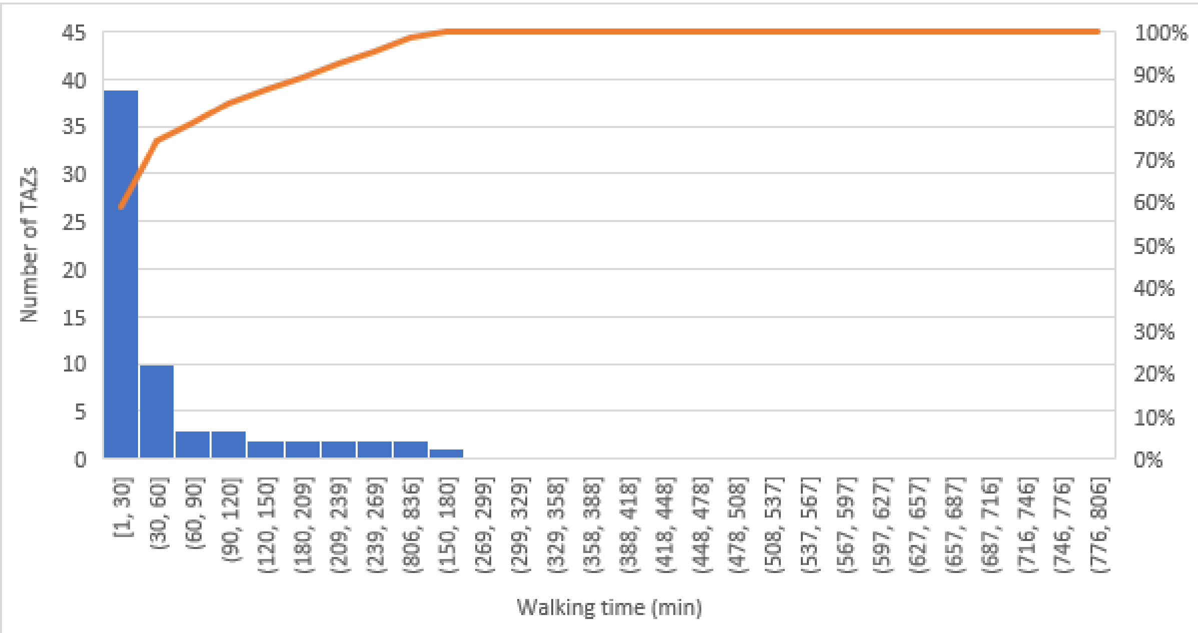


Figure 5-6 Distribution of TAZs by Walking Time to Nearest Healthcare Facility

Walking time to nearest healthcare facilities in Cape Winelands, categorised by facility type, was measured with the road network using the Google Maps Distance Matrix API. The procedure was described in the methodology section and TAZ centroids were used as proxies of local communities. Figure 5-7 displays the variation in walking time to healthcare facilities from the TAZs in the study area. Important statistics such as minimum, maximum and average travel distances, as well as the standard deviation are displayed.

It is clear that healthcare facilities were generally not accessible by walk in the CWDM. Walking times were generally not reasonable. Nevertheless, medical health clinics were the most spatially accessible healthcare facility type in this analysis since none were located further than 143 minutes away from any TAZs. The second most accessible healthcare facility type in the CWDM were emergency medical services, with an observed maximum walking time of 380 minutes from the furthest TAZ.

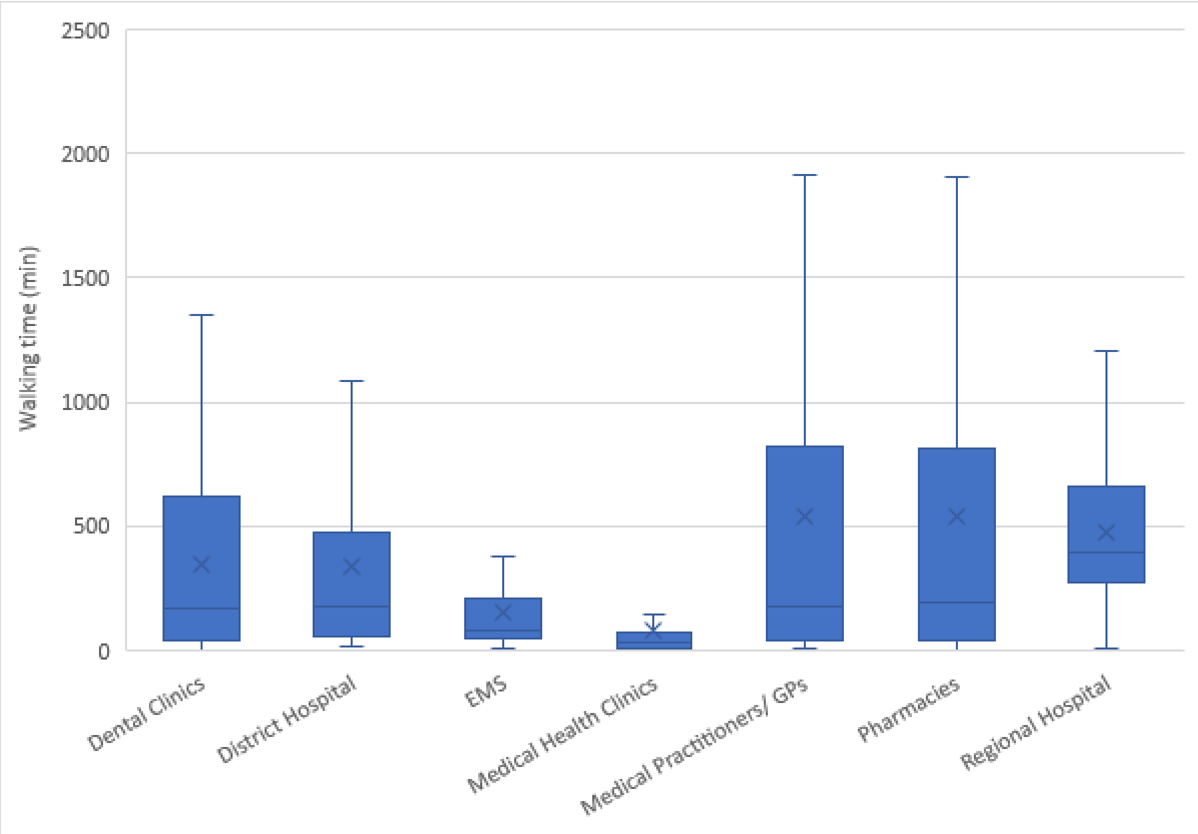


Figure 5-7 Walking Times to Healthcare Facilities from TAZs

At some locations, residents had to walk for 8 hours, and in some cases, the had to walk more than 24 hours, to access the nearest dental health clinic or a pharmacy. That is not reasonable. On average, the residents of Cape Winelands were required to walk almost 6 hours (347 minutes or 340 minutes) to a dental health clinic or to a district hospital. The average walking time from TAZs was more than 2,5 hours (151 minutes) to an emergency medical station, more than 1 hour (76 minutes) to a medical health clinic and hospital, close to 9 hours (535 minutes or 535 minutes) to a medical practitioner/GP or to a pharmacy and just under 8 hours (471 minutes) to a regional hospital.

A proximity analysis of healthcare facilities filtered by categories was conducted. Figure 5-8 shows the distribution of TAZs located within a specified walking time to the categories of healthcare facilities under investigation. It was found that 39% was the largest amount of TAZs (n=26) that were located within a 15 minutes' walk to the nearest Healthcare facility of a single type. This was the case for medical health clinics category. Then, 13% of the TAZs (n=9) were located within a 15 minutes' walk to the nearest dental health clinic. The proximity analysis revealed that 10% of the TAZs (n=7) were located within a 15 minutes' walk to the nearest medical practitioner/GPs and 9% of the TAZs (n=6) were located within a 15 minutes' walk to the nearest EMS. Only 6% of TAZs (n=4) were located within a 15 minutes' walk to the nearest pharmacies. Worcester, in the Breede Valley local municipality, was the only TAZ (n=1) located within a 15 minutes' walk to the nearest regional hospital. Lastly, there were no TAZs (n=0) located within a 15 minutes' walk to any district hospitals.

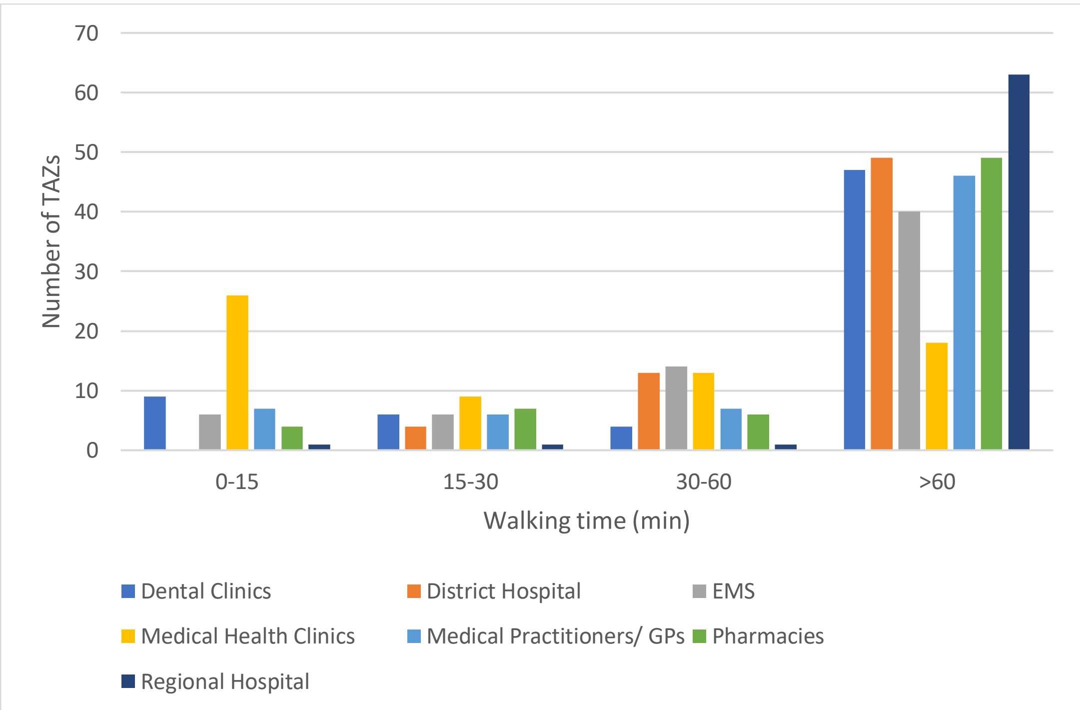


Figure 5-8 Number of TAZs within Specified Walking Time to Healthcare Facilities

Likewise, results were obtained for the number of TAZs located more than 1 hour walk to the categories of healthcare facilities under investigation. These numbers were generally high, which indicate that most healthcare facilities were not accessible by walk. It was found that

95% was the largest amount of TAZs (n=63) that were located more than 1 hour walk to the nearest healthcare facility of a single type. This was the case for regional hospitals. At that time, 74% of the TAZs (n=49) were located more than 1 hour walk to the nearest pharmacies and district hospitals. The proximity analysis also revealed that 71% of the TAZs (n=47) were located more than 1 hour walk to the nearest dental clinics. It was found that 70% of TAZs (n=46) were located more than 1 hour to the nearest medical practitioners/GPs and that 61% of the TAZs (n=40) were further than 1 hour walk to the nearest EMS. Lastly, 27% of the TAZs (n=18) were located more than 1 hour walk to nearest medical clinics.

It was established that only a small portion of CWDM population were able to reach their nearest healthcare facilities within an acceptable walking time. A frequency distribution of CWDM population over the walking time to nearest healthcare facilities was conducted. The analysis revealed the portion of the CWDM population that was able to reach healthcare facilities at specific walking time intervals. The results are shown under Figure 5-9. For any given walking time interval, it was found that medical clinics were accessible by the largest portion of the population, in comparison to the other healthcare facility types. In fact, almost 50% of the CWDM population were able to access a medical clinic within a 15 minutes' walk.

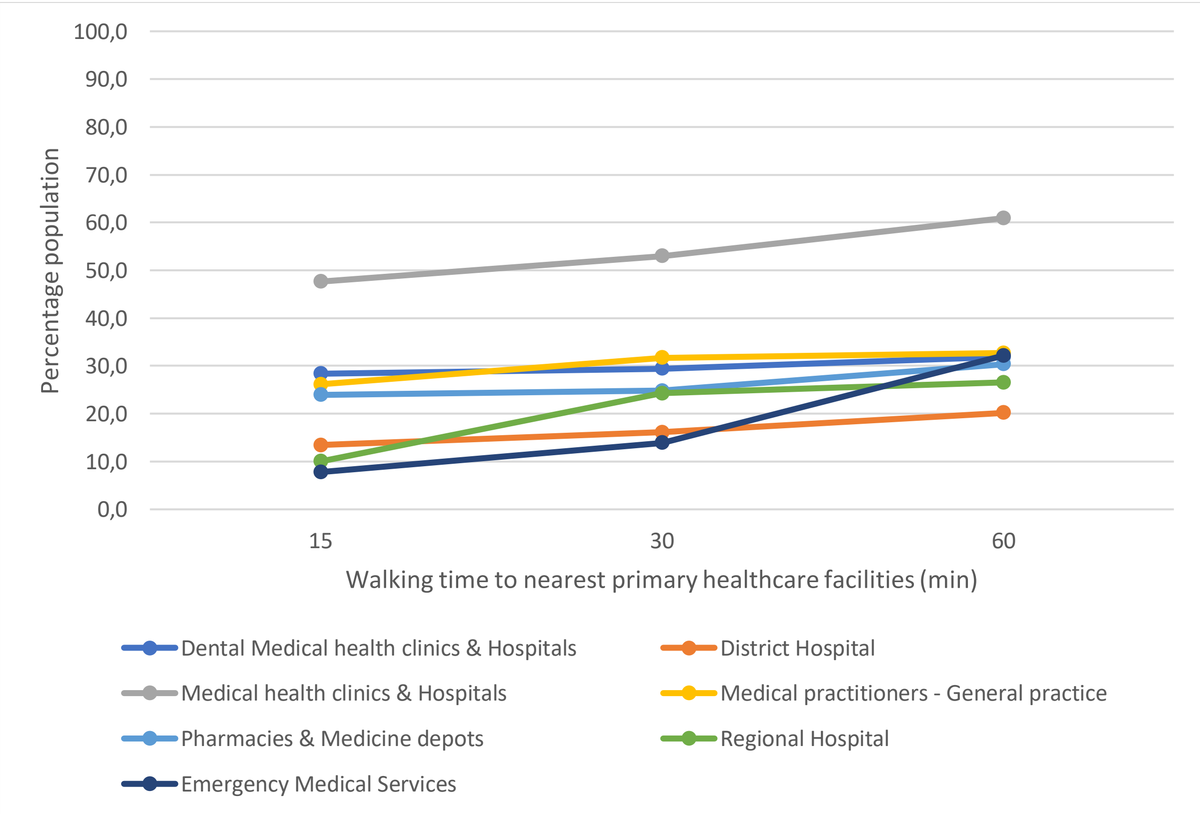


Figure 5-9 CWDM Residents within Specified Walking Time to Healthcare Facilities

Medical clinics were the closest facility type, accessible to most of the population. Within a 30 minutes' walk interval, Figure 5-9 shows that 53% of the CWDM population were able to access a medical clinic. It was approximately 30% of the population that were able to access medical practitioners/GPs and dental clinics within a 30 minutes' walk. For pharmacies and regional hospitals, almost 25% of the population were able to access within a 30 minutes' walk. Lastly, 16% and 14% of the population were able to access district hospitals and EMS respectively, within 30 minutes' walk.

For the CWDM, the numbers of residents that did not own a private vehicle and that were located within or beyond the 1 hour walk interval were also calculated. Car ownerships levels were used as proxies. Percentage of the CWDM population without a car and falling within or beyond 1 hour walk to their nearest healthcare facilities are illustrated under Figure 5-10.

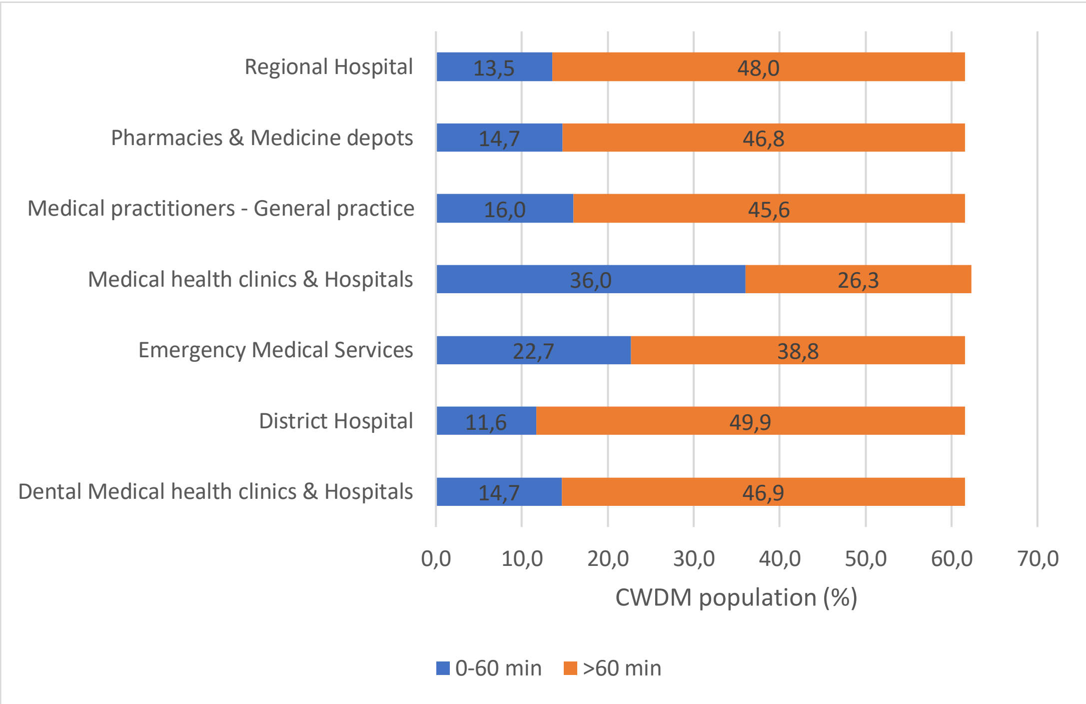


Figure 5-10 CWDM Residents without Car per Walking Time to Healthcare Facilities

Figure 5-10 shows that a large proportion of the CWDM population did not own a car and were located further than 1 hour walk to their nearest healthcare facilities. District hospitals, with 49.9% (n=392,958), had the largest number of residents falling under that category. It was 48% (n=377,995) for regional hospitals, 46,9% (n=369,332) for dental clinics, 46,8% (n=368,545) for pharmacies, 45,6% (n=359,095) for medical practitioners/GPs, 38,8% (n=305,546) for EMS and 26,3% (n=217,110) for medical clinics.

5.2.2 Driving Time to Healthcare Facilities

Driving time to nearest healthcare facilities in Cape Winelands, regardless of facility type, was measured with the road network using the Near Facility tool in ArcGIS. The procedure was described in the methodology section and TAZs centroids were used as proxies of local communities. Figure 5-11 displays the distribution of TAZs grouped into shortest walking time to the closest healthcare facility. It shows the relative portion of each factor to the total number of TAZs. The most significant factor in the data was that 62% of TAZs (n=41) were located within 5 minutes of driving time to their nearest healthcare facility.

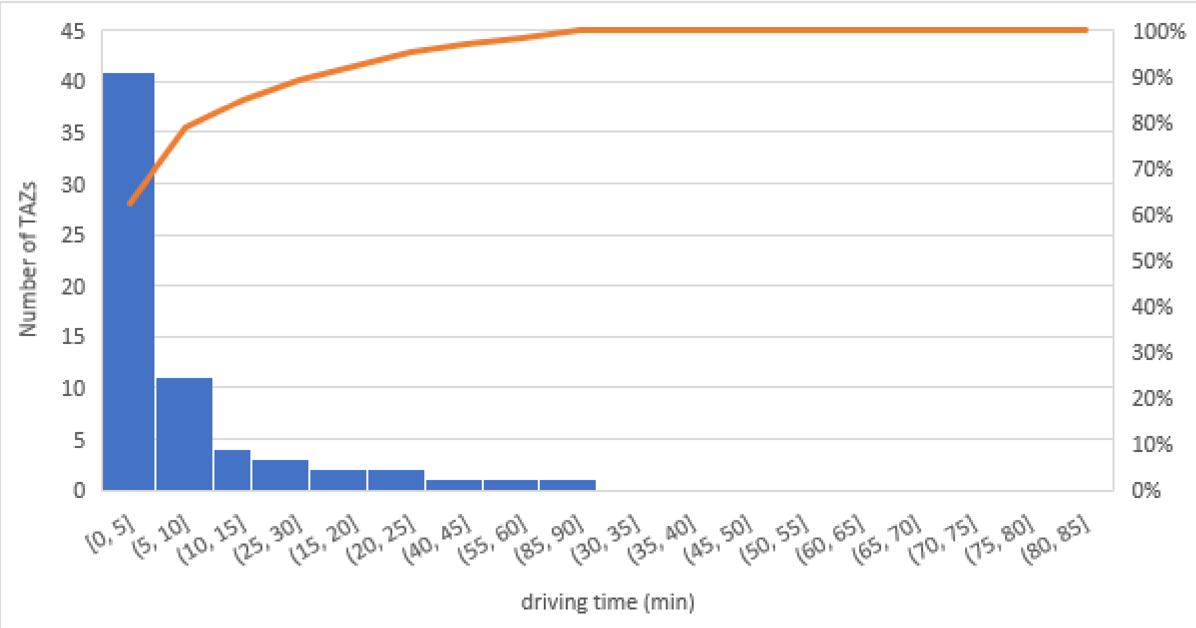


Figure 5-11 Distribution of TAZs by Driving Time to Nearest Healthcare Facility

Driving time to nearest healthcare facilities in Cape Winelands, categorized by facility type, was measured with the road network using the Google Maps Distance Matrix API. The procedure was described in the methodology section and TAZ centroids were used as proxies of local communities. Figure 5-12 displays the variation in driving time to healthcare facilities from the TAZs in the study area. Important statistics, such as minimum, maximum and average travel distances, as well as the standard deviation are displayed.

Healthcare facility were relatively accessible by driving in the CWDM. Medical health clinics were the most spatially accessible healthcare facility type in this analysis since none were located further than 21 minutes away from any TAZs. The second most accessible healthcare facility type in the CWDM were emergency medical services, with an observed maximum walking time of 33 minutes from the furthest TAZ.

At some locations, residents had to drive for 1,5 hours, and in some cases, even more than 2 hours, to access the nearest dental health clinic or a pharmacy. That is not reasonable. On average, the residents of Cape Winelands were required to drive almost 30 minutes to a dental health clinic or to a district hospital. The average driving time from TAZs was 15 minutes to an emergency medical station, 10 minutes to a medical health clinic and hospital, almost 40 minutes to a medical practitioner/GP or to a pharmacy and 35 minutes to a regional hospital.

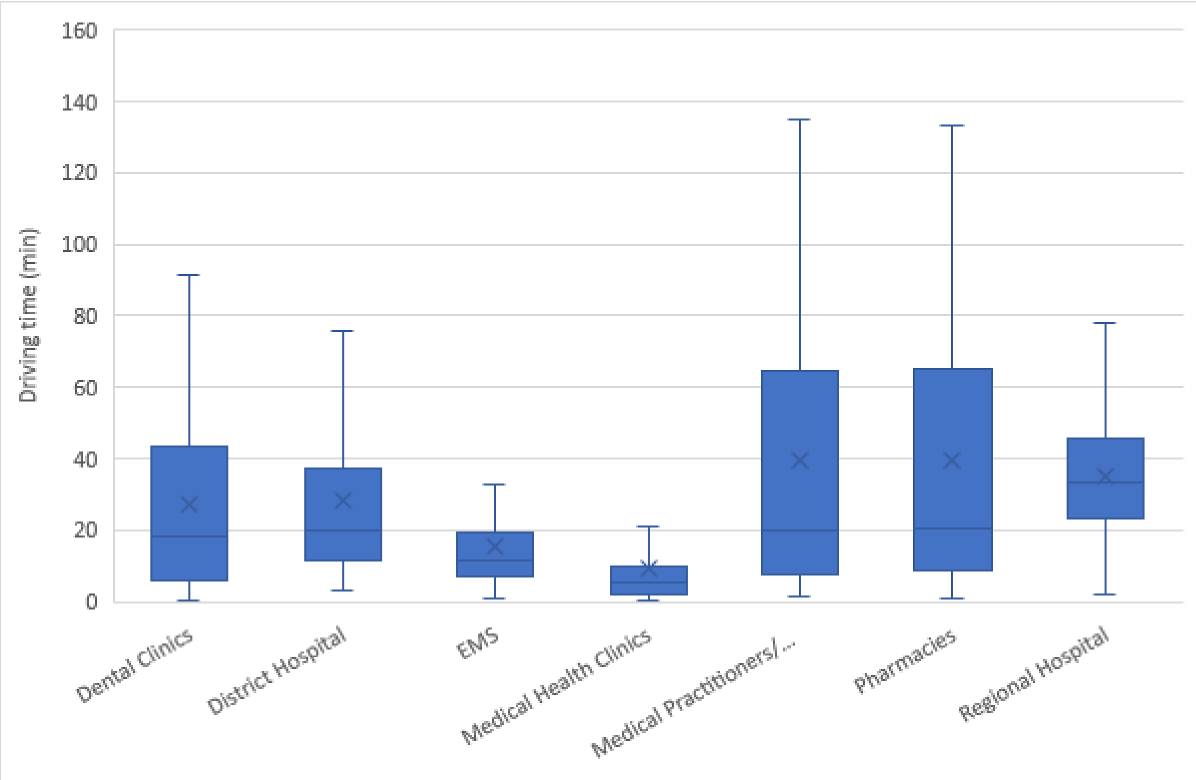


Figure 5-12 Driving Times to Healthcare Facilities from TAZs

A proximity analysis of healthcare facilities filtered by categories was conducted. Figure 5-13 shows the distribution of TAZs located within a specified driving time to the categories of healthcare facilities under investigation. It was found that 85% was the largest amount of TAZs (n=56) that were located within a 15 minutes' drive to the nearest Healthcare facility of a single type. This was the case for medical health clinics category. Then, 62% of the TAZs (n=41) were located within a 15 minutes' drive to the nearest EMS. The proximity analysis revealed that 44% of the TAZs (n=29) were located within a 15 minutes' drive to the nearest dental clinic and that 40% of the TAZs (n=27) were located within a 15 minutes' drive to the nearest pharmacies and medical practitioners/GPs. Almost 35% of TAZs (n=23) were located within a 15 minutes' drive to the nearest district hospitals. Lastly, 10% of the TAZs (n=7) located within a 15 minutes' drive to the nearest regional hospitals.

Likewise, results were obtained for the number of TAZs located more than 1-hour drive to the categories of healthcare facilities under investigation. These numbers were generally low, which indicate that most healthcare facilities were accessible by drive.

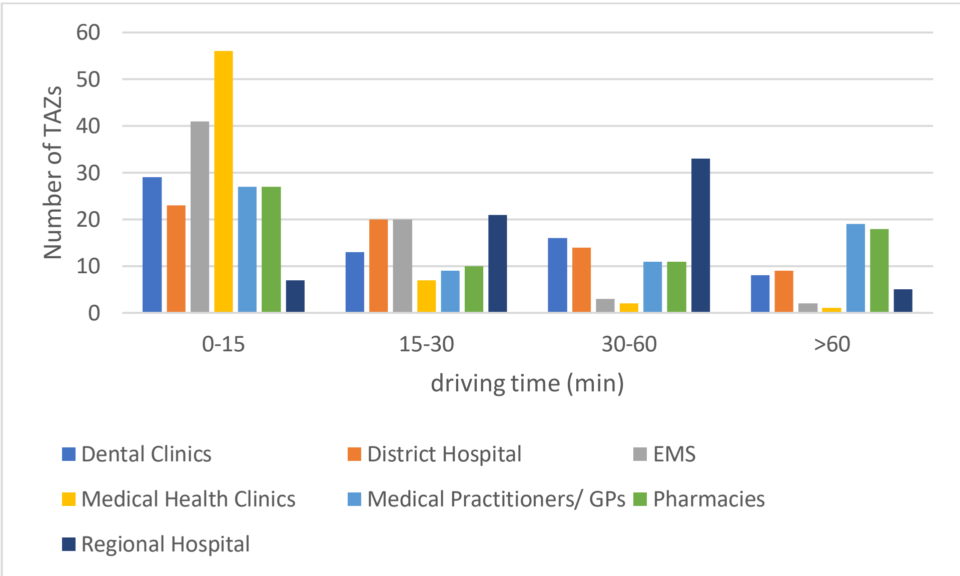


Figure 5-13 Number of TAZs within Specified Driving Time to Healthcare Facilities

It was found that 28% was the largest amount of TAZs (n=19) that were located more than 1-hour drive to the nearest healthcare facility of a single type. This was the case for medical practitioners/GPs. Then, 27% of the TAZs (n=18) were located more than 1-hour drive to the nearest pharmacies. The proximity analysis also revealed that 14% of the TAZs (n=9) were located more than 1-hour drive to the nearest district hospitals. It was found that 12% of TAZs (n=8) were located more than 1-hour drive to the nearest dental clinics and that 8% of the TAZs (n=5) were further than 1-hour walk to the nearest regional hospitals. Only 3% of the TAZs (n=2) were located more than 1-hour drive to nearest EMS. Lastly, only 1,5% of the TAZs (n=1) was located more than 1-hour drive to the nearest medical clinics.

It was established that a large portion of CWDM population were able to reach their nearest healthcare facilities within an acceptable driving time. A frequency distribution of CWDM population over the driving time to nearest healthcare facilities was conducted. The analysis revealed the portion of the CWDM population that was able to reach healthcare facilities at specific driving time intervals. The results are shown under Figure 5-14. For any given driving time interval, it was found that medical clinics were accessible by the largest portion of the population, in comparison to the other healthcare facility types. In fact, more than 70% of the CWDM population were able to access a medical clinic within a 15 minutes' drive.

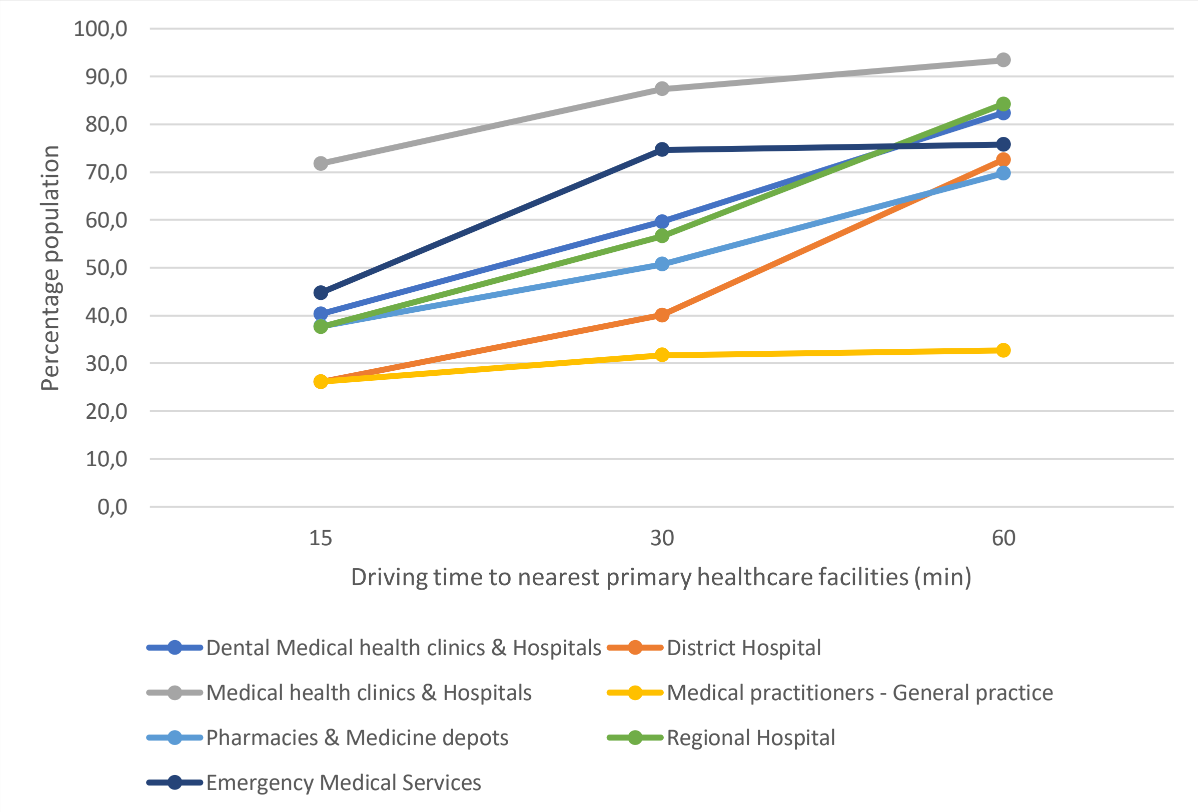


Figure 5-14 CWDM Residents within Specified Driving Time to Healthcare Facilities

Medical clinics were the closest facility type, accessible to most of the population. Within a 30 minutes' drive interval, Figure 5-9 shows that almost 90% of the CWDM population were able to access a medical clinic. It was 75% of the population that were able to access EMS within a 30 minutes' drive. For pharmacies and regional hospitals, almost 60% of the population were able to access within a 30 minutes' drive. Half of the CWDM population were able to access dental clinics within a 30 minutes' drive. Lastly, 40% and 32% of the population were able to access district hospitals and medical practitioners/GPs respectively, within 30 minutes' drive.

For the CWDM, the numbers of residents that did not own a private vehicle and that were located within or beyond the 1-hour drive interval were also calculated. Car ownerships levels were used as proxies. Percentage of the CWDM population without a car and falling within or beyond 1 hour walk to their nearest healthcare facilities are illustrated under Figure 5-15.

Figure 5-15 shows the proportion of the CWDM population did not own a car and were located further than 1-hour drive to their nearest healthcare facilities.

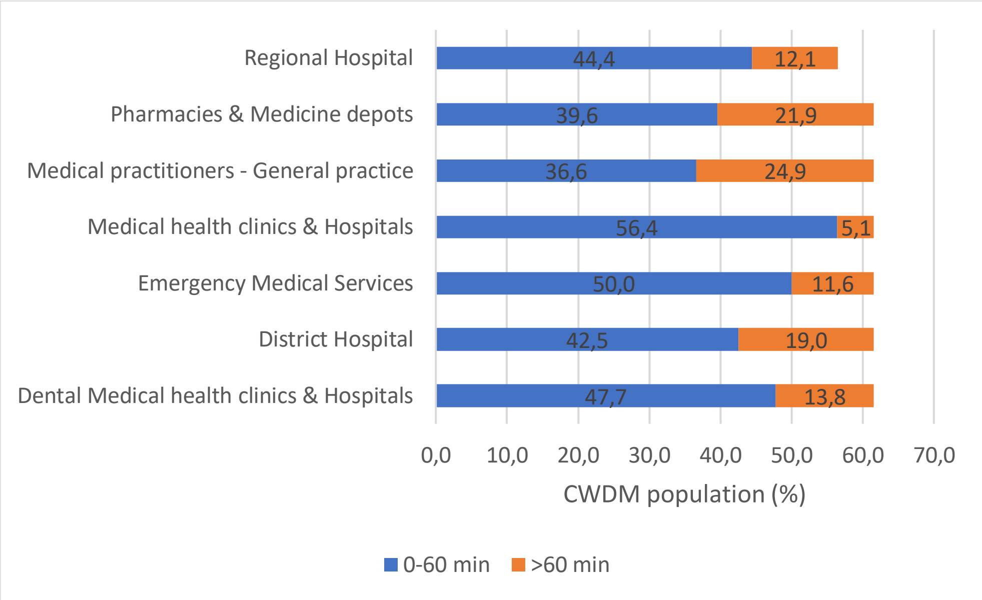


Figure 5-15 CWDM Residents without Car per Driving Time to Healthcare Facilities

Medical practitioners/GPs, with 24,9% (n=196,085), had the largest number of residents falling under that category. It was 21,9% (n=172,460) for pharmacies, 19% (n=149,623) for district hospitals, 13,8% (n=108,674) for dental clinics, 12,1% (n=95,286) for regional hospitals, 11,6% (n=91,349) for EMS and 5,1% (n=40,162) for medical clinics.

5.3 Accessibility Maps to Nearest Healthcare Facilities

This section includes the maps of accessibility indicators for the CWDM to the various types of primary healthcare facilities under investigation in this study. The maps were generated from an IDW analyses that were computed in the ArcGIS model for minimum distances and travel times to healthcare facilities. The IDW interpolation tool in ArcGIS was used to create the raster cells of the Accessibility maps. For full explanation of the IDW interpolation refer to the methodology section of this document.

5.3.1 Dental Medical Health Clinics & Hospitals

Figure 5-16 represents a map of the accessibility to 'Dental Medical Health Clinics & Hospitals' in the CWDM. From this map it was deduced that most settlements in the Southern region of the CWDM had relatively good accessibility to ‘Dental Medical Health Clinics & Hospitals’, with shorter travel distances and travel times. Settlements and towns in the Stellenbosch and Drakenstein LMs had a large concentration of facilities in their vicinity in comparison to other LMs. In Stellenbosch LM, the Settlements of Jamestown, Dalsig and Stellenbosch respectively scored the highest accessibility levels to ‘Dental Medical Health Clinics & Hospitals’. Other settlements with relatively high accessibility to these destinations were Paarl and Wellington in the Drakenstein LM as well as Robertson in the Langeberg LM.

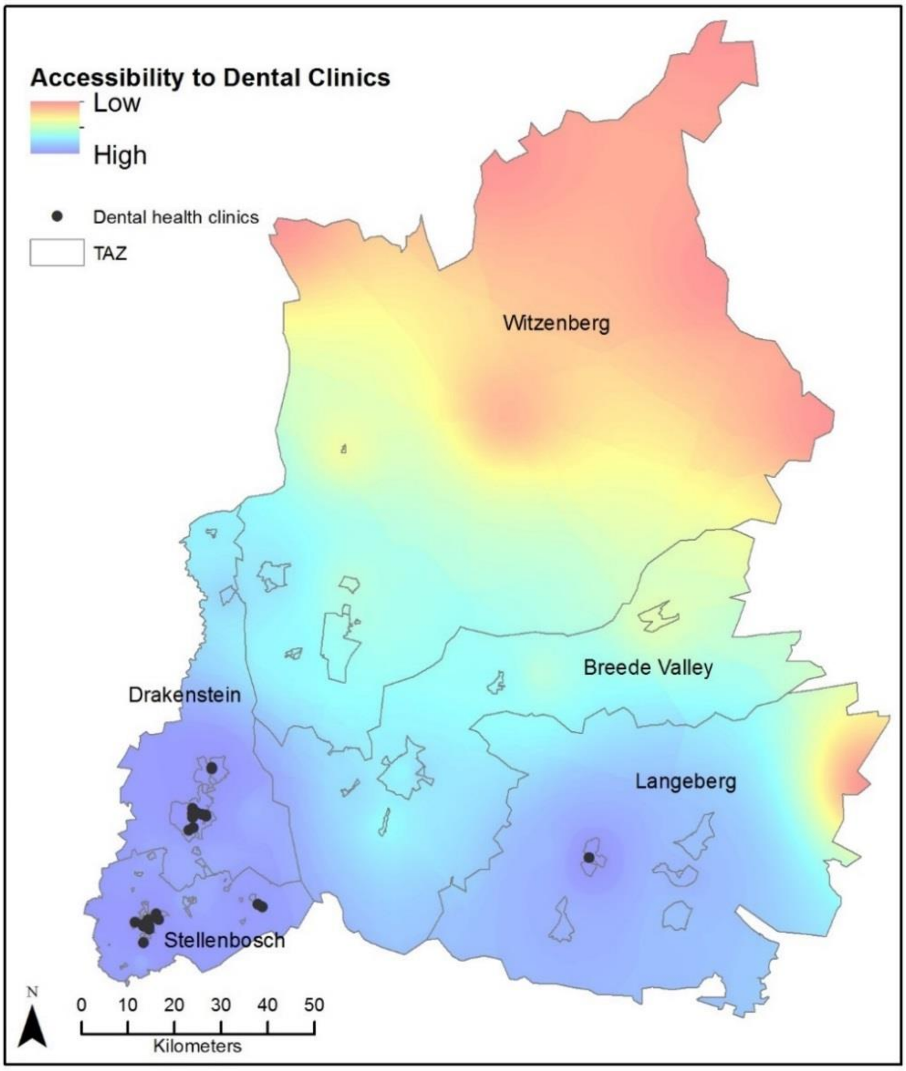


Figure 5-16 Accessibility to Dental Medical Health Clinics & Hospitals

Isolated rural settlements were found in the Northern region of the CWDM. The variable nature of the accessibility in the region was representative of the lower income areas in these settlements, where inhabitants were required to travel long distances to the destinations. The settlement of Touwsriver, located North in the Breede Valley LM had the lowest accessibility score within its respective LM. Witzenberg LM also had relatively poor access to 'Dental Medical Health Clinics & Hospitals' indicated by the large 'red' areas on the map. The poor accessibility was attributed to large travel distances and travel times to reach dental clinics in the region. Within Witzenberg LM, the rural settlements of Op-die-berg, Prince Alfred Hamlet and eNduli scored amongst the lowest accessibility levels to 'Dental Medical Health Clinics & Hospitals' in the CWDM.

5.3.2 District Hospitals

Figure 5-17 represents a map of the accessibility to 'District Hospitals' in the CWDM. From this map it was deduced that most settlements in the Western and South-Eastern regions of the CWDM have relatively good accessibility to 'District Hospitals', with shorter travel distances and travel times. District hospitals locations were mainly concentrated in Langeberg, Stellenbosch and Witzenberg LMs.

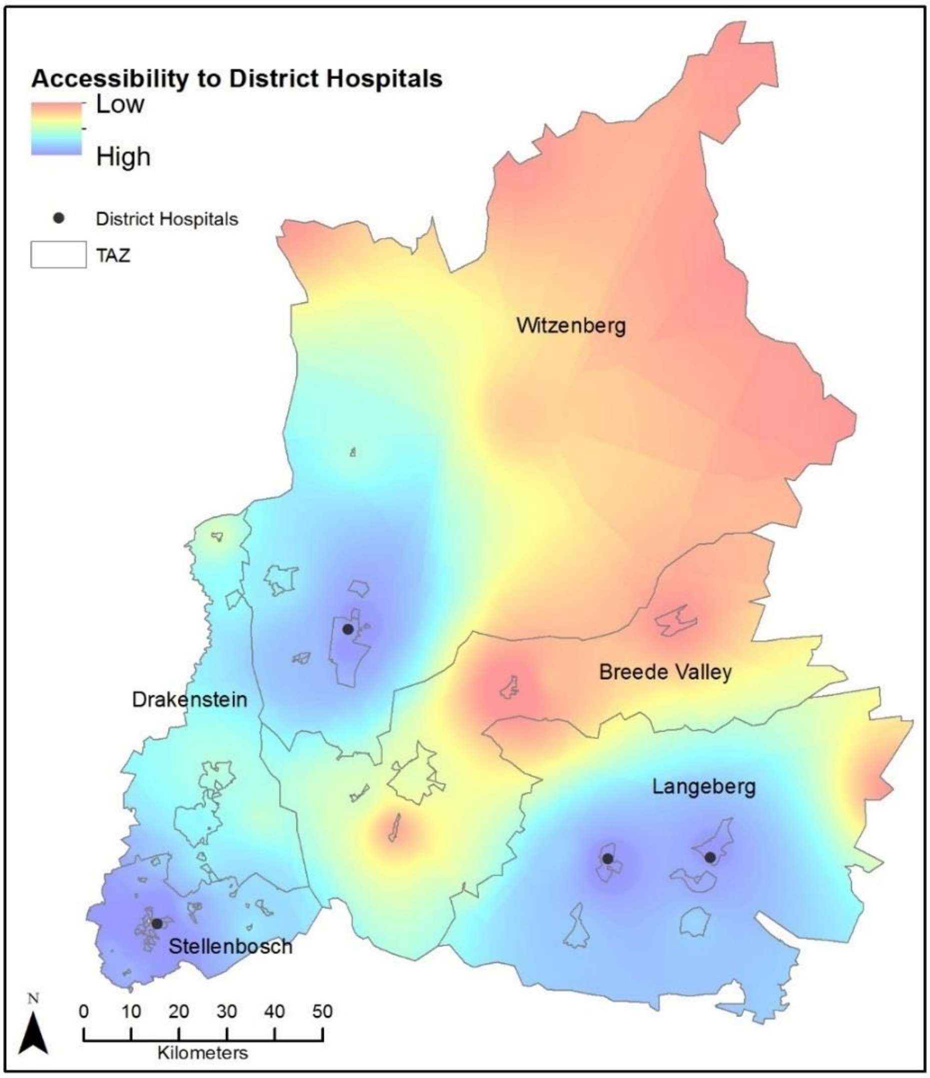


Figure 5-17 Accessibility to District Hospitals

The settlement of Robertson in Langeberg, as well as settlements in Stellenbosch LM scored relatively high accessibility levels to 'District Hospitals'. Nevertheless, the settlements of Ceres, Bella Vista and eNduli, located in the Western region of Witzenberg LM also had relatively high accessibility to 'District Hospitals'.

Isolated rural settlements were found in the Middle and the North-Eastern regions of the CWDM. The variable nature of the accessibility in the region was representative of the lower income areas in these settlements, where inhabitants were required to travel long distances to the destinations. In fact, Breede Valley LM had poor access to 'District Hospitals' indicated by the 'red' areas on the map. Within Breede Valley LM, the settlements of Hassie square, De Doorns, Ekupumeleni, Touwsriver and Brandvlei scored amongst the lowest accessibility levels to 'District Hostipals' in the CWDM. The poor accessibility was attributed to large travel distances and travel times to reach district hospitals in the region.

5.3.3 Emergency Medical Services

Figure 5-18 represents a map of the accessibility to 'EMS' in the CWDM. For the most part, accessibility to 'EMS' in the CWDM was good. 'EMS' facilities were adequately spread in the CWDM. Hence, the LMs of Breede Valley, Drakenstein, Langeberg and Stellenbosch respectively had high accessibility levels to 'EMS'. The settlements of De Doorns and Touwsrivier were found to have the highest accessibility levels in the Breede Valley LM. The settlements of Wellington and Paarl were found to have the highest accessibility levels in the Drakenstein LM. The settlements of Bonnievale and Robertson were found to have the highest accessibility levels in the Langeberg LM. Finally, it was Stellenbosch and La Colline that were found to have to highest accessibility levels in the Stellenbosch LM.

Poor accessibility to 'EMS' were mostly recorded in the Northern region of the CWDM. The rural settlement of Op-die-berg as well as the rest of the Witzenberg LM toward the North had relatively poor accessibility to 'EMS'. Isolated cases of poor accessibility to 'EMS' were found in the Breede Valley LM, at the settlements of Brandvlei, as well as in the rural areas in the East of Langeberg.

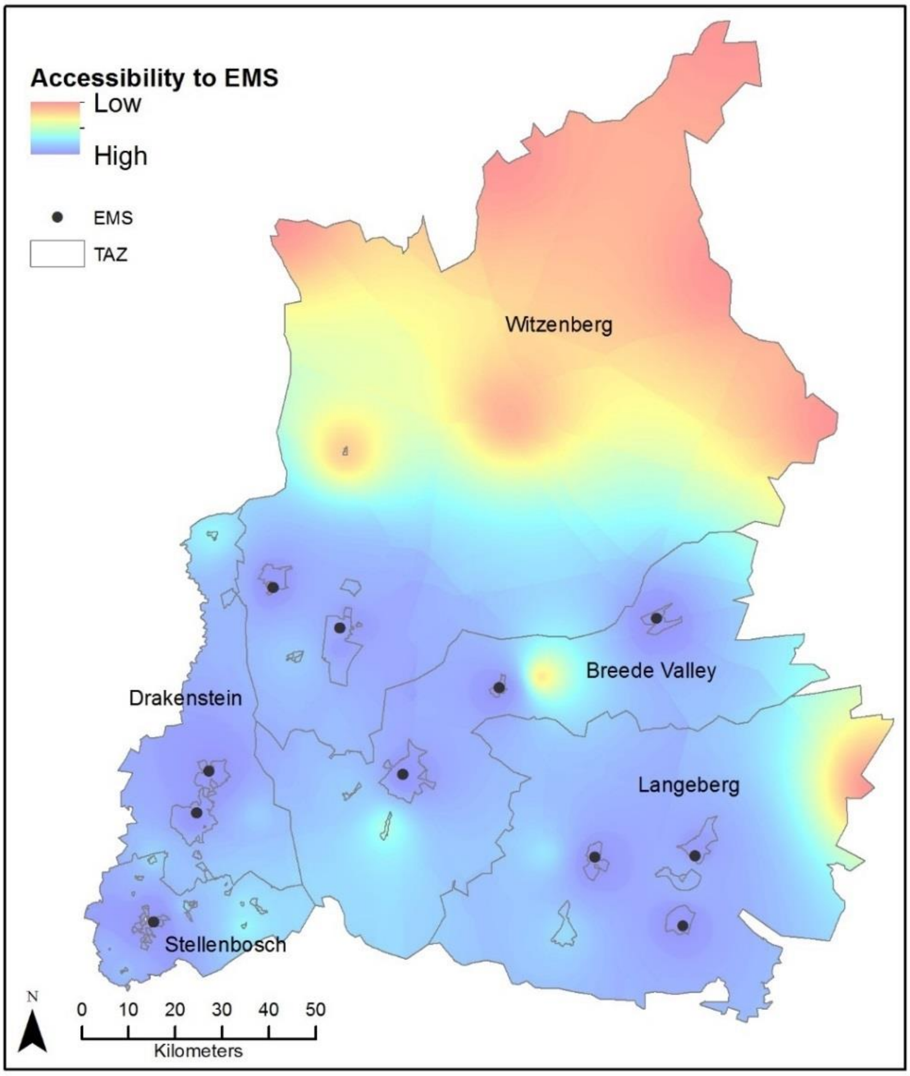


Figure 5-18 Accessibility to EMS

5.3.4 Medical Health Clinics & Hospitals

Figure 5-19 represents a map of the accessibility to 'Medical Health Clinics & Hospitals' in the CWDM. For the most part, accessibility to 'Medical Health Clinics & Hospitals' in the CWDM was good. 'Medical Health Clinics & Hospitals' facilities were adequately spread in the CWDM. Hence, the LMs of Breede Valley, Drakenstein, Langeberg and Stellenbosch, as well as most of the Witzenberg had high accessibility levels to 'Medical Health Clinics & Hospitals'.

The settlements of Zweletemba and Hassie Square were found to have the highest accessibility levels in the Breede Valley LM. The settlements of Saron and Paarl were found to have the highest accessibility levels in the Drakenstein LM. The settlements of Nkqubela and Ashton were found to have the highest accessibility levels in the Langeberg LM. It was Kylemore and Khayamandi that were found to have the highest accessibility levels in the Stellenbosch LM. Finally, the settlements of Op-die-berg and eNduli had the highest accessibility levels to 'Medical Health Clinics & Hospitals' within the Witzenberg LM.

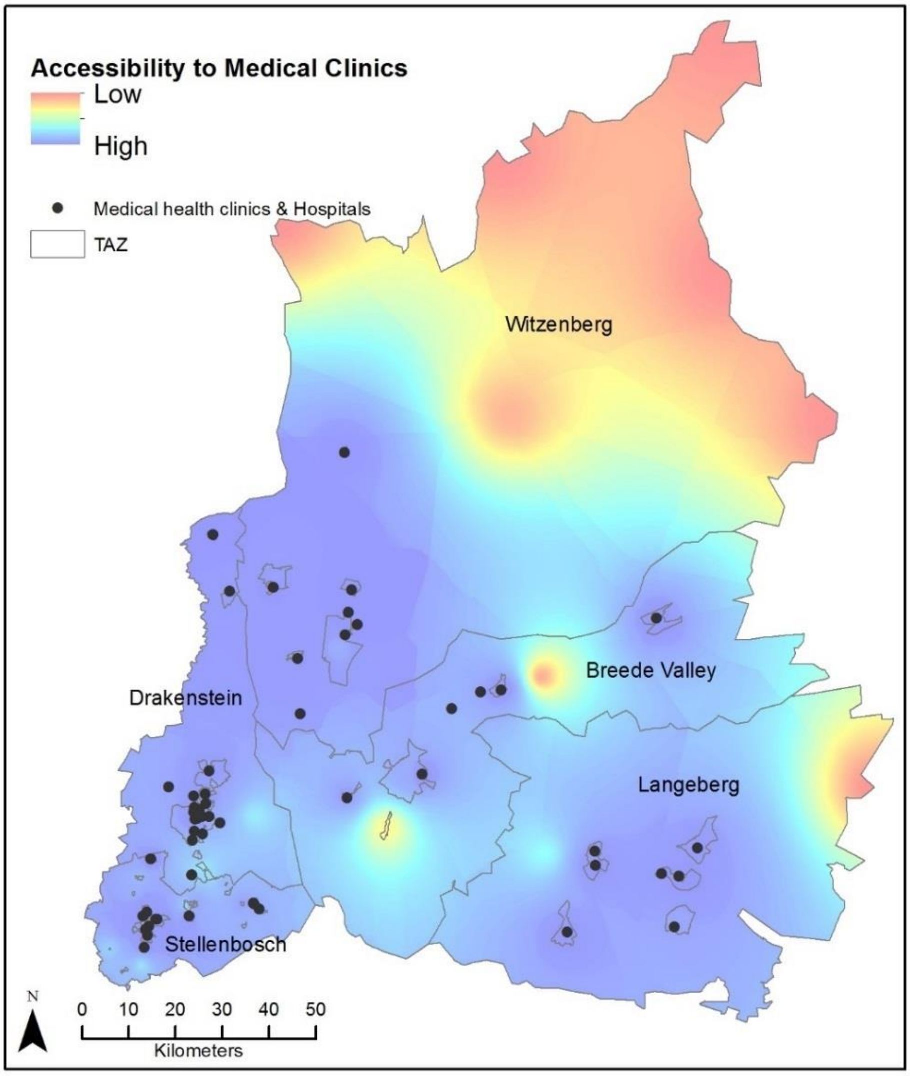


Figure 5-19 Accessibility to Medical Health Clinics & Hospitals

Poor accessibility to 'Medical Health Clinics & Hospitals' were mostly recorded in the Northern region of the CWDM. Further North of the rural settlement of Op-die-berg, in the Witzenberg LM, the accessibility levels to 'Medical Health Clinics & Hospitals' gradually decreased to reach its lowest value. Other isolated cases of poor accessibility to 'Medical Health Clinics & Hospitals' were recorded in the Breede Valley LM, such as the settlement of Brandvlei, but also in the rural areas East of the Langeberg LM.

5.3.5 Medical Practitioners – General Practice

Figure 5-20 represents a map of the accessibility to 'Medical Practitioners/GPs' in the CWDM. From this map it was deducted that most settlements in the South-Western region of the CWDM had relatively good accessibility to 'Medical Practitioners/GPs', with shorter travel distances and travel times. Settlements in the Stellenbosch as well as the Drakenstein LMs had a large concentration of facilities in their vicinity in comparison to the other LMs.

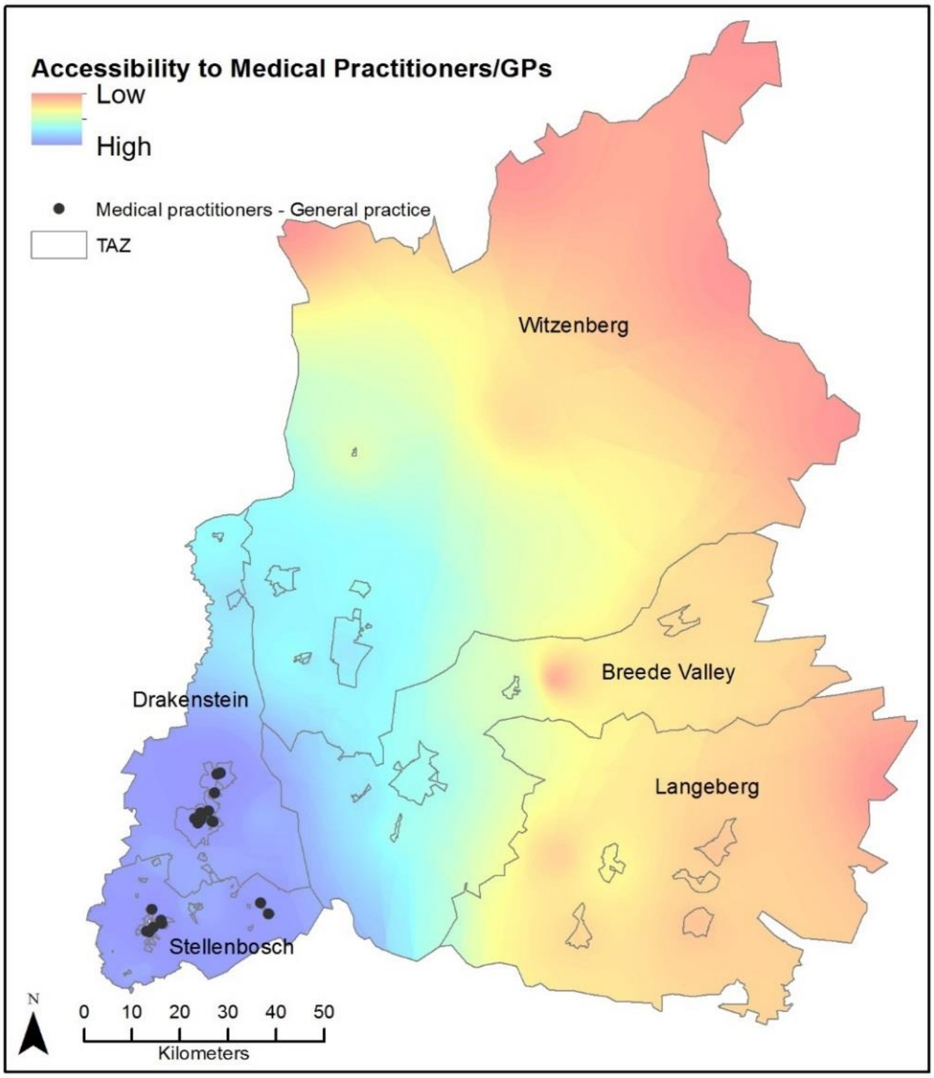


Figure 5-20 Accessibility to Medical Practitioners/GPs

Within Stellenbosch LM, the settlements of Welgevonden, Stellenbosch and Dalsig respectively scored the highest levels of accessibility to 'Medical Practitioners/GPs'. Within Drakenstein LM, the settlements of Wellington, Paarl and Onverwacht respectively scored the highest levels of accessibility to 'Medical Practitioners/GPs'. Other settlements with relatively high levels of accessibility to ‘Medical Practitioners/GPs’ were located within the Witzenberg (Ceres and Tulbagh) and the Breede Valley LMs (Rawsonville and Worcester).

Since most facilities were located within Stellenbosch and Drakenstein LMs, the accessibility levels had the tendency to decrease further away from these hubs. Poor accessibility to ‘Medical Practitioners/GPs’ were mostly recorded in the Eastern and Northern regions of the CWDM.

In the Langeberg LM, most settlement had relatively poor accessibility levels. The variable nature of the accessibility in those regions was representative of the lower income areas in the settlements, where inhabitants were required to travel long distances to the destinations. In the Breede Valley LM, settlements such as Touwsrivier, Ekupumeleni and Hassie Square were found to have poor accessibility to ‘Medical Practitioners/GPs’. While in the Witzenberg LM, poor accessibility was recorded in the settlements of Op-die-berg as well as the rural areas in the North of the region.

5.3.6 Pharmacies & Medicine Depots

Figure 5-21 represents a map of the accessibility to ‘Pharmacies & Medicine Depots’ in the CWDM. From this map it was deducted that most settlements in the South-Western region of the CWDM had relatively good accessibility to ‘Pharmacies & Medicine Depots’, with shorter travel distances and travel times. Settlements in the Stellenbosch as well as the Drakenstein LMs had a large concentration of facilities in their vicinity in comparison to the other LMs.

Within Stellenbosch LM, the settlements of Stellenbosch, Kleingeluk and Dalsig respectively scored the highest levels of accessibility to ‘Pharmacies & Medicine Depots’. Within Drakenstein LM, the settlements of Paarl, Wellington and Onverwacht respectively scored the highest levels of accessibility to ‘Pharmacies & Medicine Depots’. Other settlements with relatively high levels of accessibility to ‘Pharmacies & Medicine Depots’ were located within the Witzenberg (Montana and Wolseley) and the Breede Valley LMs (Rawsonville and Worcester).

Since most facilities were located within Stellenbosch and Drakenstein LMs, the accessibility levels had the tendency to decrease further away from these hubs. Poor accessibility to ‘Pharmacies & Medicine Depots’ were mostly recorded in the Eastern and Northern regions of the CWDM. In the Langeberg LM, most settlement had relatively poor accessibility levels.

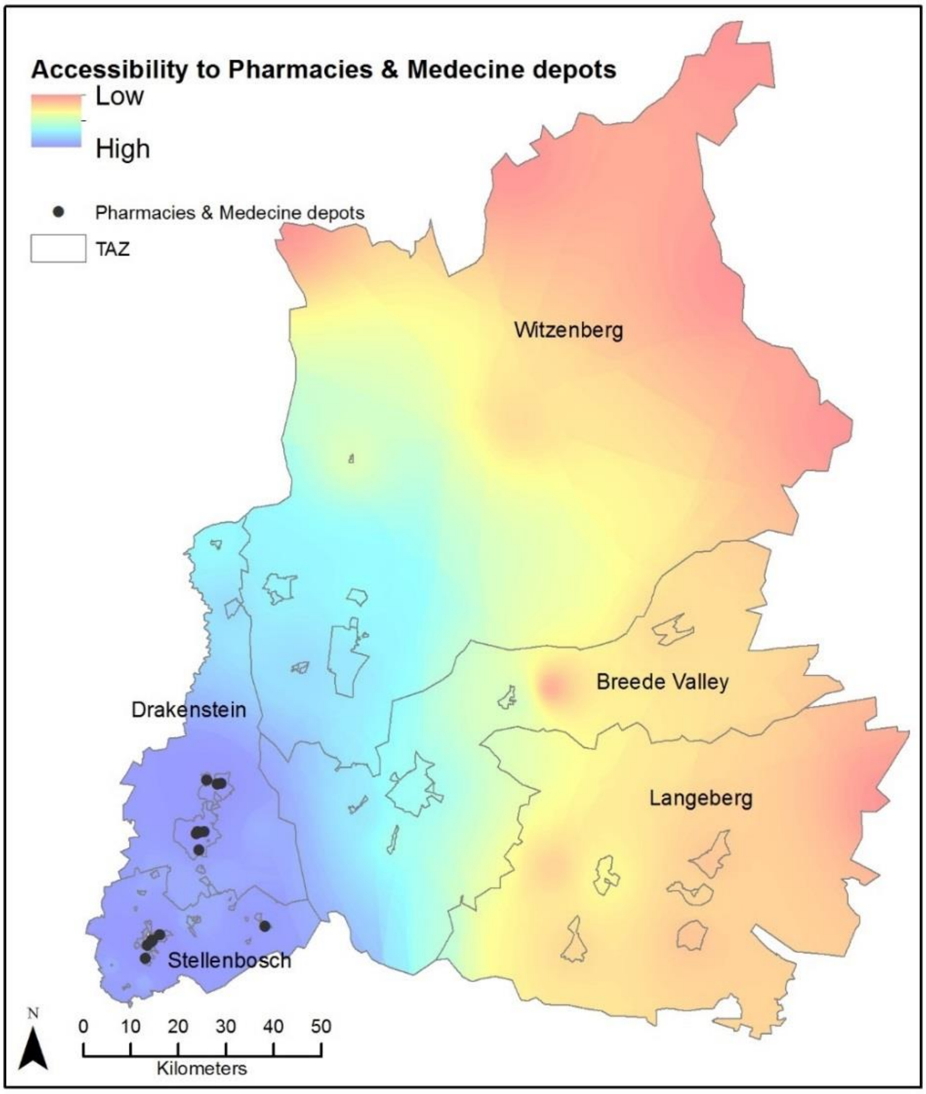


Figure 5-21 Accessibility to Pharmacies & Medicine Depots

The variable nature of the accessibility in those regions was representative of the lower income areas in the settlements, where inhabitants were required to travel long distances to the destinations. In the Breede Valley LM, settlements such as Touwsrivier, Ekupumeleni and Hassie Square were found to have poor accessibility to 'Pharmacies & Medicine Depots'. While in the Witzenberg LM, poor accessibility was recorded in the settlements of Op-die-berg as well as the rural areas in the North of the region.

5.3.7 Regional Hospitals

Figure 5-22 represents a map of the accessibility to 'Regional Hospitals' in the CWDM. From this map it was deduced that most settlements in the Southern and Middle regions of the CWDM had relatively good accessibility to 'Regional Hospitals', with shorter travel distances and travel times. ‘Regional Hospitals’ were only located in the Drakenstein and Breede valley LM. Hence, the absolute values of travel time from most settlements to ‘Regional Hospitals’ were high. Paarl in the Drakenstein LM, as well as Zweletemba in the Breede Valley LM were found to have the highest accessibility levels to ‘Regional Hospitals’ for the CWDM.

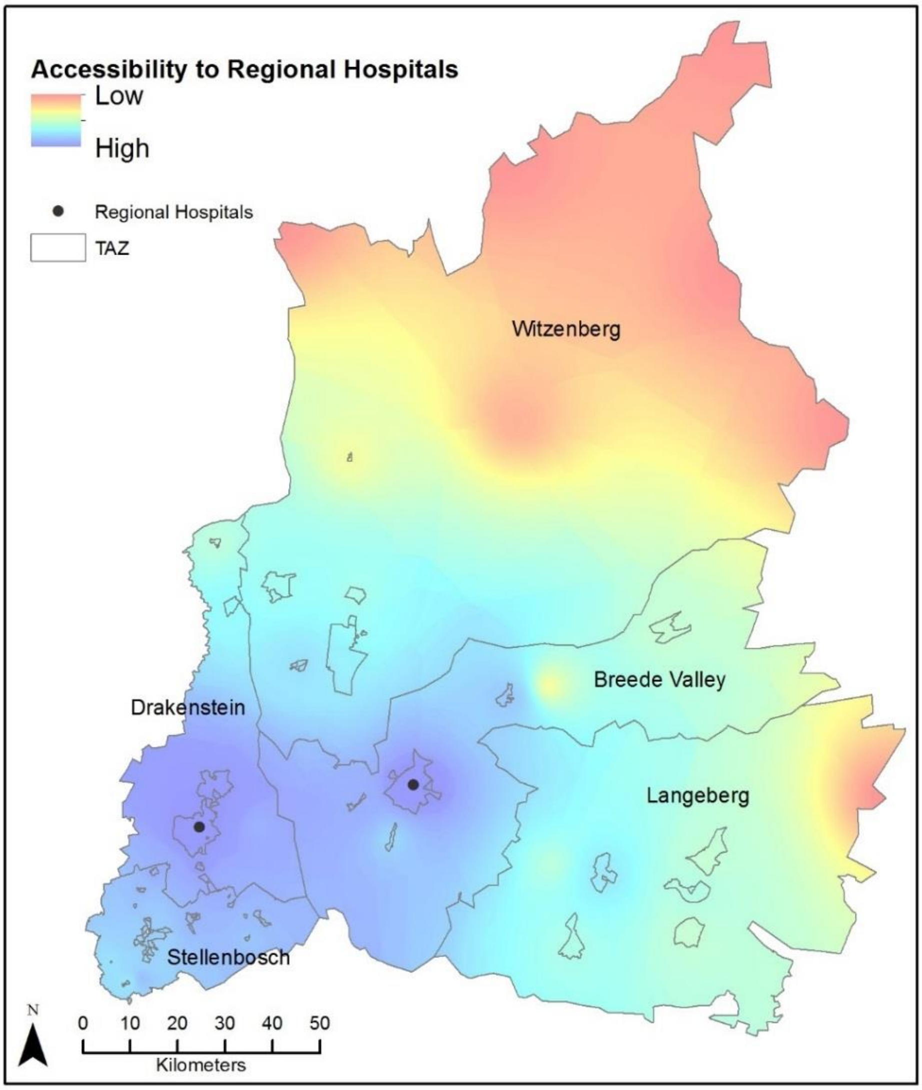


Figure 5-22 Accessibility to Regional Hospitals

Poor accessibility to ‘Regional Hospitals’ were mostly recorded in the Northern region of the CWDM. From the rural settlement of Op-die-berg in the Witzenberg LM, moving North, the accessibility levels to ‘Regional Hospitals’ gradually decreased to reach its lowest value. Other isolated cases of poor accessibility to ‘Regional Hospitals’ were recorded in the Breede Valley LM, such as the settlement of Touwsrivier, but also in the rural areas in the East of the Langeberg LM, including the settlements of Zolani and Ashton.

Chapter 6: Accessibility Index to Healthcare in CWDM

This chapter includes the final calculated accessibility indices for the CWDM, as well as the results of the various IDW analyses computed in ArcGIS and a comparison of the outcomes of these analyses.

6.1 Resultant Accessibility Indices to Healthcare

Spatial accessibility indices to healthcare facilities were calculated for the local communities in Cape Winelands. The indices were derived from three different measures of accessibility, namely, the Minimum Travel Time measure, the Primary Healthcare Gravity measure and the Two-step Cluster Primary Healthcare Gravity measure. For a full explanation of these measures refer to the methodology section of this document.

Figure 6-1 represents a map of the accessibility indices derived from the Minimum Travel Time measure.

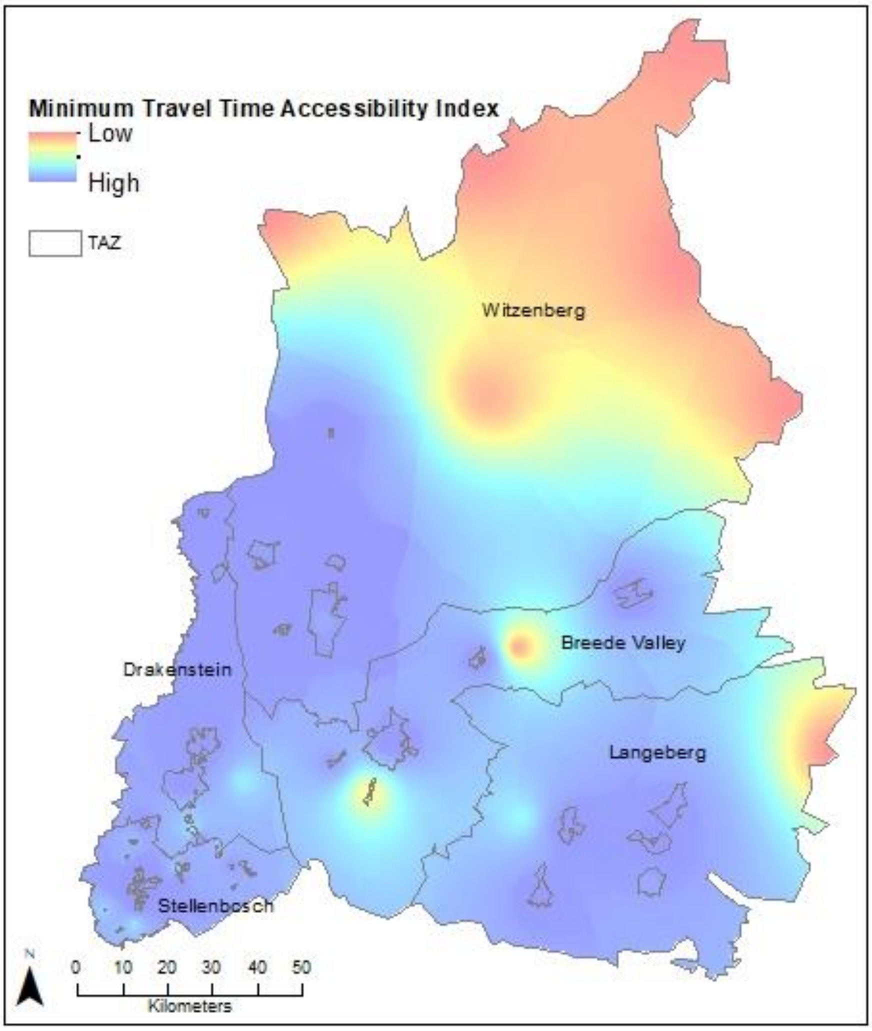


Figure 6-1 Minimum Travel Time Accessibility Index in CWDM

This measure defined spatial accessibility from TAZs to the nearest healthcare facility. From this map it was deducted that most of the settlements in the CWDM had relatively good accessibility to healthcare facilities. In fact, the Western region and the South-Eastern region of the CWDM had relatively high accessibility indices. The settlements of Zweletemba and Hassie Square were found to have the highest accessibility indices in the Breede Valley LM. The settlements of Saron and Paarl were found to have the highest accessibility indices in the Drakenstein LM. The settlement of Nkqubela and Ashton were found to have the highest accessibility indices in the Langeberg LM, while the settlements of Jamestown and Kylemore were found to have the highest accessibility indices in the Stellenbosch LM. Finally, the settlements of Op-die-berg and eNduli were found to have the highest accessibility indices in the Witzenberg LM.

Low accessibility indices were mostly recorded in the Northern region of the CWDM, as well as in a few isolated areas of the Breede Valley and Langeberg LMs. Only the rural areas, in the East region of the Langeberg LM were found to have relatively low accessibility to healthcare. On the other hand, the settlements of Brandvlei and De Doorns were found to have low accessibility indices in the Breede valley LM region. Finally, it was the rural areas in the North of Witzenberg LM, including the settlements of Ceres and Meulstroom that were found to have low accessibility indices in the Witzenberg LM.

Figure 6-2 represents the map of the accessibility indices derived from the Primary Healthcare Gravity measure. In the Primary Healthcare Gravity measure, all healthcare facilities were evaluated in relation to each TAZ. From this map it was deducted that most of the settlements in the CWDM had relatively low accessibility to healthcare facilities. In fact, only the major settlements in the Western region of the CWDM had relatively high accessibility indices. These include settlements such as Paarl and Saron in the Drakenstein LM, as well as Stellenbosch and Dalsig in the Stellenbosch LM.

Low accessibility indices to healthcare were mostly found in the Northern region and the Eastern region of the CWDM. They are indicated with the ‘red’ areas on the map. The rural areas in the North, including the settlements of Meulstroom and Pine Valley had the lowest accessibility indices in the Witzenberg LM. On the other hand, the settlements of Brandvlei and De Doorns, as well as the rural areas in the East had the lowest accessibility indices in the Breede Valley LM. Finally, the settlements of Bonnievale, McGregor and Zolani had the lowest accessibility indices in the Langeberg LM.

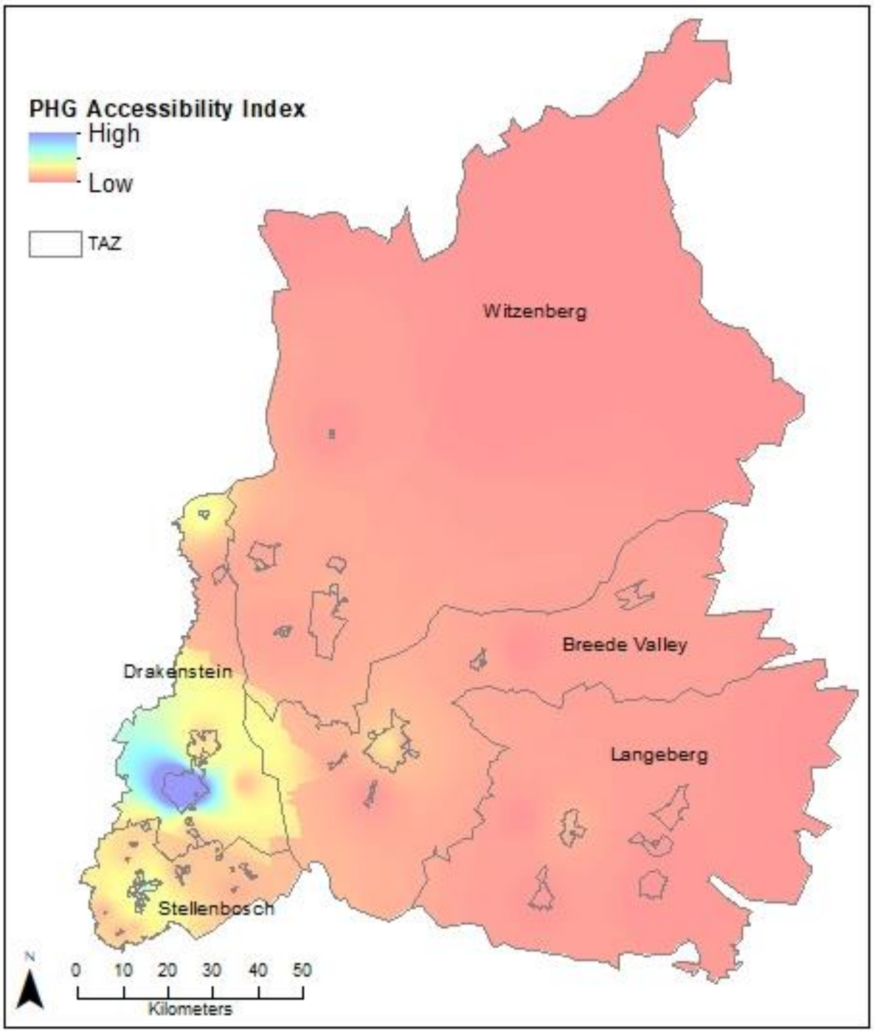


Figure 6-2 Primary Healthcare Gravity Index in CWDM

Figure 6-3 represents the map of the accessibility indices derived from the Two-step Cluster Primary Healthcare Gravity measure. This measure recognised that facilities that served too large a population may not be preferred destinations, because it becomes difficult to schedule desired appointment times or receive personal service. From this map it was deducted that most of the settlements in the Western region of the CWDM had relatively high accessibility indices. The Drakenstein and Stellenbosch LMs had the largest concentration of settlements with high accessibility indices. The settlement of Paarl, Saron and Mbekweni had the highest accessibility indices in the Drakenstein LM. The settlement of Stellenbosch, Dalsig and La Colline had the highest accessibility indices in the Stellenbosch LM. Other settlements such as Worcester and Hassie Square (Breede Valley LM), as well as Robertson (Langeberg LM), were found to have relatively high accessibility indices as well.

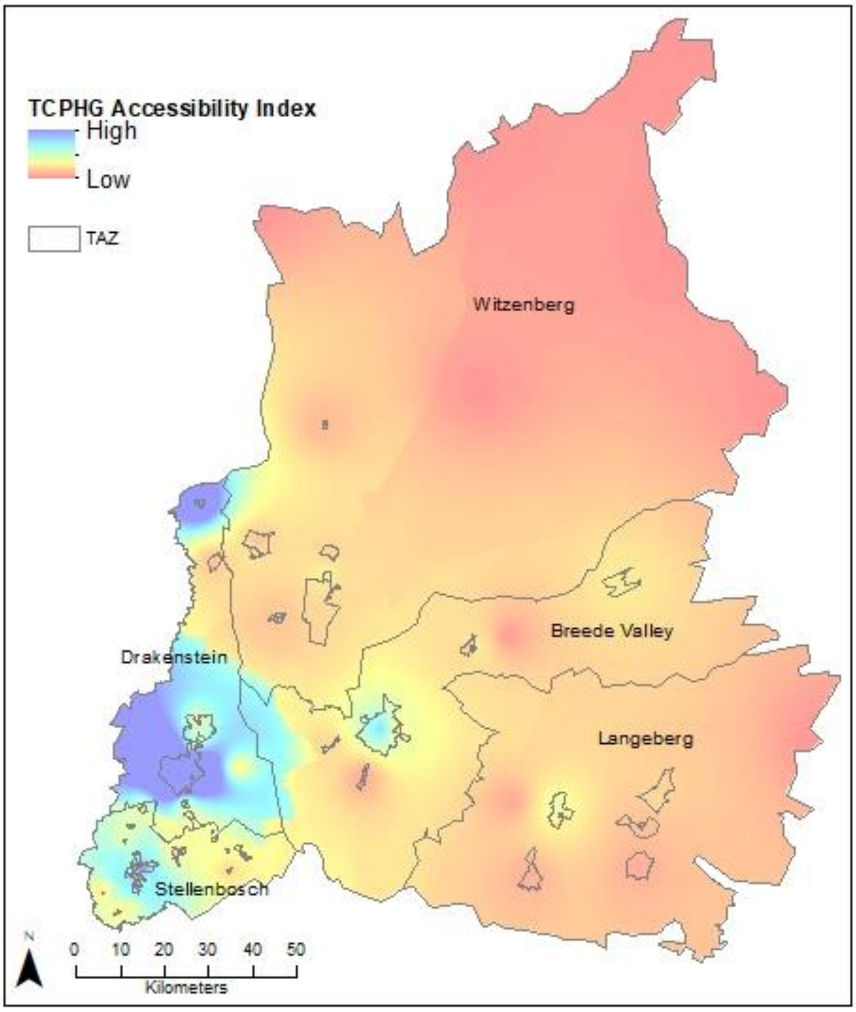


Figure 6-3 Two-step Cluster Primary Healthcare Gravity Index in CWDM

Except for a few isolated settlements, low accessibility indices were mostly found in the Northern region of the CWDM. They are indicated with the 'red' areas on the map. The rural areas in the North, including the settlements of Meulstroom and Pine Valley had the lowest accessibility indices in the Witzenberg LM. On the other hand, the settlements of Brandvlei and Rawsonville, as well as the rural areas in the East had the lowest accessibility indices in the Breede Valley LM. Finally, the settlements of Bonnievale, McGregor and Zolani had the lowest accessibility indices in the Langeberg LM.

6.2 Statistical Evaluation across Measures of Spatial Accessibility

Inferential statistics were used to determine if there was a significant difference between the means of the spatial accessibility measures presented in Section 6.1. A T-test and P-test were performed to assess whether the distributions of spatial accessibility to healthcare in Cape Winelands, obtained from the measures presented in Section 6.1 displayed any significant differences. A description of the procedure to calculate these inferential statistics is presented in the methodology chapter of this document, under Section 3.2.8.

The null hypothesis (H_0, refer to Equation 8) stated that there was not a significant difference between the measures of accessibility used to carry out the study. Three two-sampled T-test and P-test were then conducted between the three sets of data. The data sets all had sample sizes of 66 and the critical value β at 95% confidence was 1,96. The T-test and P-test statistics were calculated, and the results are displayed in Table 6-1 underneath.

Table 6-1: T-Test Results

Data sets compared	T-value	P-value	*Θ* (2-tail)	Hypothesis outcome
MTT and PHG	5,588	0,00001	1,96	Rejected H_0
MTT and TCPHG	5,687	0,00001	1,96	Rejected H_0
PHG and TCPHG	0,468	0,32	1,96	Fail to reject H_0

The hypothesis outcome was rejected for two out of the three pairs of data sets under comparison. A significant statistical difference was found between the uses of the Minimum Travel Time measure and the other two measures. The comparison between the MTT and the PHG returned a T-value of 5,588 and a P-value of 0,00001. The null hypothesis for this pair of data set was rejected because the calculated T-value was greater than the critical value for the given confidence interval and the calculated P-value was smaller than 0,05. The statistical test results provided a strong evidence against the null hypothesis. Similarly, the comparison between the MTT and the TCPHG also provided a strong evidence against the null hypothesis, with a T-value of 5,687 and P-value of 0,0001. These results proved that the Minimum Travel Time measure is not comparable nor interchangeable with the Primary Healthcare Gravity measure or the Two-step Cluster Primary Healthcare Gravity measure. On the other hand, the comparison between the PHG and TCPHG returned a T-value of 0,468 and a P-value of 0,32. The null hypothesis for this pair of data set failed to be rejected because the calculated T-value was smaller than the critical value for the given confidence interval and the calculated P-value was greater than 0,05. In that case, the statistical test results provided a strong evidence toward the null hypothesis. Therefore, it can be concluded that statistically there is no difference between the uses of Primary Healthcare Gravity measure and Two-step Cluster Primary Healthcare Gravity measure.

Chapter 7: Conclusions and Recommendations

Based on findings for this study, this chapter engages in discussions around key themes deemed significant. Research questions are answered in the discussions. The sections presented here illustrate the findings unpacked against the literature. They describe patterns of spatial distribution of population, transport infrastructure and healthcare facilities from the demand, as well as the supply side. Assumptions and parameters governing the methodology are thoroughly discussed to reiterate the scope and limitation of the study. Conclusions are drawn and explanations are provided to show how this research differs, confirms, or adds value to the existing body of knowledge in the literature. Furthermore, it provides suggestions and recommendations for further studies.

7.1 Spatial Distribution of Population, Transport Infrastructure and Healthcare Facilities

This section describes the characteristics of the demand for healthcare, and the supply of healthcare service in CWDM. Findings from this study suggest that demographic and locational factors were the determinants of the demand for healthcare. Population sizes, gender and age distribution, as well as population groups represent significant determinants of the demand for healthcare. Employment rates, income, and household goods ownership provided insight into the development and well-being of the region. The determinants of the supply of healthcare were location specific. Solutions to the healthcare provision in South Africa are, generally, looked at from the supply-side, where healthcare resources are supposedly concentrated in the private health sector.

CWDM covers an area of 21 4 72,67 km^2 in the Western Province and it holds the second largest population density after the City of Cape Town Metropolitan Municipality. Population demographics for CWDM were obtained from Statistics SA and characterised in terms of size, gender and age distribution, and population group. CWDM remained the largest populated district outside of the metro in the Western Cape. Its population accounted for 13.5% of the total population in the province in 2011. The demographics were investigated at Census block levels for 66 zones. The total population recorded in the Census 2011 was 19 265, which accounted for a population density of 36,67 persons per km^2. The Census 2011 blocks delineated the settlements in the region (Regional Settlements and Hamlets). It was expected that low population density would be observed in hamlets, rather than in regional settlements or local towns. This was indeed the case. Most rural areas had substantially smaller populations in comparison to their urban counterparts. The most populated area was Paarl, and the least populated one was Robertsvlei. The gender ratio was 97,2 males per 100 females in 2011 and the number of persons aged between 15 and 34 years old accounted for the largest percentage (36,8%) in the age distribution.

Population was disaggregated further by racial population groups. In 2011 the Coloured population accounted for 62,7% of CWDM population, the African population accounted for 23,9%, the White population 13.0% and the Indian or Asian population for 0,4%. While the total population annual growth percentage was 3,60% over the period 2001 – 2011, it was unexpected to find that the Indian or Asian population grew at an astonishing 12,7% per year. This can be explained by the small numbers effect phenomena. The second largest growth in population group was observed for the African population (6,9%).

The population of CWDM was further characterised in terms of development and well-being. The employment and average household income levels, as well as household goods ownership, were used as indicators of development and well-being for the study area. Unemployment rate is a key macro-economic indicator to determine the health of an economy. An increase in unemployment rate was observed from 2001 – 2011. The unemployment rate increased by 8,3%. This can be interpreted as an ongoing recession in the economy that was reflected on the population. Unemployment does not just affect the individual, but also his/her household and, in the long run, the rest of the population as well. It negatively affects people’s life expectancy by forcing them to live their life in a manner that they do not wish to. There are many aspects in which the ease by which people live and satisfy their needs can be negatively affected by unemployment. A study conducted by Faisalabad (2009) indicated that individuals are prone to develop mental health problems derived from the absence of income and the frustration involved in it. Hopelessness, low self-confidence, and depression are examples of common mental health issues. Overall, unemployment tension can increase general health issues of individuals. Unemployment can be the cause for argument and quarrels in the households. This can lead to an increased number of divorces. Unemployment can be the cause for loss of trust in the government and in administration, which may lead to political instability. Furthermore, it can be the cause for increased crime rates and violence, or even suicide cases. Unemployment rate in South Africa, in the first quarter of 2017, had reached its highest level (27,7%), since 2003.

Household income is a measure of the combined income of all people sharing a household, including every form of income, e.g. salaries, wages, and retirement income. This data was obtained from Statistics South Africa. The findings indicate the percentage of households within income brackets for each LMwithin the study area. Interestingly, the most populated municipalities represent the largest number of households without an income. Stellenbosch LM and Drakenstein LM, respectively, topped the list with 20,6% and 13,0% of households that did not have an income. However, these two municipalities also had the highest percentage of residents with over R153 801 average household income. Respectively, 22,0% and 20,1% of the households, for Drakenstein LM and Stellenbosch LM, earned above the R153 801 income bracket. These observations reflected the income inequality, not only for these municipalities, but also for South Africa as a whole. As reported by many sources, including the International Monetary Fund (IMF), South Africa is known for its extreme income inequality, one of the highest in the world. While income share depicts this phenomenon, tax and survey data suggested that 10% of the South African population owns at least 90-95% of all assets. This share is much higher than in advanced economies, where the richest 10% owned approximately 50-75% of all assets. These findings echo the results of similar research conducted. For instance, Orthofer (2016) reported that, in South Africa, the wealthiest 10% of the population owned at least 90-95% of all wealth, whereas the highest-earning 10% received only 55-60% of income. The next 40% of the population (middle class) earned about 30-35% of all income, but only 5-10% of all wealth. Finally, the poorest 50% of the population, who still earned about 10% of all income, owned no measurable wealth at all.

Household goods and motorcar ownership also provided an indication of the standard of living within CWDM. Witzenberg LM had the highest motorcar ownership in CWDM, at 71.6% of households. Surprisingly, a general trend was that the most populated LMs were found to have the least motorcar ownership. Only 56.0% and 56.5% of households owned at least one car, for Drakenstein LM and Stellenbosch LM, respectively. This fits with the interpretation that urbanised areas tend to have a network of public transport, to cater for the transportation needs of the population, unlike their rural counterparts. Hence, the motorcar ownership demand is prone to be lower for households in urban than the demand in rural areas, due to the availability of other means of transport, such as public transport. It should be noted that this research did not consider public transport availability for the study of spatial accessibility to healthcare.

Healthcare facilities and their characteristics represented the supply of healthcare in CWDM in this study. Combining public and private funded healthcare services, 196 healthcare facilities were identified. There were 143 private healthcare facilities, and 53 public funded healthcare facilities. Overall, private healthcare plays a surprisingly large role in the healthcare decisions of all South Africans. Studies show that even poor respondents reveal a clear preference for private healthcare, despite constraints of money and access (Havemann & Van der Berg, 2003). There is a major gap between private and public healthcare in South Africa (Young, 2016). Public healthcare is funded by the South African Government. The advantages of publicly funded health services consist of free care to all citizens, which also includes pharmaceuticals, crutches, wheelchairs, toilet seats, home care visits etc. These advantages benefit the population that otherwise could not afford healthcare. However, the disadvantages consist of relatively poor quality of care in comparison to private healthcare, long waiting times, rushed appointments, poor disease control and prevention practices, as well as dilapidated facilities. On the other hand, private healthcare services differ from public healthcare services, as it is not funded by the government. This means that citizens bare the cost of treatment at private healthcare facilities. In CWDM there are more private funded healthcare facilities than public funded ones. The presumed advantages of private healthcare are quality of care, short waiting time, adequate resources available, better facilities, appointments are not rushed, and proper disease control and prevention practices are utilised. The disadvantages of private healthcare are that it is relatively expensive in comparison to public healthcare.

"The South African healthcare system has been described as a two-tiered system divided along socio-economic lines" (Republic of South Africa Health Department, 2015). Whether private funded, or public funded healthcare services, there are three levels of care: primary, secondary, and tertiary. With hospitals, for instance, primary level hospital care includes internal medicine, obstetrics and gynaecology, paediatrics, general surgery and general practices. They offer limited laboratory services and do not require referrals. Secondary level hospitals are differentiated by function and usually have multiple clinical specialities. A rehabilitation centre is an example of secondary level hospital, since it would typically include specialities, such as physiotherapy, occupational therapy, orthotics and prosthetics, speech therapy, dietetics and podiatry. Tertiary level hospitals offer highly specialised equipment and expertise in areas, such as coronary artery bypass surgery, renal or haemodialysis, neurosurgeries, sever burn treatments and other complex treatments and procedures.

One hundred and forty-nine (149) healthcare facilities were selected for the study and organised by types of primary healthcare services. The seven types of primary healthcare for this study were: dental health clinics, district hospitals, emergency medical services, medical health clinics, medical practitioners, pharmacies and regional hospitals. It was expected that most healthcare facilities were located within regional settlements and local towns. Drakenstein LM and Stellenbosch LM had the largest number of healthcare facilities. Paarl and Stellenbosch had by far the largest concentration of healthcare facilities in CWDM, 48 and 38 facilities, respectively. Amongst the 66 localities within CWDM, in this study, only 26 of them had at least one healthcare facility. Hotspots, where healthcare facilities concentration was large, were mainly found around regional settlements and local towns such as Ceres, Franschhoek, Paarl, Stellenbosch, Tulbagh, Wellington and Worcester. The geographical coverage of healthcare services, based on facility locations, was poor. More than half of the settlements, delineated according to Census 2011 data, did not have any healthcare facilities. These areas were deprived of healthcare facilities within their vicinity and the nearest healthcare facility was often found in the surrounding local towns or regional settlements. Finally, all settlements in this study were accessible by roads. The road network in the study area consisted of approximately 4 900 km of road, with various speed limits and, supposedly, different traffic conditions throughout the day (refer to Figure 4-13 for the road network map). The predominantly rural northern part of CWDM accounted for fewer small towns and fewer roads, compared to its predominantly urban southern counterpart.

7.2 Measures of Spatial Accessibility to Healthcare Facilities

Characteristics of spatial accessibility to healthcare facilities were obtained from an investigation of travel distance to nearest facilities. Travel time to nearest facilities and spatial accessibility indices for local communities to healthcare facilities were also constructed. In the methodology, a set of spatial accessibility measures was suggested. These measures were derived from the discussion on accessibility models, in the literature section of this thesis. The methods were developed for cumulative models, and gravity models. Cumulative measures calculate the shortest distance that an individual should travel to arrive at the nearest activity opportunity. In other words, they estimate individuals' spatial accessibility to equate the cumulative number of activity opportunities within a specific distance or time frame from his/her location of origin. Gravity measures share similarities with the transportation gravity models of the four-step planning model. For gravity measures, individuals' spatial accessibility is calculated as a function of activity opportunity attractiveness, and the travel distance between other zones and the individual's resident zone.

To identify spatial clusters of disadvantaged locations and communities in CWDM, the accessibility measures were developed and implemented in a way that was consistent with theories and the spectrum in accessibility research. Van Eck (1995), Hansen (1959), Thouez Bodson et al. (1988), McLafferty (1982), Lui (2008), Braby and Skelly (2002), Maher (1994), and Knox (1979), have used either of the two accessibility model types, across a range of disciplines, including: urban planning, geography and health, public health and public policy. Therefore, results from the spatial accessibility investigation in CWDM, using the above-mentioned methods, were expected to fit and stay consistent with other researches within the discipline.

Three spatial accessibility measures were developed from two sets of models (cumulative and gravity models) for CWDM, respectively, Minimum Travel Time measure (distance, walking and driving), Primary Healthcare Gravity measure and Two-step Cluster Gravity measure. The results highlighted a few important conclusions regarding the comparability and interchange of accessibility measures. First, the categories of accessibility models, cumulative and gravity models, provided drastically different interpretations of spatial accessibility that could not be duplicated by each other.

Measures within the same category were often comparable and interchangeable, as they described spatial accessibility in similar terms. T-values, and P-value, statistical analysis of the results has shown that the added complexity of the Two-step Cluster Gravity measure did not provide significantly different results than the simpler Primary Healthcare Gravity measure. However, they both provided significantly different results when compared with the measure based on cumulative models. This trend in results was consistent with past work of Lamondia (2010) who compared transit accessibility measures in a case study of MetroAccess in Austin, Texas USA. Similarly, Lamondia (2010) used five of the most commonly-utilised statistics to quantitively evaluate how similar the three main categories of accessibility models were, i.e. cumulative models, gravity models and utility-based models. In response to the variety of travel demand methods, introduced for over a decade, researchers have developed many methods for evaluating a model's ability to match current travel patterns. Amongst the most commonly used methods are: percent root means square error, correlation coefficient, Theil's inequality, mean absolute deviation and tracking signal.

7.3 Conclusions

While the World Summit on Sustainable Development promotes an integrated approach to policy-making at national, regional, and local levels of transport services and systems, there is a long history of awareness in healthcare service supply and travel distance in South Africa.

However, the role played by these factors, in securing healthcare access for populations, could be more appreciated if policy makers and researchers offered constant and due attention to the spatial features and socio-economic magnitudes of healthcare access. This thesis has investigated spatial accessibility to healthcare services in the Cape Winelands District Municipality in South Africa. This section concludes the study, presenting the main findings and the thesis' contribution to research.

An investigation of accessibility, such as the one presented in this thesis, brings the spatial features and socio-economic dimensions of healthcare access into relief. It can support researchers to polish questions and gather information in the most suitable manner. Three principal objectives were set during the initial stages of the study. The first objective was to illustrate variations in spatial accessibility in terms of the transportation infrastructures, healthcare services and spatial distribution of the population. The next objective was to identify communities and locations where spatial accessibility to healthcare services was relatively poor, and the last was to conduct the investigation at a satisfactory spatial resolution using a GIS analytical approach.

Accessibility, in the wider spectrum of transport research, was initially analysed through a literature review. The concept of accessibility has been used in several fields during the last decades. The literature review identified the theoretical body of knowledge from which the research draws (see Chapter 2). Many studies focus on place accessibility (for example Handy and Niemeier, 1997; Song, 1996; Geertman and Ritsema van Eck, 1995) and others, such as Kwan (1998) and Pirie (1979), focus on individual accessibility. The review covered general issues on accessibility and key terms such as "access", "accessibility", and "spatial accessibility" were defined and contextualised for the study. The literature shows that different accessibility measures often result in different approaches to accessibility. Nonetheless, Handy and Niemeier (1997) identified four inter-related issues that must be resolved regardless of the approach to accessibility. These issues are: the degree and type of disaggregation, the definition of origins and destinations, the measurement of travel impedance and the measurement of attractiveness. Finally, the review of literature presented a synthesis of spatial accessibility to healthcare services that provides an indication of the general trend of research and accessibility issues for the Western Cape Province in South Africa.

This study has shown that different measures of accessibility can be interchangeable, but are not always. Three spatial accessibility measures were implemented with GIS to calculate levels of accessibility to healthcare facilities in the study area (Minimum Travel Time measure, Primary Healthcare Gravity measure, and Two-step cluster gravity measure). Findings were consistent with other studies that show that gravity measures perform relatively better results than cumulative measures. Results from the gravity measure of spatial accessibility were not significantly different compared to the results from the two-step cluster gravity measure. The similarities between the results from these two measures of spatial accessibility can be attributed to the nature and similarities of the parameters required for their calculations. In essence, the two-step cluster gravity measure of spatial accessibility was built upon foundations of the initial gravity measure of spatial accessibility, from which a degree of complexity was added by means of introducing additional parameters. On the other hand, the Minimum Travel Time measure (cumulative model of spatial accessibility), which was purely based on shortest travel distance and travel time to healthcare facilities, provided significantly different results when compared to the previous two measures.

This study established that, within CWDM there exist spatial variations in the distribution of the population and associated demographic and socio-economic characteristics (see Chapter 4). The distribution of healthcare facilities was not evenly spread across the study area but, instead, concentrated in a few large towns. Amongst 66 localities within CWDM, only 26 localities had at least one healthcare facility. Many residents had to travel long distances to access healthcare facilities. Healthcare facilities were distributed in such a way that most TAZ were located further than an hour away (walking time) from the nearest facility. The majority of the population resided beyond 10 km of travel distance to the nearest healthcare facilities. The average travel distance to any nearest facility was greater than 20 km throughout CWDM, except for EMS (13 km) and Medical Health Clinics (7 km). Socio-economic conditions for residents of TAZ, located further than the mean travel distance or travel (driving) time to the nearest healthcare facilities, were relatively poor in comparison to the residents of TAZ located within the mean. In those disadvantaged locations, a combination of low spatial accessibility to healthcare facilities, higher proportion of dependent population and low-income households reflected a population that was prone to deprivation (refer to deprivation in the research problem statement, Chapter 1).

Adequate, fair and easy access to healthcare is a fundamental human right. Even though it is not practically realistic to obtain absolute equal spatial accessibility for all, it is possible to plan and implement healthcare systems in ways that allow adequate spatial accessibility for a maximum number of people or inhabitants. It is necessary to also consider expansion of the localities and growth of the communities, and measure how the supply of healthcare systems could match a growing demand. Implementing new healthcare facilities, or relocating existing ones to more suitable locations, are examples of solutions that could lead to equal access for the population, keeping in mind that the spatial distribution of healthcare facilities and population are not the only factors worthy of consideration, but also the socio-economic conditions of residents. In contrast, since a large portion of the population reside within large towns or their surroundings, a centralised healthcare system into large towns may facilitate access and provide choice options to select appropriate services for residents, while not compromising the requirement of equitable access. Ultimately, the improvement of overall accessibility in CWDM may be achieved by re-allocating healthcare facilities according to the spatial and socio-economic needs of the resident population.

7.4 Opportunity for Future Research

Resources and time were the initial limitation that shaped this study. They are the main determinant of the scope of the study. More resources and time allocation would offer a more detailed pool of results, discussion and a richer analysis to draw from such a study. The correspondence with officials from the Department of Transport and other Government entities was poor, or non-existent, throughout the study and data was only available through public sources. The scope and conditions that impacted and restricted the methods and analysis of the research were presented in the introduction chapter of this thesis. The scope of the study, as well as the parameters that restricted the spatial accessibility measures used in the method, are emphasised in this section. Their implications are discussed and opportunities for further research are proposed.

Walking and the use of private vehicles were the only modes of transport considered. Public transportation, or any other mode, was not considered. Data has shown that most of the population did not own a private vehicle. This implies that a large portion of the population in CWDM must rely on other modes of transportation to reach services that are located further than adequate walking distance. Interested researchers are encouraged to incorporate public transport, or any other mode of transport, in future research. Accessibility models that could include public transport in a similar study will extend the scope of the current study and provide more insight to the real ability of the population of CWDM to access services.

The investigation was limited to healthcare services. A sample was drawn from seven categories of primary healthcare services. The categories considered were dental health clinics, district hospital, emergency medical services, medical health clinics, medical practitioners, pharmacies and regional hospitals. They provided a good representation of healthcare service supply for the region. The study took the advantages of a statistically based sampling process, rather than a complete enumeration. According to Cochran (1977), the advantages of statistical sampling are reduced costs, higher speed, grater scope and a loss of accuracy that is negligible when compared to a complete enumeration.

The sampling process was similar to (Vanderschuren et al. 2013) in the development of a rural accessibility index for South Africa. A confidence level and margin of error were the statistical tools used to identify the required sampling size. Confidence levels allowed concluding that the travel time to any healthcare facilities would be the same as the average travel time calculated, based on healthcare facilities locations. Even though the study did not include all types of healthcare services available in the case study area, it provided a statistical representation of the availability of healthcare services.

The tool was developed to facilitate matching between the supply and the demand for services. This tool can be used to understand and gain insight on the ease for people to access a multitude of services. There are many possibilities for further research to investigate different issues and gain insights on access to other destinations. (Vanderschuren et al., 2013) calculated accessibility index for 15 domains including educational institutions, work and shopping, amongst others.

Furthermore, the parameters used to model the spatial accessibility measures are also limiting factors to the study. Destination attractiveness was considered in the calculations of spatial accessibility. It referred to individual perceptions about a destination and its ability to satisfy their needs. The attractiveness of healthcare facilities was considered equal for all individuals. A value of attractiveness was assigned to each healthcare facility under investigation. The major assumption was that the size of the healthcare facilities will determine their attractiveness. For instance, a medical clinic situated inside of a large commercial estate, such as a mall, would have a greater attractiveness value than a medical clinic situated in a residential neighbourhood parcel.

The square footage of facilities was used as the measure of attractiveness. This assumption averred itself satisfactorily for the investigation. However, further research should consider a more intricate method to derive attractiveness values. Destinations attraction is a key research topic in other related fields, such as medical tourism studies. Research on this topic (Islam et al., 2017; Sultana et al., 2014; Kre, 2011) often suggest empirical methods to calculate attractiveness of destinations. Islam et al. (2017) constructed and empirically tested a methodology for a destination attractiveness assessment of nature-based tourism in Bangladesh. His research identified the most important drivers for destination competitiveness by evaluating tourists' perception. Similarly, future research on accessibility to healthcare should make use of managerial tools that could be used for quantitative description of destination attractiveness level. This could be achieved through the calculation of index of destination attractiveness.

The characteristics of travel behaviours were not considered in this study. Travel behaviour refers to how people interact with space, and how people use transport. Knowing how individuals move between places is important to advance our understanding of accessibility to healthcare facilities, improve infrastructure planning and drive the development of transport systems. In this study, route choice algorithms were governed by the assumption that individuals would only consider the shortest route to reach healthcare facilities. Current route-choice models that are used in transportation planning are based on this widely accepted assumption. However, it is known that people do not always choose the shortest route to reach a destination for various reasons, but this assumption was convenient for the investigation conducted in this study.

Several researchers have gained insight on individual travel behaviour by means of tracking surveys. These surveys are commonly conducted using mobile communication instruments. Fundamental concepts and methodologies of using mobile communication instruments for tracking survey of individual travel behaviour are commonly available in the literature. Asakura et al. (2004) presented the characteristics of a tracking method for travel behaviour in urban space. In addition to tracking type data collection procedure, data transfer and labelling algorithms, it was suggested that the proposed methodologies could be added in a toolbox of transport assessment. Recommendations in this study agrees with Asakura et al. (2004) suggestions. Understanding travel behaviour will improve our knowledge of accessibility to services. Such methodologies could be implemented in future studies of accessibility to healthcare.

The last parameter, discussed in this section, is the travel impedance factor or distance decay parameter that was used in the Primary Healthcare Gravity measure and the Two-step Cluster Gravity measure. The impedance factor was used to account for travel distance and time separation between zones. This parameter is important since the gravity models distribute trips to the traffic analysis zones based on impedance between the TAZ and their attractions. In this study the standard home-based trip value of 1.285 was assumed based on Martin et al. (1998). In practice, impedance factors can be created for each trip purpose. They are generated through formulas, roadside surveys, household travel surveys or borrowed from other study areas or models. Future research on accessibility to healthcare facilities are encouraged to calulate impedance factors for the study area. The product of the attractions and the impedance factor will represents each zone's relative attractiveness and accessibility. Obtaining calibrated impedance factors is the principal operation of gravity model calibration.

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Appendix

Traffic Analysis Zones in CWDM

Settlement Name	Municipality	Latitude	Longitude	Population	Area (Km^2)
Ashton	Langeberg	-33,84277	20,09173	7727	22,1
Bella Vista	Witzenberg	-33,33212	19,31804	13460	2,9
Bonnievale	Langeberg	-33,92174	20,08833	9092	27,1
Brandvlei	Breede Valley	-33,74699	19,40805	1171	4,1
Brandwacht	Stellenbosch	-33,95690	18,87111	265	0,3
Breede Valley NU	Breede Valley	-33,57166	19,70299	46075	3724,6
Ceres	Witzenberg	-33,40090	19,29764	10413	77,1
Cloetesville	Stellenbosch	-33,91041	18,85314	15390	1,7
Dalsig	Stellenbosch	-33,94846	18,85965	1234	1,4
De Doorns	Breede Valley	-33,47571	19,66567	10583	7,3
De Hollandsche	Stellenbosch	-33,85744	19,03812	192	0,2
Devon Valley	Stellenbosch	-33,94506	18,83056	215	1,4
Diemersfontein	Drakenstein	-33,66396	19,00881	84	1,9
Drakenstein NU	Drakenstein	-33,59049	19,00472	36995	1421,7
Ekupumeleni	Breede Valley	-33,47872	19,68094	173	0,2
Elsenburg	Stellenbosch	-33,84508	18,83721	744	1,0
eNduli	Witzenberg	-33,35578	19,34345	9351	0,7
Franschhoek	Stellenbosch	-33,89540	19,03995	17556	7,1
Gouda	Drakenstein	-33,30359	19,04235	3441	7,7
Hassie Square	Breede Valley	-33,47769	19,67403	522	0,1
Idasvallei	Stellenbosch	-33,92253	18,89010	8762	2,1

Settlement Name	Municipality	Latitude	Longitude	Population	Area (Km^2)
Jamestown	Stellenbosch	-33,97676	18,84871	2840	1,6
Khayamandi	Stellenbosch	-33,91985	18,84510	24645	1,5
Klapmuts	Stellenbosch	-33,81021	18,86728	7703	1,8
Kleingeluk	Stellenbosch	-33,95394	18,85421	226	0,0
Koelenhof	Stellenbosch	-33,87503	18,82300	302	0,3
Kylemore	Stellenbosch	-33,91841	18,95182	4328	0,9
La Colline	Stellenbosch	-33,92470	18,85981	1497	0,5
Langeberg NU	Langeberg	-33,78390	20,05609	29292	4389,0
Languedoc	Stellenbosch	-33,89730	18,96726	4289	0,6
Lynedoch	Stellenbosch	-33,98247	18,76817	108	0,1
Mbekweni	Drakenstein	-33,67904	18,99120	30875	2,0
McGregor	Langeberg	-33,94066	19,82251	3125	22,0
Meulstroom	Witzenberg	-33,26201	19,14962	1084	21,3
Montagu	Langeberg	-33,77059	20,13601	15176	32,7
Montana	Witzenberg	-33,42064	19,20444	6262	1,6
Nkqubela	Langeberg	-33,81997	19,89546	5786	0,7
Onder Papegaaiberg	Stellenbosch	-33,93730	18,83537	1504	1,8
Onverwacht	Drakenstein	-33,63207	19,00454	830	0,4
Op-die-berg	Witzenberg	-33,02174	19,31168	1531	1,0
Paarl	Drakenstein	-33,73098	18,96304	112045	64,6
Paradyskloof	Stellenbosch	-33,96341	18,85768	1614	1,3
Pine Valley	Witzenberg	-33,41722	19,18535	4340	1,1
Pniel	Stellenbosch	-33,89439	18,95807	1975	0,6

Settlement Name	Municipality	Latitude	Longitude	Population	Area (Km^2)
Prince Alfred Hamlet	Witzenberg	-33,28175	19,32565	6810	8,7
Raithby	Stellenbosch	-34,02319	18,80271	908	0,7
Rawsonville	Breede Valley	-33,67949	19,32708	3099	2,4
Robertson	Langeberg	-33,80928	19,89088	21929	22,7
Robertsvlei	Stellenbosch	-33,93731	19,07960	9	0,6
Saron	Drakenstein	-33,18248	19,00758	7843	2,1
Stellenbosch	Stellenbosch	-33,93869	18,86361	19068	8,2
Stellenbosch NU	Stellenbosch	-33,92634	18,94676	35570	793,5
Tennantville	Stellenbosch	-33,92083	18,85698	563	0,1
Touwsrivier	Breede Valley	-33,34471	20,03291	8126	21,6
Tulbagh	Witzenberg	-33,28517	19,14150	8969	3,8
Val De Vie	Drakenstein	-33,80105	18,97125	303	1,9
Victor Verster	Drakenstein	-33,84088	18,99893	2827	3,1
Water-Vliet	Drakenstein	-33,82251	18,98150	476	2,1
Welgevonden	Stellenbosch	-33,90149	18,85331	2493	0,6
Wellington	Drakenstein	-33,64516	19,00477	55543	30,2
Wiesiesdraai	Stellenbosch	-33,89498	19,07536	1727	0,4
Witzenberg NU	Witzenberg	-32,94509	19,69375	52200	10632,0
Wolseley	Witzenberg	-33,41474	19,19965	1528	2,4
Worcester	Breede Valley	-33,64670	19,45362	78906	71,1
Zolani	Langeberg	-33,83906	20,09371	5598	1,4
Zweletemba	Breede Valley	-33,64660	19,49286	18172	2,1

Primary Healthcare Facilities in CWDM

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Aan Het Pad Clinic	Medical health clinics & Hospitals	Public	Stellenbosch	-33.91143	18.855
Alex S Scott (Pty) Ltd	Pharmacies & Medecine depots	Private	Paarl	-33.73018	18.96543
All Smiles Dental Clinic	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.93387	18.88475
Annie Brown Clinic	Medical health clinics & Hospitals	Public	Ceres	-33.37681	19.31238
Bella Vista Clinic	Medical health clinics & Hospitals	Public	Ceres	-33.333	19.32
Bergrivier Pharmacy	Pharmacies & Medecine depots	Private	Wellington	-33.63898	19.00967
Bergsig Clinic	Medical health clinics & Hospitals	Public	Robertson	-33.79074	19.89122
Bonnievale Ambulance Station	Emergency Medical Services	Public	Bonnievale	-33,93279	20,09585
Boschenmeeer Health & Beauty	Medical health clinics & Hospitals	Private	Paarl	-33.76046	18.98417
Breeriver Clinic	Medical health clinics & Hospitals	Private	Ceres	-33.52862	19.20842
Carecross Kliniek	Medical health clinics & Hospitals	Public	Paarl	-33.71427	18.97666
Ceres Ambulance Station	Emergency Medical Services	Public	Ceres	-33.36292	19,29959
Ceres Hospital	District Hospital	Public	Ceres	-33.3629	19.30105
Charles Kiek	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.94281	18.85034
Clicks Pharmacy - Paarl Mall	Pharmacies & Medecine depots	Private	Paarl	-33.76444	18.96820

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Cloete D Dental Surgeon	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.95298	18.86191
Coetzenburg Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.92602	18.87848
Cogmanskloof Clinic	Medical health clinics & Hospitals	Public	Ashton	-33.83327	20.04609
Dalevale Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.70228	18.99165
De Doorns Ambulance Station	Emergency Medical Services	Public	De Doorns	-33,47677	19,66819
De Doorns Clinic	Medical health clinics & Hospitals	Public	De Doorns	-33.48143	19.67184
De Oude Renbaan Sub-Aku Kliniek	Medical health clinics & Hospitals	Private	Paarl	-33.77271	18.96044
De Villiers	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.94293	18.85039
Dental Techniques	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.93920	18.82884
Diabetes Centre	Medical health clinics & Hospitals	Public	Paarl	-33.73050	18.97215
Dis-Chem Pharmacies - Paarl Mall	Pharmacies & Medecine depots	Private	Paarl	-33.73417	18.96251
Don & Pat Bilton Clinic	Medical health clinics & Hospitals	Private	Jamestown	-33.97953	18.84908
Dr Abdurahman E	Dental Medical health clinics & Hospitals	Private	Paarl	-33.73022	18.96838
Dr Adams	Medical practitioners - General practice	Private	Paarl	-33.73249	18.99312
Dr Allie	Dental Medical health clinics & Hospitals	Private	Paarl	-33.73033	18.98337

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Dr Bernard	Medical practitioners - General practice	Private	Paarl	-33.73549	18.96202
Dr Blake	Medical practitioners - General practice	Private	Stellenbosch	-33.93631	18.86061
Dr Booysen	Dental Medical health clinics & Hospitals	Private	Wellington	-33.63906	19.00762
Dr C M Baker	Dental Medical health clinics & Hospitals	Private	Paarl	-33.72869	18.96258
Dr Clara Van Zyl-Erasmus	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.72761	18.97430
Dr Conradie	Medical practitioners - General practice	Private	Wellington	-33.63888	19.01214
Dr Cyster	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.93599	18.86075
Dr De Klerk	Medical practitioners - General practice	Private	Stellenbosch	-33.92983	18.88038
Dr De Kock	Dental Medical health clinics & Hospitals	Private	Franschoek	-33.90455	19.11469
Dr Dewald Colen	Medical practitioners - General practice	Private	Paarl	-33.72855	18.96615
Dr Etienne Van Wyk	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.72866	18.96303
Dr Hj Baatjes	Medical practitioners - General practice	Private	Paarl	-33.71985	18.96929
Dr Hp Van Der Merwe	Medical practitioners - General practice	Private	Paarl	-33.71662	18.96787
Dr Ivann Kirsten	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.93379	18.85983
Dr Jacobs	Medical practitioners - General practice	private	Paarl	-33.71288	18.98491

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Dr Kader	Medical practitioners - General practice	Private	Stellenbosch	-33.90223	18.85817
Dr Leon Meiring	Medical practitioners - General practice	Private	Stellenbosch	-33.94395	18.84531
Dr Malan Dawid	Dental Medical health clinics & Hospitals	Private	Paarl	-33.72815	18.96568
Dr Marais	Dental Medical health clinics & Hospitals	Private	Paarl	-33.75601	18.96486
Dr Mcdonald	Medical practitioners - General practice	Private	Paarl	-33.73375	18.99628
Dr Mm Allie	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.92313	18.879
Dr Nell	Medical practitioners - General practice	Private	Wellington	-33.64172	19.00495
Dr Pistorius Chris	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.97836	18.84817
Dr Selena Tonkin	Medical practitioners - General practice	Private	Paarl	-33.71839	18.96980
Dr Serdyn	Medical practitioners - General practice	Private	Wellington	-33.64171	19.00497
Dr Shelley Hellig	Medical practitioners - General practice	Private	Paarl	-33.72793	18.95512
Dr Small	Medical practitioners - General practice	Private	Franschoek	-33.88975	19.10349
Dr Sp Weideman	Medical practitioners - General practice	Private	Stellenbosch	-33.94520	18.85103
Dr Thirion Gj	Dental Medical health clinics & Hospitals	Private	Paarl	-33.71826	18.96257
Dr Van Der Merwe	Medical practitioners - General practice	Private	Franschoek	-33.91059	19.12091

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Dr Van Wyk	Medical practitioners - General practice	Private	Wellington	-33.64176	19.00516
Dr Wayne Johnsn	Medical practitioners - General practice	Private	Paarl	-33.72197	18.97037
Dr Wentley	Medical practitioners - General practice	private	Stellenbosch	-33.92338	18.87881
Drakenstein Apteek	Pharmacies & Medecine depots	Private	Paarl	-33.73002	18.97924
Drostdy Pharmacy	Pharmacies & Medecine depots	Private	Wellington	-33.63820	19.01885
Empilisweni Clinic	Medical health clinics & Hospitals	Public	Worcester	-33.64427	19.4915
Franschoek Pharmacy	Pharmacies & Medecine depots	Private	Franschoek	-33.90898	19.11775
Genis	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.93977	18.85961
Global Smiles Sa	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.94516	18.85167
Gouda Clinic	Medical health clinics & Hospitals	Public	Gouda	-33.29267	19.0457
Groendal Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.89584	19.10243
Groendal Clinic	Medical health clinics & Hospitals	Public	Franschoek	-33.89499	19.10111
Groenleegte Retirement	Medical health clinics & Hospitals	Private	Paarl	-33.70982	18.96437
Gys Smit Pharmacy	Pharmacies & Medecine depots	Private	Paarl	-33.72933	18.96496
Happy Valley Clinic	Medical health clinics & Hospitals	Public	Bonnievale	-33.9362	20.07729

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Huis Mccrone Ambulance Station	Emergency Medical Services	Public	Huis McCrone	-33.63913	18,99904
Huis Mccrone Clinic	Medical health clinics & Hospitals	Public	Wellington	-33.63921	18.99858
Idas Valley Clinic	Medical health clinics & Hospitals	Public	Stellenbosch	-33.92537	18.87497
J J Du Pre Le Roux Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.7279	18.98238
Joerings Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.93744	18.85982
Joernings Eikestad Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.93704	18.86140
Joubert	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.94717	18.8625
Kayamandi Clinic	Medical health clinics & Hospitals	Public	Stellenbosch	-33.91890	18.84650
Kemp Gj & Du Toit Pc	Medical practitioners - General practice	Private	Paarl	-33.72992	18.96832
Klapmuts Clinic	Medical health clinics & Hospitals	Public	Klapmuts	-33.8096	18.86389
Klein Drakenstein Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.7392	19.02431
Klein Nederburg Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.72705	18.99919
Kylemore Clinic	Medical health clinics & Hospitals	Public	Kylemore	-33.9194	18.95311
L P G Endermologie Clinic	Medical health clinics & Hospitals	Private	Paarl	-33.71689	18.96592
L W Pretorius	Medical practitioners - General practice	Private	Wellington	-33.67804	18.99888

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Louw	Dental Medical health clinics & Hospitals	Private	Stellenbosch	-33.94686	18.84827
Malan Johan. Dr - Tandarts	Dental Medical health clinics & Hospitals	Private	Paarl	-33.76131	18.95493
Mc Gregor Clinic	Medical health clinics & Hospitals	Public	Mc Gregor	-33.94763	19.82906
Mediclinic - Paarl	Medical health clinics & Hospitals	Private	Paarl	-33.71988	18.96930
Mediclinic - Stellenbosch	Medical health clinics & Hospitals	Private	Stellenbosch	-33.94518	18.85108
Mediclinic Private Hospital Group	Medical health clinics & Hospitals	Private	Stellenbosch	-33.95703	18.85613
Milan	Dental Medical health clinics & Hospitals	Private	Franschoek	-33.90919	19.12497
Montagu Clinic	Medical health clinics & Hospitals	Public	Montagu	-33.78281	20.12903
Montagu Ambulance Station	Emergency Medical Services	Public	Montagu	-33,79818	20,12252
Montagu Hospital	District Hospital	Public	Montagu	-33.79753	20.12318
Nduli Clinic	Medical health clinics & Hospitals	Public	Ceres	-33.35636	19.34004
Nieuwedrift Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.68779	18.96345
Nkqubela Clinic	Medical health clinics & Hospitals	Public	Robertson	-33.81859	19.89348
Op Die Berg Clinic	Medical health clinics & Hospitals	Public	Op Die Berg	-33.02388	19.31005
Orchard Clinic	Medical health clinics & Hospitals	Public	Orchard	-33.4854	19.62465

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Paarl Ambulance Station	Emergency Medical Services	Public	Paarl	-33,72014	18,97002
Paarl Dental Laboratory	Dental Medical health clinics & Hospitals	Public	Paarl	-33.72524	18.96741
Paarl Hospital	Regional Hospital	Public	Paarl	-33.72598	18.97145
Paarl Pharmacy	Pharmacies & Medecine depots	Private	Paarl	-33.73112	18.96484
Parceval (Pty) Ltd	Pharmacies & Medecine depots	Private	Wellington	-33.63177	18.98527
Patriot Plein Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.73212	18.96596
Phola Park Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.68392	18.99074
Prime Cure Medi-Centre	Medical health clinics & Hospitals	Private	Stellenbosch	-33.92594	18.87837
Prince Alfred Hamlet Clinic	Medical health clinics & Hospitals	Public	Prince Alfred Hamlet	-33.28934	19.32678
Rawsonville Clinic	Medical health clinics & Hospitals	Public	Rawsonville	-33.69041	19.31814
Robertson Ambulance Station	Emergency Medical Services	Public	Robertson	-33,80181	19,89194
Robertson Hospital	District Hospital	Public	Robertson	-33.80174	19.89113
Robertson Oral Health Centre	Dental Medical health clinics & Hospitals	Public	Robertson	-33.81037	19.88341
Rokewood Clinic	Dental Medical health clinics & Hospitals	Private	Paarl	-33.73643	18.96290
Salon Bella Health & Skin Care Clinic	Medical health clinics & Hospitals	Private	Paarl	-33.71820	18.96258

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Sandhills Clinic	Medical health clinics & Hospitals	Public	De Doorns	-33.51785	19.55866
Saron Clinic	Medical health clinics & Hospitals	Public	Saron	-33.18381	19.00761
Scott Pharmacy	Pharmacies & Medecine depots	Private	Paarl	-33.73085	18.96937
Simondium Clinic	Medical health clinics & Hospitals	Public	Simondium	-33.8403	18.95921
Simonsrust Apteek	Pharmacies & Medecine depots	Private	Stellenbosch	-33.92606	18.8785
Soetendal Clinic	Medical health clinics & Hospitals	Public	Wellington	-33.8403	18.95921
Stelkor Doctors	Medical health clinics & Hospitals	Private	Stellenbosch	-33.93975	18.85974
Stellenbosch Ambulance Station	Emergency Medical Services	Public	Stellenbosch	-33,93065	18,87038
Stellenbosch Hospital	District Hospital	Public	Stellenbosch	-33.93028	18.87039
Stellenbosch Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.94507	18.85027
Stellenbosch Square Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.97012	18.84512
Supplementary Health Services	Medical health clinics & Hospitals	Private	Paarl	-33.75617	18.96489
Swiss Laser Clinic	Medical health clinics & Hospitals	Private	Franschoek	-33.90565	19.11441
Touws River Ambulance Station	Emergency Medical Services	Public	Touws River	-33,34071	20,02888
Touws River Clinic	Medical health clinics & Hospitals	Public	Touws River	-33.34062	20.02891

Facility Name	Facility Type	Ownership	Town Address	Latitude	Longitude
Trust-Kem Pharmacy	Pharmacies & Medecine depots	Private	Stellenbosch	-33.93550	18.86000
Tulbagh Ambulance Station	Emergency Medical Services	Public	Tulbagh	-33,28493	19,14687
Tulbagh Clinic	Medical health clinics & Hospitals	Public	Tulbagh	-33.28459	19.14657
Wellington Dental Laboratory	Dental Medical health clinics & Hospitals	Private	Wellington	-33.64125	19.00745
Windmeul Clinic	Medical health clinics & Hospitals	Public	Paarl	-33.67074	18.90555
Wolseley Clinic	Medical health clinics & Hospitals	Public	Wolseley	-33.42218	19.20265
Worcester Hospital	Regional Hospital	Public	Worcester	-33.64485	19.45831
Worcester Ambulance Station	Emergency Medical Services	Public	Worcester	-33,64426	19,44662
Zolani Clinic	Medical health clinics & Hospitals	Public	Ashton	-33.83753	20.08604
Zwaan'S Dental Laboratory	Dental Medical health clinics & Hospitals	Private	Paarl	-33.73062	18.99255

Inter-zonal Travel Time and Distance Calculations

The following presents the parameters configuration that was used for Google Maps Distance Matrix API.

Key

The application's API key. Login details plus API Key were required to use Google Maps Distance Matrix API. This key identifies the application for purposes of quota management.

Mode

Specifies the mode of transport to use when calculating distance. Modes options are listed as follow:

- Driving (default) for road network.
- Walking for pedestrian paths and sidewalks.
- Bicycling for cycle lanes and preferred streets (not available in region).
- Transit for public transport routes (not available is region).

Language

The language in which to return results.

- English

Avoid

Restrictions to the route were set using this parameter. Avoid ferries was used. No other restriction was used for this study. The available restrictions are:

- Avoid tolls
- Avoid highways
- Avoid ferries

Units

The unit system to use when expressing distance as text.

- Units metric

The unit system to use when expressing travel time as text

- Units seconds

Accessibility Measures: Index Observations

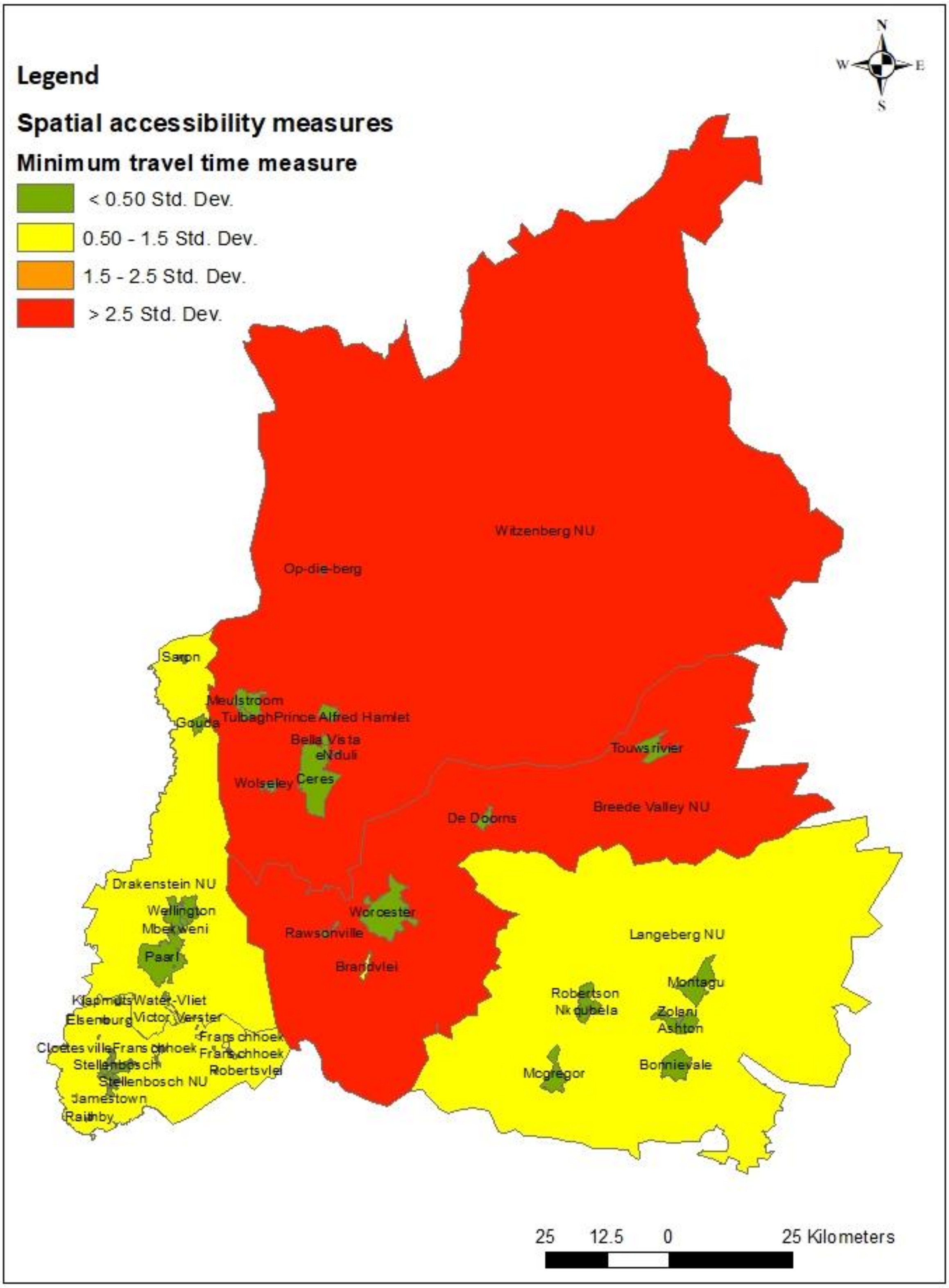
Settlement Name	Municipality	Distance to Near HCF (m)	Driving Time to Near HCF (min)	Walking Time to Near HCF (min)	Accessibility Index PHG	Accessibility Index TCPHG
Ashton	Langeberg	891	3,2	10,8	1,823	2,452
Bella Vista	Witzenberg	498	1,5	6,0	4,317	5,037
Bonnievale	Langeberg	4163	7,4	50,7	1,302	1,664
Brandvlei	Breede Valley	51106	44,7	189,0	1,440	1,581
Brandwacht	Stellenbosch	1280	2,5	15,0	8,390	7,563
Breede Valley NU	Breede Valley	67927	56,6	832,3	0,887	1,017
Ceres	Witzenberg	5233	7,0	68,8	3,076	3,448
Cloetesville	Stellenbosch	358	1,4	4,4	9,476	8,630
Dalsig	Stellenbosch	734	2,0	9,4	14,012	12,426
De Doorns	Breede Valley	3154	4,7	40,0	2,461	3,020
De Hollandsche	Stellenbosch	9613	13,5	116,9	5,509	5,453
Devon Valley	Stellenbosch	1472	2,5	17,6	10,981	9,840
Diemersfontein	Drakenstein	3186	4,7	38,0	7,670	7,280
Drakenstein NU	Drakenstein	20181	21,9	237,8	5,303	5,016
Ekupumeleni	Breede Valley	1152	2,3	12,7	3,421	4,532
Elsenburg	Stellenbosch	9070	9,7	111,5	6,688	6,316

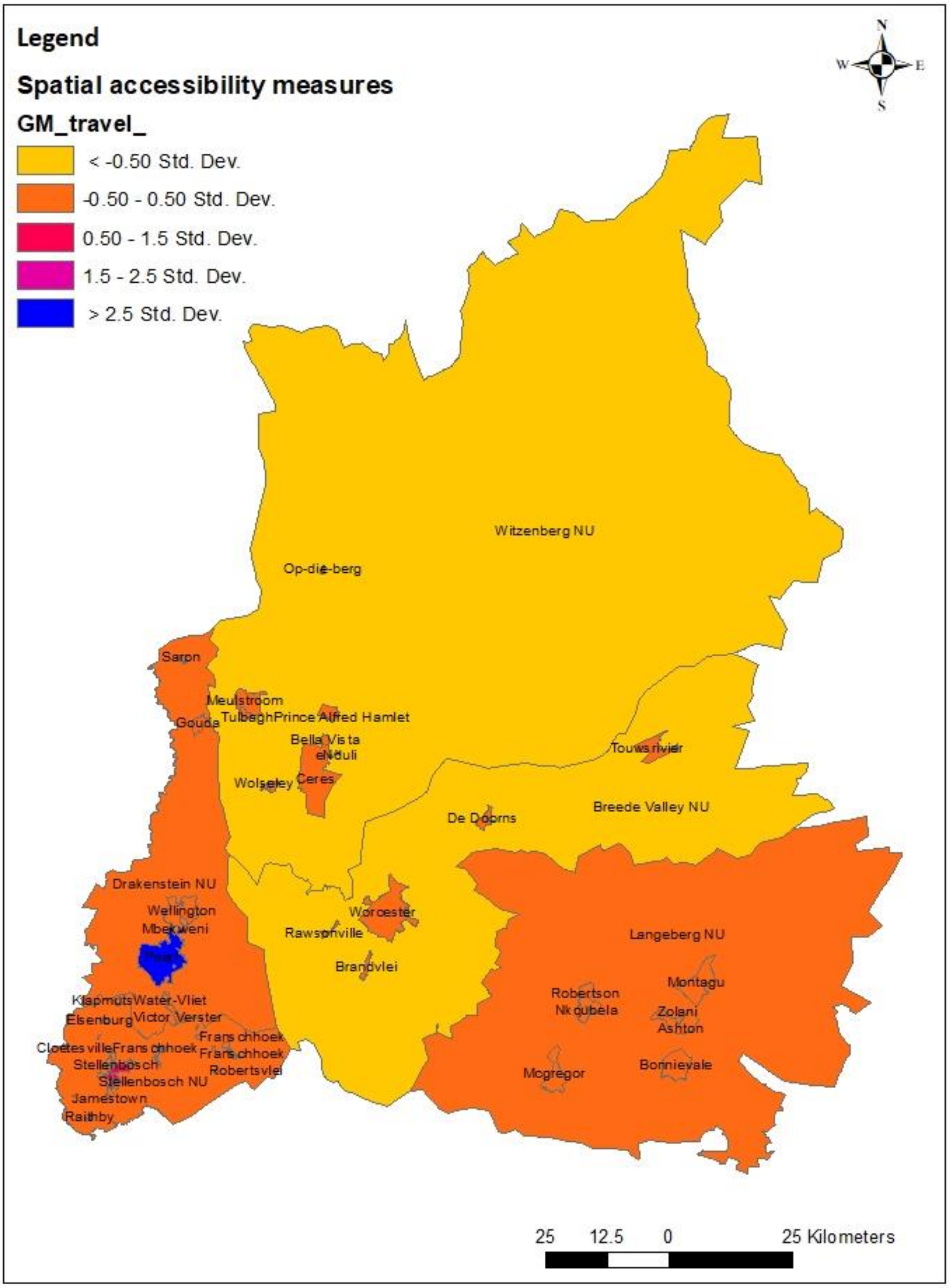
Settlement Name	Municipality	Distance to Near HCF (m)	Driving Time to Near HCF (min)	Walking Time to Near HCF (min)	Accessibility Index PHG	Accessibility Index TCPHG
eNduli	Witzenberg	362	1,2	4,2	3,193	3,659
Franschhoek	Stellenbosch	16397	27,3	175,1	3,527	3,472
Gouda	Drakenstein	2726	6,2	31,0	2,627	2,716
Hassie Square	Breede Valley	575	2,1	7,0	3,478	4,665
Idasvallei	Stellenbosch	1267	3,9	14,5	9,253	8,362
Jamestown	Stellenbosch	51	0,1	0,6	11,712	10,456
Khayamandi	Stellenbosch	255	1,4	2,8	7,701	7,027
Klapmuts	Stellenbosch	477	1,4	5,8	6,694	6,453
Kleingeluk	Stellenbosch	2019	4,2	9,6	12,143	10,813
Koelenhof	Stellenbosch	7693	9,1	81,9	6,281	5,899
Kylemore	Stellenbosch	230	0,7	3,1	7,397	6,740
La Colline	Stellenbosch	1283	4,1	15,4	12,748	11,429
Langeberg NU	Langeberg	23586	28,5	254,4	1,283	1,596
Languedoc	Stellenbosch	3639	11,1	45,6	5,178	4,957
Lynedoch	Stellenbosch	14009	15,7	146,7	4,563	4,234
Mbekweni	Drakenstein	775	2,4	9,0	7,667	7,424
McGregor	Langeberg	1181	3,6	14,9	1,496	1,836
Meulstroom	Witzenberg	3431	4,8	40,1	2,520	2,722
Montagu	Langeberg	1481	2,5	17,9	2,111	3,610
Montana	Witzenberg	1032	2,8	11,5	2,778	2,901

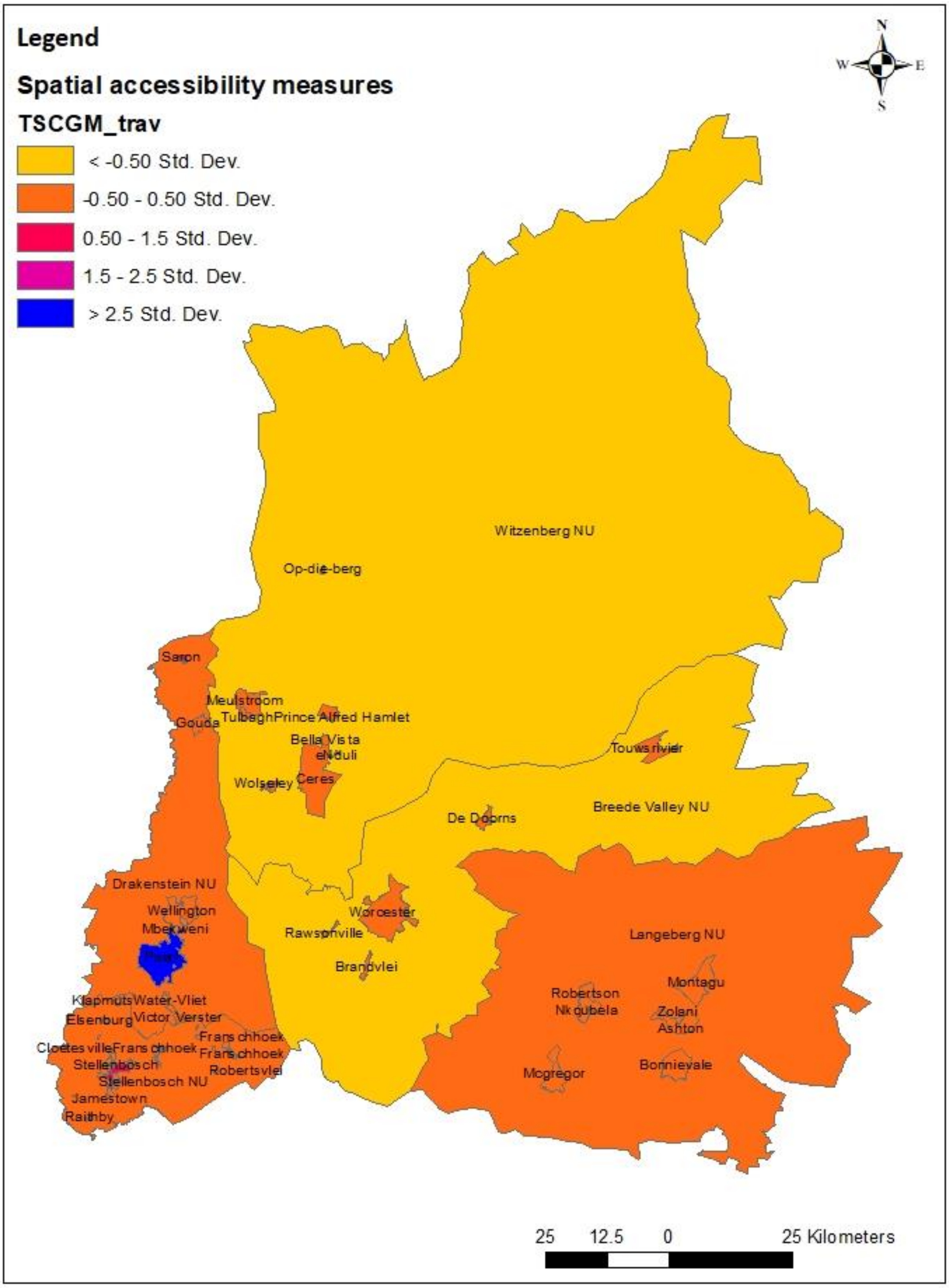
Settlement Name	Municipality	Distance to Near HCF (m)	Driving Time to Near HCF (min)	Walking Time to Near HCF (min)	Accessibility Index PHG	Accessibility Index TCPHG
Nkqubela	Langeberg	298	1,2	3,8	3,056	4,098
Onder Papegaaiberg	Stellenbosch	1125	2,6	13,0	10,128	9,101
Onverwacht	Drakenstein	1797	5,7	19,3	5,822	5,426
Op-die-berg	Witzenberg	288	1,0	3,8	1,493	2,278
Paarl	Drakenstein	163	0,8	1,9	100,000	100,000
Paradyskloof	Stellenbosch	1063	2,3	11,6	12,063	10,743
Pine Valley	Witzenberg	2757	5,4	31,3	2,465	2,625
Pniel	Stellenbosch	4433	7,2	47,3	7,060	6,652
Prince Alfred Hamlet	Witzenberg	1020	1,7	11,9	2,808	3,397
Raithby	Stellenbosch	9529	11,3	112,5	4,441	4,115
Rawsonville	Breede Valley	2573	6,8	31,7	3,286	3,482
Robertson	Langeberg	1092	2,6	13,0	4,909	6,881
Robertsvlei	Stellenbosch	5890	9,3	72,1	3,805	3,829
Saron	Drakenstein	117	0,2	1,5	12,630	20,646
Stellenbosch	Stellenbosch	1621	4,9	20,1	23,209	20,339
Stellenbosch NU	Stellenbosch	17845	25,6	208,4	5,963	5,566
Tennantville	Stellenbosch	2268	7,0	26,5	12,310	11,064
Touwsrivier	Breede Valley	585	1,5	7,3	2,510	4,506

Settlement Name	Municipality	Distance to Near HCF (m)	Driving Time to Near HCF (min)	Walking Time to Near HCF (min)	Accessibility Index PHG	Accessibility Index TCPHG
Tulbagh	Witzenberg	653	1,6	8,3	3,693	4,257
Val De Vie	Drakenstein	11264	12,9	124,4	7,452	7,361
Victor Verster	Drakenstein	1	18,1	217,5	5,530	5,479
Water-Vliet	Drakenstein	21640	21,7	263,3	5,323	5,278
Welgevonden	Stellenbosch	508	1,5	6,5	8,645	7,928
Wellington	Drakenstein	564	1,7	6,5	8,920	8,084
Wiesiesdraai	Stellenbosch	3262	4,8	41,2	5,396	5,477
Witzenberg NU	Witzenberg	66418	88,5	835,7	0,666	0,730
Wolseley	Witzenberg	1548	3,4	19,0	2,811	2,966
Worcester	Breede Valley	1016	2,2	9,9	9,025	11,255
Zolani	Langeberg	945	3,0	10,5	1,851	2,496
Zweletemba	Breede Valley	395	1,6	4,9	4,197	4,987

Accessibility Measures: Statistics Maps




Legend
Spatial accessibility measures
GM_travel_
< -0.50 Std. Dev.
-0.50 - 0.50 Std. Dev.
0.50 - 1.5 Std. Dev.
1.5 - 2.5 Std. Dev.
> 2.5 Std. Dev.
N
W
E
S
Witzenberg NU
Op-die-berg
Saron
Meulstroom
Gouda
Tulbagh
Prince Alfred Hamlet
Bella Vista
eNduli
Wolseley
Ceres
Touwsrivier
De Doorns
Breede Valley NU
Drakenstein NU
Wellington
Mbekweni
Worcester
Rawsonville
Brandvlei
Langeberg NU
Robertson
Nkqubela
Montagu
Zolani
Ashton
Bonnievale
Mcgregor
Klapmuts
Water-Vliet
Elsenburg
Victor Verster
Franschhoek
Cloetesville
Stellenbosch
Robertsvlei
Stellenbosch NU
Jamestown
Raithby
25
12.5
0
25 Kilometers


Legend
Spatial accessibility measures
TSCGM_trav
< -0.50 Std. Dev.
-0.50 - 0.50 Std. Dev.
0.50 - 1.5 Std. Dev.
1.5 - 2.5 Std. Dev.
> 2.5 Std. Dev.
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Op-die-berg
Saron
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Breede Valley NU
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Ashton
Franschhoek
Cloetesville
Franschhoek
Franschhoek
Stellenbosch
Robertsvlei
Stellenbosch NU
Mcgregor
Bonnievale
Jamestown
Raithby
25 12.5 0 25 Kilometers