OPTIMISING GEOGRAPHIC ACCESSIBILITY IN RURAL AREAS:

A CASE STUDY OF THE THUSONG SERVICE CENTRES IN LIMPOPO PROVINCE

by

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A dissertation submitted in fulfilment of the requirements for the degree

Master of Arts

in the Department of Geography

at the

UNIVERSITY OF PRETORIA

FACULTY OF HUMANITIES

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July 2017

DECLARATION

I, Lourens Fourie Snyman, declare that the dissertation / thesis, which I hereby submit for the degree Master of Arts at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: ……………………………..

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ACKNOWLEDGEMENTS

I wish to thank and acknowledge the following people for their insights, love and support during my studies.

Thank you to my wife Daleen, for all your love, support and encouragement.

My supervisor Serena Coetzee, for your advice and guidance and patience.

Lydette Fouche, for you continuous support and assistance.

Charl Fouche, thank you for believing in me and always pushing my boundaries.

I wish to acknowledge the guidance and support from Trevor Holdsworth. The lessons you taught me over the past few years proved invaluable during this dissertation. Thank you.

My appreciation to AfriGIS, especially Magnus Rademeyer and Charl Fouche for this wonderful opportunity.

May we never stop exploring!

ABBREVIATIONS AND ACRONYMS

.cdf	Compact Geographic File
.dbd	Standard Geographic File
.shp	Shapefile
CSIR	Council for Scientific and Industrial Research
CSV	Comma-separated Values
DPSA	Department of Public Service and Administration
EA	Enumerator area
GCIS	Government Communication and Information System
GIS	Geographic Information Systems
Km	Kilometres
SAL	Small Area Layer
SANS	South African National Standards
SAPS	The South African Police Service
SASSA	The South African Social Security Agency
SNRDA	Swedish National Rural Development Agency
Stats SA	Statistics South Africa
TIN	Triangular Irregular Network
TXT	Text file
UK	United Kingdom
UN	United Nations
USA	United States of America
www	World Wide Web

ABSTRACT

Travelling long distances to reach public service centres is costly and time consuming, especially to those who suffer the burden of poverty and deprivation. Geographic access to public service centres tends to be worse in rural areas because they are usually sparsely populated with limited road infrastructure.

This research presents a novel method to assess the availability and geographic accessibility of Thusong Service Centres and Thusong Service Clusters in Limpopo province. Thusong Service Centres are permanent structures where services of key departments are provided on a daily basis and housed under a single roof. Thusong Service Clusters are permanent structures consisting of three or more key departments situated in close proximity to each other. These serve as de facto Thusong Service Centres. Key departments which were considered in the study to represent Thusong Service Clusters include the Department of Home Affairs, Department of Labour, South African Social Security Agency and selected services of the South African Police Service. These key departments were identified since they provide services which people require to transact their daily lives.

The distances that people in urban and rural areas travel to their nearest Thusong Service Centre or Cluster were compared. Accessibility in rural areas was optimised by identifying additional locations where accessibility was inadequate and where the establishment of additional Thusong Service Centres and Clusters could improve accessibility.

Limpopo province was selected as a case study, since it is ranked highest in the country based on the level of unemployment. Poverty levels are also noticeably high, strengthening the need to bring services closer to the people.

The novel method to measure geographic accessibility considers factors such as population size and density, as well as the availability of roads. Since rural areas in Limpopo province tend to have limited road infrastructure, people are likely to travel between settlements on unofficial trails and footpaths that are not mapped. To include an approximated representation of these trails and footpaths in the overall travel network, a triangular irregular network was created to connect rural settlements to each other, as well as to the road network. Natural barriers, such as mountain ranges and large rivers or dams were also considered. They impact the level of accessibility in a province, because people have to travel great distances around them to reach Service Centres.

Optimal locations were identified through different facility location procedures in a geographic information system. The objective was to identify the minimum number of additional locations for Service Centres that would maximise accessibility in the province.

Results emanating from this research indicate that accessibility to Thusong Service Centres and Clusters is uneven between urban and rural settlements. People in rural areas need to travel significantly further to their nearest Service Centre compared to those living in urban areas. In order to increase accessibility in rural areas and to achieve a more equitable distribution of Service Centres across the province, five optimal locations were identified.

1. INTRODUCTION AND BACKGROUND INFORMATION

1.1 INTRODUCTION

"Accessibility is the most widely used metric in measuring the value of a location in public service delivery" (Church & Murray 2009).

The question of "where" is increasingly considered, also for the establishment of public service centres across the country. Knowing where the population demand is in relation to public service centres provides valuable information in order to assess the current level of accessibility and to identify areas where accessibility is inadequate. Optimising accessibility to public service centres in rural areas is a challenge because they typically cover large geographical areas that are characterised by limited road infrastructure.

This research proposes a novel method to measure and optimise accessibility in rural areas where there is limited road infrastructure and footpaths have not been mapped. Accessibility in this research, refers to the physical distance that people travel to reach services. A more detailed discussion on accessibility follows in 2.2 of this document. The aim of this research is firstly, to calculate and compare the current level of accessibility in urban and rural areas within different travel distance thresholds, and secondly, to propose the least number of additional locations for Service Centres that could improve accessibility in the province and ensure equal accessibility to Service Centres in both urban and rural areas.

The method used to measure accessibility is presented and evaluated with a case study of the Thusong Service Centres and Thusong Service Clusters in Limpopo Province where high levels of unemployment and poverty are experienced. These Thusong Service Centres are mostly situated in rural areas and function as one-stop-shops providing multiple key services to communities such as social security services; delivering of identity documents or birth and death certificates; Unemployment Insurance Fund (UIF) as well as selected services from the South African Police Service. Thusong Service Clusters on the other hand, are typically situated in town centres and comprise multiple key departments in close proximity to one another.

Base data that was considered for this research comprises urban and rural settlement types; location data of Thusong Service Centres and Thusong Service Clusters; population data and a routable travel network.

The method followed a systematic approach that includes a network-based cost matrix to firstly calculate the actual travel distance between populated areas and their nearest Thusong

Service Centre or Cluster. Results from the cost matrix was subsequently used to measure and compare the level of accessibility between urban and rural areas. By using spatial analysis tools such as kernel density maps and thematic maps, gaps could be identified where accessibility is currently inadequate. Secondly, location analysis was done to identify optimal locations that could potentially increase accessibility in areas where accessibility is currently inadequate. Location analysis consisted of facility location models that were tested with various costs of service constraints.

This research provides detailed descriptions of the methods and procedures that were adopted to measure accessibility and to identify optimal locations in the province.

1.2 BATHO PELE – PEOPLE FIRST

Batho Pele is a Sesotho phrase that means "people first". This principle was recognised by government in 1997 for the improvement of public service delivery (DPSA 1997).

Department of Public Service and Administration

The Department of Public Service and Administration (DPSA) is responsible for the development of norms and standards with regards to public services in South Africa. These norms and standards relate to the following:

- "The functions of the public service;
- Organisational structures and of departments and other organisational and governance arrangements in the public service;
- Labour relations, conditions of service and other employment practices for employees;
- The Health and wellness of employees;
- Information management;
- Electronic government in the public service;
- Integrity, ethics, conduct and anti-corruption, and
- Transformation, reform, innovation and any other matter to improve the effectiveness and efficiency of the public service and its service delivery to the public" (DPSA 2014).

Based on the constitutional mandate, the DPSA "must be governed by the democratic values and principles enshrined in the constitution" (DPSA 2014). These principles became known as the Batho Pele principles.

The Batho Pele handbook describes the core principles to improve service delivery in South Africa (DPSA 2003). These principles include *Consultation, Service Standards, Access, Courtesy, Information, Openness and transparency, Redress and Value for Money*. Although each of these principles is important and significant to improve service delivery, the concept of "*Access"* (specifically access to public services that are offered by Thusong Service Centres and Clusters) is the primary focus of this research. See *Figure 1* for a description of each principle as described in the Batho Pele handbook.

Access focuses on providing services to those "who were and still are denied access to them" (DPSA 1997). The objective is to identify and implement strategies that will improve geographic access, specifically to people in "remote" areas that need to travel long distances to reach Service Centres.

Figure 1: Batho Pele Principles

1.3 THE THUSONG SERVICE CENTRE PROGRAMME

Multipurpose community centres (MPCC) coordinated by the Government Communication and Information System (GCIS) were established where a variety of services and information are offered to communities (GCIS n.d.-a). The MPCCs (currently known as Thusong Service Centres) include services from various government departments. “The combined aim of government as a whole is to move towards the establishment of MPCCs” (GCIS n.d.-a). MPCCs will provide access to government services including “legal services, arts and culture, passports and identity documents, information on welfare, health, housing, education, bursaries, etc.” (GCIS n.d.-a).

“The Thusong Service Centre programme of government was initiated in 1999 as one of the primary vehicles for the implementation of development communication and information, and to integrate government services into primarily rural communities” (GCIS n.d.-b). These centres serve as a central point where multiple services can be offered based on the “*Six-Block Service Model*”. Services offered could include government social and administrative services, office services, education and skills development services, local economic development services, business services and community opportunities, as well as information and communication activities (GCIS n.d.-b).

Figure 2 shows two pictures of the Thusong Service Centre in Mokwakwaila, Limpopo province (GCIS 2011).

Figure 2: Images of the Thusong Service Centre in Mokwakwaila, Limpopo province

The current footprint of Thusong Service Centres covers all nine provinces in the country (GCIS n.d.-c). With the inception of this research there were 343 Service Centres across the country. These included 178 Thusong Service Centres and 165 Thusong Service Clusters.

1.4 OVERVIEW OF LIMPOPO PROVINCE

Limpopo is one of nine provinces in South Africa. The province is situated in the northern part of South Africa, bordering Botswana, Mozambique and Zimbabwe. *Figure 3* shows the location of Limpopo province in relation to South Africa and in relation to the world.

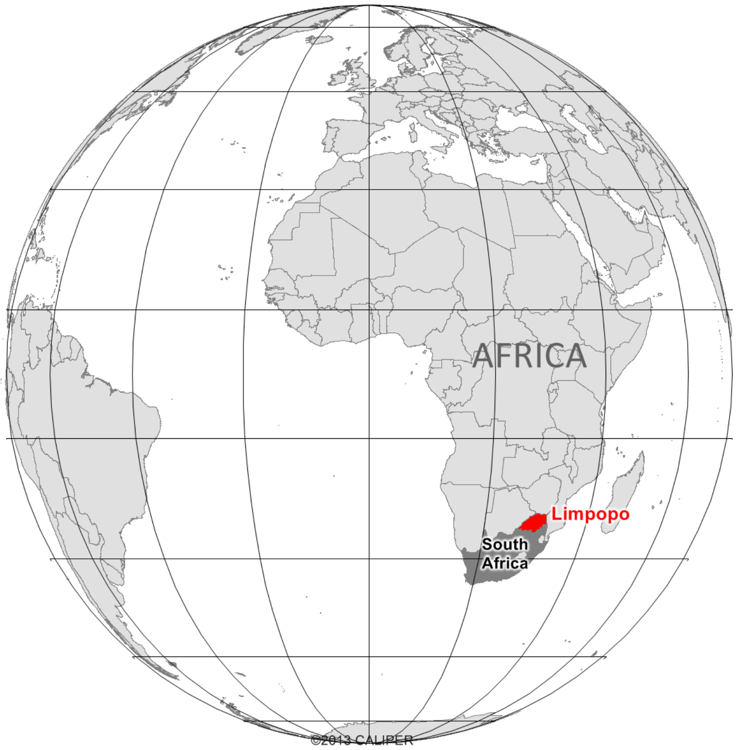

Figure 3: Locality map of Limpopo province

The province covers 125 754 square kilometres, representing 10.3% of the total land area in South Africa (Statistics South Africa 2012a). Highways running through the province include the N1 and the N11. Polokwane is the capital of Limpopo province, situated in the Capricorn District Municipality. Other major towns include Thohoyandou, Mokopane and Phalaborwa.

Based on the Census 2011 survey, the population count in Limpopo is 5 404 868, or 10.44% of the total population in the country (Statistics South Africa 2012a). From the five district municipalities in the province, Vhembe District Municipality has the highest population count of 1 294 722, followed by Capricorn District Municipality with 1 261 463 people. Waterberg District Municipality has the lowest population count with only 679 336 people (Statistics South Africa 2012d).

Greater Sekhukhune District Municipality is the most densely populated district with close to 80 people per square kilometre, followed by Capricorn District Municipality with 58 people.

Limpopo province experiences high levels of unemployment and poverty, strengthening the need to bring services closer to the people. The official unemployment rate in 2011 for Limpopo province was 38.9% which is ranked highest in the country. Eastern Cape is ranked second with 37.4% (Statistics South Africa 2012c). Poverty levels are also significantly high in Limpopo with 50.9% of households in the province living in poverty (Statistics South Africa 2014b).

Limpopo province is also the province with the lowest average household income calculated in 2011 with only R57 000.00 per annum, followed by Eastern Cape with R64 000.00 per annum. The province with the highest average income is Gauteng with R156 000.00 per annum (Statistics South Africa 2012c).

Figure 4 is an orientation map of Limpopo province consisting of administrative boundaries, towns and road infrastructure.

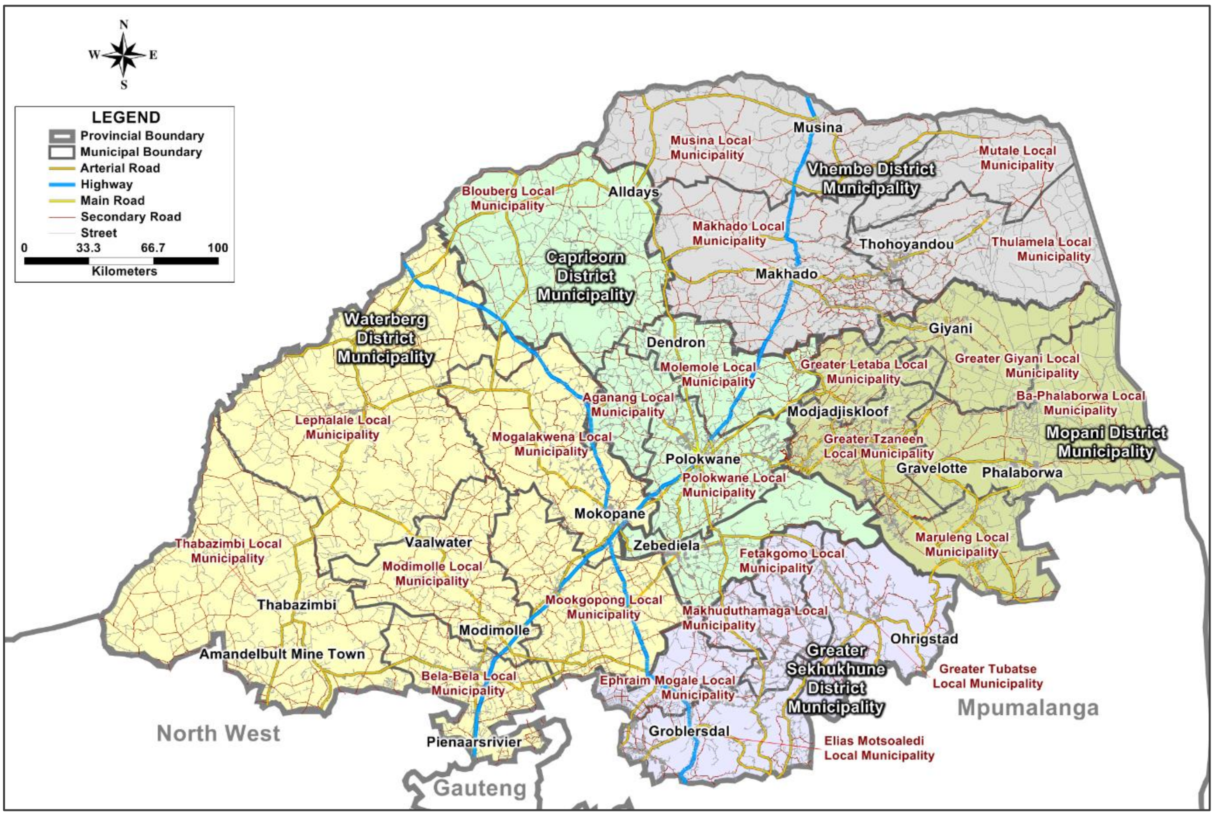

Figure 4: Orientation map of Limpopo province

1.5 RESEARCH QUESTIONS

The following accessibility questions in relation to Thusong Service Centres and Clusters are examined in this research:

1. How is accessibility measured?
2. How can accessibility be measured in rural areas with limited road infrastructure and where footpaths are not mapped?
3. What is the current level of access provided by Thusong Service Centres and Thusong Service Clusters in the Limpopo province?
4. How does the level of accessibility differ between urban and rural areas?
5. How can accessibility be optimised in the province?

1.6 HYPOTHESIS TO BE TESTED

Geographic access to Thusong Service Centres and Thusong Service Clusters is uneven across Limpopo province. People residing in rural areas need to travel significantly further to Service Centres compared to those living in urbanised areas. Additional Service Centres are required to improve accessibility in rural areas.

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1.7 AIM AND OBJECTIVES OF THIS RESEARCH

The aim of this research is to evaluate the current levels of access (in both urban and rural areas) to Thusong Service Centres and Clusters in Limpopo province by utilising geographic information and various spatial analytical methods. The objective is firstly, to define maximum travel distances thresholds for both urban and rural areas and secondly, to elicit recommendations for the optimum provisioning and location of Thusong Service Centres or Clusters. The intention would be to achieve similar levels of accessibility in both urban and rural areas based on defined maximum travel distance thresholds, while minimising the need for the establishment of new facilities.

The research objective is divided into three different parts. The first objective (research questions 1 and 2) is to review methods and procedures that can accurately measure accessibility, specifically in rural areas with limited infrastructure. The second objective (research questions 3 and 4) is to measure and compare the level of accessibility within urban and rural settlements and to determine if accessibility differs between these two settlement types. The last objective (research question 5) is to identify optimal locations for the establishment of additional Service Centres in poorly serviced rural areas to improve accessibility.

1.8 SIGNIFICANCE OF THE RESEARCH

The significance of this research in twofold. Firstly, it provides insight on the current level of accessibility in Limpopo province and describes the various geographical challenges limiting access to services. Secondly, the novel method used to measure accessibility and to identify optimal locations proved to be useful and this could be used in many other areas/countries with similar accessibility problems.

1.9 ETHICAL CONSIDERATIONS

The research topic and objectives of this study were approved by the Department of Public Service and Administration (DPSA) under the following conditions: Firstly, the researcher shall not refer to any information classified as confidential, secret or top secret. Secondly, the researcher will not use or refer to any information of a personal nature without the consent of the affected individual(s). Based on these conditions, only aggregated population figures from Statistics South Africa were used in this study, hence no personal information was disclosed.

The following datasets were obtained with permission from the relevant data owners:

- Population data was extracted from the Census 2011 Community Profiles in SuperCROSS (Statistics South Africa 2012d). The dataset is published and free to use under the following license conditions: http://www.statssa.gov.za/?page_id=425
- Facility points of Thusong Service Centres and key departments for the establishment of Thusong Service Clusters were obtained from the DPSA (see Appendix 5 for approval letter).
- Street centrelines, provincial, municipal and town boundaries, as well as the rivers and dams datasets were obtained from AfriGIS (see Appendix 6 for approval letter).
- Other datasets that were used in this research, primarily for display purposes include Web Map Layers from Google to display satellite imagery and terrain data. The use of the Google data/service is subject to the terms declared in http://code.google.com/intl/nl/apis/maps/terms.html and http://www.google.com/intl/en_ALL/help/terms_maps.html
- A derived slope dataset, created by AfriGIS was used to identify high mountains and steep slopes in Limpopo province (see Appendix 6 for approval letter). The original

source data consists of the Shutter Radar Topography Mission (SRTM) data. The dataset is free to download through https://earthexplorer.usgs.gov/. Terms of use: https://lta.cr.usgs.gov/sites/default/files/USGS-Certification.pdf

1.10 RELATIONSHIP BETWEEN THIS RESEARCH AND THE ACCESSIBILITY STUDY CONDUCTED BY THE DPSA

In 2013, the DPSA submitted an Invitation to Bid. The requirement was to conduct a national study of the geographic accessibility of Thusong Centres in eight provinces (Bid number DPSA001/2013). Objectives from the terms of reference included a current accessibility analysis of Thusong Service Centres. Recommendations had to be made on:

- Access standards (travel distances and population thresholds of centres).
- Identification of measures to improve accessibility in areas where access to Thusong Service Centres or Clusters is inadequate.
- Identification of areas where Thusong Service Clusters could be considered.

The researcher was part of the team appointed to conduct the accessibility analysis. He was the technical lead on the project and primarily responsible for the analysis of the optimal provisioning of Service Centres, as well as writing the report depicting results emanating from the analysis. The approach was collaborative by nature, hence close interaction between DPSA and the team members was required.

Upon completion of the project, the researcher continued analysing the geographic accessibility of Thusong Service Centres in Limpopo province. The primary focus of the extended research presented in this dissertation includes an accessibility comparison between urban and rural settlements with a core objective to identify optimal locations in predominantly rural areas of the province.

1.11 OVERVIEW OF THE METHODOLOGY

The geographic accessibility analysis considers factors such as population size and density, the distance for people to travel to service points and the availability of roads. Other factors such as natural barriers (including mountains, large rivers or dams) and the existence of footpaths were also considered and included in the analysis. The analysis uses a geographic movement network to determine travel distance, hence actual travel distances were used.

The approach of this study was to optimise the provisioning and location of different types of Service Centres that include Thusong Service Centres and Thusong Service Clusters. This was done in order to achieve similar levels of accessibility in both urban and rural areas based on defined maximum travel distance thresholds. Optimal locations were identified to maximise geographic accessibility with the least number of additional facilities. The methodology was implemented as follows:

Step 1: Collection and preparation of data – This step included the collection of various data sets and the preparation of the data for use in a GIS.

Step 2: Assessment of the current provisioning and location of Thusong Service Centres and Clusters – Accessibility analysis was done to determine firstly, the current level of access provided by these centres and secondly, catchment area analysis was done to determine the demand on each centre and to identify areas that are under-, over- or poorly-served. Results are reported in Chapter 4.

Step 3: Location analysis to optimise the provisioning of Service Centres – Location analysis was done to identify the optimum number and location of Service Centres for meeting the unserved population demand. This analysis accepts the current location of Thusong Service Centres and Clusters, while determining the minimum number of additional locations required to increase the number of people that have access to a Service Centre within a required maximum travel distance threshold (also known as a brownfields analysis). Results are reported in Chapter 5.

The analysis is a desktop exercise that utilises the data analysis capabilities of GIS to measure accessibility and to identify optimal locations. For this reason, the proposed locations identified in the study refer to generalised locations and not specific places.

1.12 STRUCTURE OF THIS DISSERTATION

This chapter presented an introduction of the research topic, the geographical location of the case study, as well as background on the Thusong Service Centre programme, and explains the importance and relevance of the study. The chapter also describes the high-level methodology that was followed.

Chapter 2 reviews literature relating to accessibility methods and findings, with specific focus on measuring accessibility and identifying optimal locations. Chapter 2 also defines important terminology and reviews related accessibility studies (research question 1).

Chapter 3 describes the methods and procedures that were followed for this study to calculate geographic accessibility in Limpopo province and to identify possible gaps where accessibility is inadequate (research question 2).

Chapters 4 and 5 discuss accessibility results from the analysis. In Chapter 4, the level of geographic accessibility currently provided by Thusong Service Centres and Clusters in Limpopo province is calculated. Results are analysed and conclusions drawn with regard to accessibility differences between urban and rural settlement typologies (research questions 3 and 4). Possible locations that could be considered to increase accessibility are discussed in Chapter 5 (research question 5). These locations are then mapped together with the current footprint of Service Centres to calculate the potential level of access that can be achieved with additional locations.

Chapter 6 includes a summary of finding and recommendations emanating from this study, as well as various research limitations.

2. LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides an overview of the literature that explores the concept of accessibility, specifically the measurement of geographic accessibility to public service centres. Important terminologies are defined and methods to calculate accessibility are investigated, primarily those that utilise capabilities of a geographic information system (GIS). The chapter also provides a historic overview of facility location models that were used to identify optimal locations for the establishment of new facilities. The last part of the chapter reviews a number of geographic accessibility studies that have been done in the past.

2.2 TERMINOLOGY AND DEFINITIONS

2.2.1 ACCESSIBILITY AND COVERAGE

The Oxford Advanced Learner's Dictionary describes ***accessible*** as "that can be reached or used" (Hornby & Cowie 1991). The word "accessibility" has different meanings depending on context and interpretation. Khan (1992) distinguishes between spatial and aspatial access dimensions. Spatial refers to geographic access and aspatial refers to social access. In this research, accessibility refers to spatial (or geographic) access and can be described as "the measure of the capacity of the locations to be reached by, or to reach, different locations" (Rodrigue, Comtois & Slack 2009), by vehicle or on foot, measured with reference to the physical distance one has to travel (expressed as kilometres or travel time).

Church and Murray (2009) indicate that it is costly and time consuming for people to travel to services if they are situated too far. Accessibility includes both location and distance (Rodrigue, Comtois and Slack 2009), where the distance is measured between locations based on a defined network. They also distinguish between topological accessibility and contiguous accessibility. *Topological accessibility* relies on a defined travel network to measure the distance between locations whereas *contiguous accessibility* is measured across a surface. It is important to note that some places will be more accessible than others due to different spatial structures (Rodrigue, Comtois and Slack 2009). For example, the distribution of settlements across Limpopo province could be referred to as spatial structures, and within this research it became evident that some places (or facilities) are more accessible than other.

Coverage, on the other hand refers to the number of people that have access to a service centre within a required maximum threshold. According to Drezner and Hamacher (2001), covering models, specifically in the public sector focus on “acceptable proximity” meaning that if a service is located within a maximum set distance, the service location is “acceptable” and the customer (or population) would be covered (Drezner & Hamacher 2001). Church and Murray (2009) refer to complete coverage and maximal coverage. Complete coverage is reached when all the people are covered within a defined standard. A maximal coverage approach finds the least number of facilities to maximise coverage to a satisfactory level. This approach is usually followed where too many facilities will be required to establish complete coverage. This research followed a maximal coverage approach where additional locations for centres were identified to maximise coverage to a defined (or acceptable) level.

2.2.2 URBAN AND RURAL CLASSIFICATION

Since this research compares geographic accessibility between urban and rural settlements, it is essential to understand the differences between these two settlement types, specifically in South Africa, where the classification appears to be difficult and complex.

The Oxford Advanced Learner’s Dictionary describes urban as: “situated in or living in a city or town”. Rural is defined as: “in or suggesting the countryside” (Hornby & Cowie 1991). According to Laldaparsad (2006), South Africa’s apartheid past influenced urban and rural classifications for the country, hence these classifications are unique compared to other countries.

In a more recent document on urban and rural trends in South Africa, Laldaparsad (2011) mentioned that the difference between urban and rural areas is complex and that “no standard definition exists for the country”. She also highlighted an evolving trend that considers settlement typologies for cities and towns, rather than defining urban and rural. Medani (2016) noted that according to the United Nations (UN), “the distinction between the urban and rural populations is not yet amendable to a single definition that would be applicable to all countries”.

The following section provides an overview of different methodologies used classify urban and rural areas, both locally and internationally. On a local level, Statistics South Africa is responsible for the creation of official statistics for the country (including national census surveys). Key services comprise economic statistics, population statistics and statistical services support and advice (Statistics South Africa n.d.). Urban and rural classifications were defined by Statistics South Africa for the 1996, 2001 and 2011 national census surveys. Key findings are listed below.

2.2.2.1 Census 1996 and 2001

Statistics South Africa released a discussion document in 2003 with the title: *Investigation into appropriate definitions of urban and rural areas for South Africa*. The methodology of this discussion document, firstly outlines the urban and rural classification for the 1996 and 2001 census where enumerator areas (EAs) were classified as urban or rural based on various factors that include cadastre and land use (Statistics South Africa 2003).

Table 1 shows the number of urban and rural population for census 1996 and 2001 per province based on EA type classification. The urban/rural split for Limpopo province and South Africa is highlighted in grey.

Table 1: 2001 Urban and rural classification based on EA type (Source: Statistics South Africa 2003)

		1996 original classification (Table 2.1-1)		1996 reclassified to 2001 (Table 2.2-1)		2001 (Table 2.1-2)	
		Column (a)		Column (b)		Column (c)	
		Number	%	Number	%	Number	%
W. Cape	Urban	3 516 007	88,9	3 537 956	89,4	4 088 709	90,4
	Rural	440 867	11,1	418 918	10,6	435 626	9,6
	Total	**3 956 875**	**100**	**3 956 874**	**100**	**4 524 335**	**100**
E. Cape	Urban	2 304 378	36,6	2 405 446	38,2	2 500 234	38,8
	Rural	3 998 148	63,4	3 897 080	61,8	3 936 529	61,2
	Total	**6 302 525**	**100**	**6 302 526**	**100**	**6 436 763**	**100**
N. Cape	Urban	588 906	70,1	631 627	75,2	680 460	82,7
	Rural	251 415	29,9	208 694	24,8	142 267	17,3
	Total	**840 321**	**100**	**840 321**	**100**	**822 727**	**100**
F. State	Urban	1 806 651	68,6	1 811 151	68,8	2 052 115	75,8
	Rural	826 853	31,4	822 353	31,2	654 660	24,2
	Total	**2 633 504**	**100**	**2 633 504**	**100**	**2 706 775**	**100**
KZN	Urban	3 628 268	43,1	3 716 432	44,2	4 334 642	46,0
	Rural	4 788 753	56,9	4 700 589	55,8	5 091 375	54,0
	Total	**8 417 021**	**100**	**8 417 021**	**100**	**9 426 017**	**100**
N. West	Urban	1 171 734	34,9	1 458 558	43,5	1 533 768	41,8
	Rural	2 183 091	65,1	1 896 267	56,5	2 135 581	58,2
	Total	**3 354 825**	**100**	**3 354 825**	**100**	**3 669 349**	**100**
Gauteng	Urban	7 130 277	97	7 126 491	97	8 590 798	97,2
	Rural	218 146	3	221 932	3	246 380	2,8
	Total	**7 348 423**	**100**	**7 348 423**	**100**	**8 837 178**	**100**
MP	Urban	1 094 287	39,1	1 110 046	39,6	1 288 434	41,3
	Rural	1 706 425	60,9	1 690 666	60,4	1 834 556	58,7
	Total	**2 800 711**	**100**	**2 800 712**	**100**	**3 122 990**	**100**
Limpopo	Urban	541 301	11	565 199	11,5	700 459	13,3
	Rural	4 388 067	89	4 364 169	88,5	4 573 183	86,7
	Total	**4 929 368**	**100**	**4 929 368**	**100**	**5 273 642**	**100**
S. Africa	Urban	21 781 807	53,7	22 362 906	55,1	25 769 619	57,5
	Rural	18 801 765	46,3	18 220 668	44,9	19 050 159	42,5
	Total	**40 583 573**	**100**	**40 583 574**	**100**	**44 819 778**	**100**

Based on 2001 results from Table 1, 86.7% of the population in Limpopo province lived in rural areas. This figure is slightly less than the 88.5% that was estimated in 1996.

A second classification method was explored in the discussion document that uses population counts and population densities instead of EA types to classify urban and rural areas. Although there are also no international standards for urban classification based on these criteria, towns with a population count above 1 000 are frequently classified as urban (Statistics South Africa 2003).

Table 2 (extracted from the discussion document) compares the number of urban and rural dwellers from 2001 based on both EA type and population count classifications by main-place and by sub-place for Limpopo province and the entire country (Statistics South Africa 2003).

The geographic structure of sub-places and main-places (used in *Table 2*) were created by Statistics South Africa and forms part of the Geography data model. The data model consists of seven geographic levels that include enumeration area, sub-place, main place, local municipality, district council, province and country levels (Statistics South Africa 2004).

Table 2: Urban and rural dwellers based on EA type and population count (Source: Statistics South Africa 2003)

		EA type 2001		Main place pop size >=1000 and pop density >=500		Sub-place pop size >=1000 and pop density >=500		Main place pop size >=1000 and pop density >=1000		Sub-place pop size >=1000 and pop density >=1000	
		Number	%	Number	%	Number	%	Number	%	Number	%
Limpopo	Urban	700 459	13.3	793 163	15.04	4 030 048	76.42	451 573	8.56	2 466 698	46.77
	Rural	4 573 183	86.7	4 480 479	84.96	1 243 594	23.58	4 822 069	91.44	2 806 944	53.23
	Total	**5 273 642**	**100.0**	**5 273 642**	**100.00**	**5 273 642**	**100.00**	**5 273 642**	**100.00**	**5 273 642**	**100.00**
S. Africa	Urban	25 769 619	57.5	23 182 041	51.72	30 683 794	68.46	18 682 750	41.68	25 917 453	57.83
	Rural	19 050 159	42.5	21 637 737	48.28	14 135 984	31.54	26 137 028	58.32	18 902 325	42.17
	Total	**44 819 778**	**100.0**	**44 819 778**	**100.00**	**44 819 778**	**100.00**	**44 819 778**	**100.00**	**44 819 778**	**100.00**

The number of urban and rural dwellers differ significantly within each classification method listed *Table 2*. Based on the EA type classification method, 86.7% of the population in Limpopo province lives in rural areas and only 13.3% in urban areas. When population and population densities per main-place are considered, the number of rural dwellers in Limpopo province changed to 84.96% (based on population >=1 000 and density >=500) and 91.44% (based on population >=1 000 and density >=1 000) respectively. Results based on population and population densities per sub-place indicate a rural population count of only 23.58% and 53.23% respectively.

2.2.2.2 Census 2011

In the census 2011 metadata document, the methodology for urban areas in 2011 was defined as; "*A continuously built-up area with characteristics such as type of economic activity and land use. Cities, towns, townships, suburbs, etc. are typical urban areas. An urban area is one which was proclaimed as such (i.e. in an urban municipality under the old demarcation) or classified as such during census demarcation by the Geography department of Stats SA, based on their observation of the aerial photographs or on other information*" (Statistics South

Africa 2012b). This definition is similar to the 2001 definition where various factors that include cadastre and land use were used.

Based on results derived from the Census 2011 Community Profiles in SuperCROSS, 969 302 (or 17.9%) of the people in Limpopo province reside in urban areas. The remaining 4 434 732 (or 82.1%) of the people live in either tribal, traditional or farm areas. The Census 2011 Community Profiles application is discussed in 3.2.3.

2.2.2.3 Global trends

Statistics Canada defines urban areas as "having a population of at least 1 000 and a density of 400 or more people per square kilometre. All territory outside an urban area was defined as rural" (Statistics Canada 2015).

A proposed criterion for urban areas in the United States was defined in the *Proposed Urban Area Criteria for the 2010 Census Notice*, created by the Bureau of the Census, Department of Commerce. The criteria includes urbanised areas that comprise more than 50 000 people and urban clusters that contain more than 2 500 people and less than 50 000 people (USA 2010).

In the Urban and Rural Area Definitions for Policy Purposes in England and Wales, settlements with more than 10 000 people are considered to be urban. Another method was also identified to delimit urban settlements "of built up land with a minimum area of 20 hectares and an associated population of 1,000" (Bibby & Brindley 2013).

The Australian Bureau of Statistics defines urban and rural settlements as major urban, other urban, bounded locality and rural balance. Major urban and other urban are considered urban, whereby bounded locality and rural balance are considered rural. See *Table 3* for a description of each type (Australian Bureau of Statistics 2014).

Table 3: Urban and rural classification. Source: Australian Bureau of Statistics

Identifier	Name	Definition
0	Major Urban	Major Urban represents a combination of all Urban Centres with a population of 100,000 or more
1	Other Urban	Other Urban represents a combination of all Urban Centres with a population between 1,000 and 99,999
2	Bounded Locality	Bounded Localities represents a combination of all Bounded Localities
3	Rural Balance	Rural Balance represents the Remainder of State/Territory

Based on these local and international classification methodologies for urban and rural areas, it is evident that various classification exist and that a single classification remains a challenge.

For the purpose of this research EA type classification methods (Chapter 3) were adopted to classify urban and rural areas.

2.2.3 LOCATION-ALLOCATION

According to (Church & Murray 2009), ***allocation*** is "the process of determining who is served by which facility". Within the context of this research; this refers more specifically to who is served by which Thusong Service Centre or Cluster. **Location-Allocation** can be described as a measure to identify optimal locations for several facilities (Centre for Advanced Spatial Analysis 2003). (Lloyd 2010) uses a similar definition and describes Location-Allocation as "the location of facilities and the allocation of resources from a given facility to particular locations".

2.2.4 GEOGRAPHIC INFORMATION SYSTEMS

"Geographic information systems are computer-based systems for storing and processing geographic information" (Longley 2011). These systems are widely recognised for the ability to compute large volumes of geographically referenced data. Various GIS software currently exist that are designed to solve complex spatial queries. Over the years, GIS software evolved and became more user friendly, allowing users to target specific problems within various industries. According to (Longley 2011), GIS are being used more frequently to answer the question, where? He also provides ten significant reasons for this in his book on GIS and science. One of these reasons; "Greater awareness that decision making has a geographic dimension", accurately describes the importance of GIS in this research where decision making regarding the optimal positioning of Thusong Service Centres are vital.

Michael Wegner mentioned the extensive use of spatial models in environmental and social sciences. Spatial models in social science include "regional economic development models, land and housing market models, plant and facility location models, spatial diffusion models, migration models, travel and goods transport models and urban land-use models" (European Science Foundation and National Science Foundation 1999).

2.3 MEASURING GEOGRAPHIC ACCESSIBILITY

Geographic accessibility is typically measured by calculating the distance between locations. This can be done based on a straight-line calculation (Euclidean distance) on a sphere or spheroid, or via a network (Centre for Advanced Spatial Analysis 2003). Straight-line calculations (referred to as contiguous accessibility) do not consider factors such as the availability of road infrastructure or natural barriers that could limit access between locations. (Boscoe, Henry & Zdeb 2012) noted that straight-line distance calculations are used most frequently due to the "ease of its calculation". Limitations of this method are also widely noted by various sources (Salonen et al. 2012), (Polo, Acosta and Dias 2013).

Examples of accessibility studies where straight-line distance calculations are examined and compared include work from (Case & Hawthorne 2013), (La Rosa 2014) and (Boscoe, Henry & Zdeb 2012).

For a more defined and accurate distance measurement, a network based calculation (topological accessibility) would be considered since this method calculates the shortest distance between locations via a travel network. (Mavoa et al. 2012) highlights the notion that network based calculations are "preferable" since straight-line calculations have the potential to overestimate a catchment area. A network consists of arcs, nodes and vertices (Lloyd 2010). Arcs include line (or road) segments that are connected at intersections by nodes. Vertices define the contour or shape of arcs (lines). See *Figure 5*.

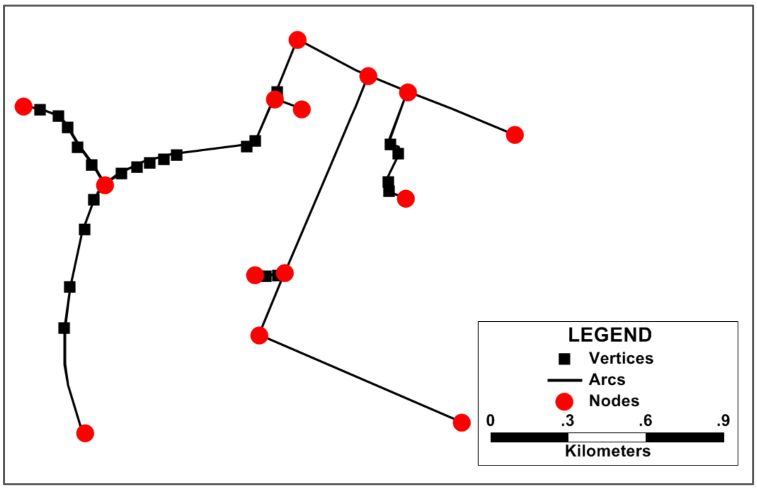


Figure 5: Example of a travel network

Rodrigue, Comtois and Slack (2009) refer to network data models and the purpose of these models is "to provide an accurate representation of a network as a set of links and nodes. Topology is the arrangement of nodes and links in the network" (Rodrigue, Comtois and Slack 2009). This arrangement includes location, direction and connectivity. Networks have the potential to become extremely complex and technical, especially when factors such a one-way streets, turn penalties, speed limitations or traffic volumes are considered.

The map in *Figure 6* displays the shortest distance between two locations based on a straight-line and via a travel network. The distance between these two locations is 3.15 km when a straight-line is considered, and 4.6 km via the travel network. Although the network based calculation is longer than the straight-line (Euclidean) calculation, it reflects a more accurate measurement. Distance calculations were done in Maptitude based on the AfriGIS street centreline dataset.

Examples of accessibility studies that used network based calculations include (Hawthorne & Kwan 2012), (Polo, Acosta & Dias 2013), (Dahlgren 2008), (Luo & Wang 2003), (Law et al. 2013).

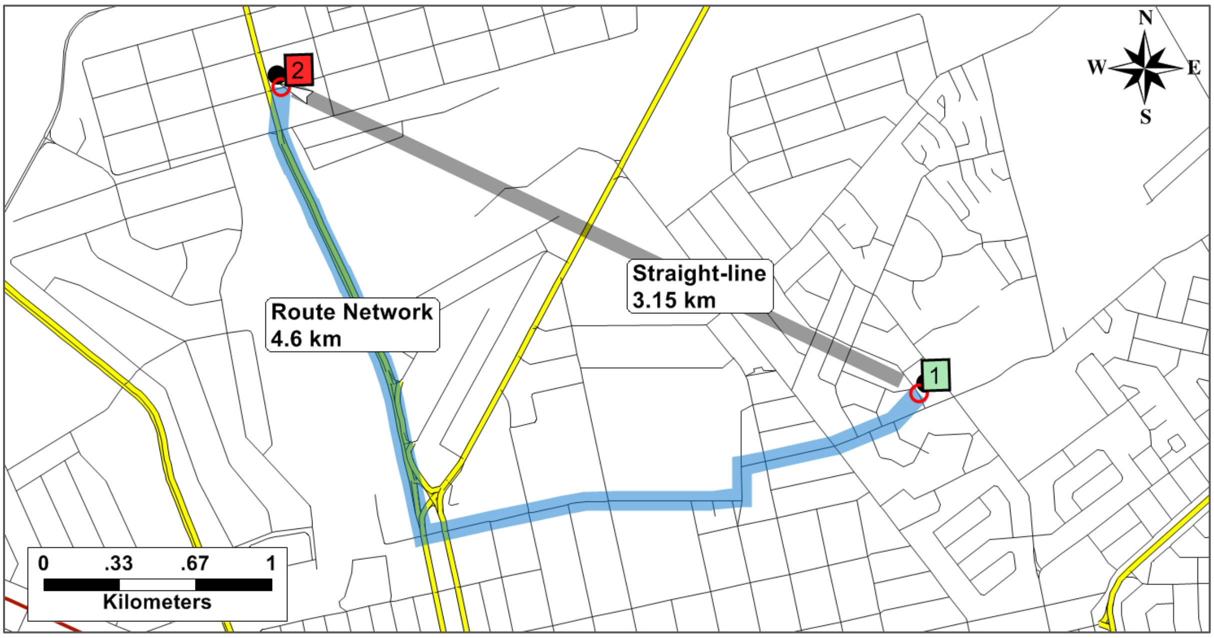


Figure 6: Straight-line versus network based distance calculation

Because there is limited road infrastructure in rural areas and footpaths are not included in commonly available travel networks, an alternative method had to be found to measure accessibility in rural areas. As part of the DPSA project (discussed in 1.10), a method was proposed to overcome these challenges, namely by adding a triangular irregular network (TIN) to the travel network in areas with limited road infrastructure. TIN lines are used to represent informal footpaths between rural settlements. The TIN included in the travel network connects these settlements, (that are stored in a GIS as points), to one another via straight, non-overlapping lines. Informal roads and footpaths are not part of the formal road network maintained by provincial and national authorities and therefore not included in geospatial datasets of these authorities. They are also not included in datasets of private vendors, because vehicles do not travel on them.

According to Lloyd (2010) a TIN is a "vector based representation of a surface". The surface comprises a number of points that are connected by lines (arcs), creating triangular shapes. A TIN is based on a process called Delauney triangulation and is more commonly used to represent elevation and slopes on a surface.

In the guideline for improving geographic access to government service points, compiled by the DPSA, a comprehensive travel network consisting of a TIN, feed-links (or centroid connectivity lines) and a road network were discussed and suggested to measure accessibility in the country (DPSA 2012). Feed-links comprise straight lines connecting settlement locations (that are stored in a GIS as points) to the travel network, allowing more accurate distance calculations between settlements and Service Centres. In Limpopo province, the combination of a road network, feed-links and a TIN are relevant, since the largest part of the province consists of scattered pockets of densely populated rural areas with few paved or gravel roads between them.

(Berglund 2001) mentioned that "Some routines in transport modelling are very demanding from a computational point of view". They utilised the macro programming language in TransCAD (http://www.caliper.com/tcovu.htm) to develop accessibility measures which makes use of the TransCAD database format for matrices.

Other GIS software for determining accessibility described by Liu and Zhu (2004) includes Flowmap (http://flowmap.geo.uu.nl/) and ArcView's network analyst, currently known as ArcGIS with Network Analyst.

http://www.esri.com/software/arcgis/extensions/networkanalyst.

In this research TransCad and Maptitude was used to determine geographic accessibility.

2.4 IDENTIFY OPTIMAL LOCATIONS FOR FACILITIES

Analysis to identify optimal locations for facilities was attempted long before GIS software was developed (Centre for Advanced Spatial Analysis 2003). Drezner and Hamacher (2001) noted that Pierre de Fermat (1601-1665) posed the following problem: "given three points in the plane, find a fourth point such that the sum of its distances to the three given points is a minimum". Literature relating to this problem dates back all the way to the seventeenth century (Drezner & Hamacher 2001). Church and Murray (2009) mentioned that already in 1909, Weber identified a facility location problem for a manufacturing facility. The objective was to position a manufacturing facility at an optimal location in order to minimise the total weighted straight-line (Euclidean) distance between three separate locations. These locations include two material points and a market (Church & Murray 2009). Owen and Daskin (1998) noted that, as the average travel distance to a facility increases, the level of accessibility declines.

Other facility location problems could require multiple facilities. Multiple police stations could be required in a city to ensure that all residents have access to these stations within a defined maximum distance standard. The P-median problem that was introduced by Hakimi (1964), attempts to find the location of multiple facilities that will reduce the total demand-weighted travel distance between demand (or population for the purpose of this research) and facilities (Owen & Daskin 1998; Murray 2010). Hakimi (1964) proved that nodes (intersections) on a discrete network represent all points in the network, making it a finite problem and hence a manageable mathematical problem (Lei, Church & Lei 2016).

Ozcan (2005) describes four quantitative methods to solve the facility location problem in health care management. These methods include: cost-profit-volume analysis, factor rating methods, multi-attribute methods, and the center-of-gravity method (Ozcan 2005). Although each of these methods has the ability to solve location specific problems, the center-of-gravity method is most relevant to this research since it focuses on geographic locations for delivery of services. In his example the center-of-gravity method was used to identify the location of a blood bank supply centre to serve seven hospitals. This method uses coordinate information of the seven hospitals that are weighted based on yearly shipments from the blood bank to each hospital, hence a travel network was not considered.

The DPSA compiled a guideline for improving geographic access to government service points (DPSA 2012). This guideline was made available to government sectors, with the intention to assist them in their planning process to improve geographic access and to establish access standards. Within this guideline, two different approaches were identified to improve accessibility:

- Greenfields approach – identifies optimal locations for service points in a given area to meet the unserved population demand.
- Brownfields approach – accepts the current footprint of service points and identifies additional locations to meet the unserved demand.

These approaches will utilise various models to meet their required objectives. The DPSA guideline recognises these three models:

- Expansion model – to increase the number of points.
- Reduction model – to reduce the number of service points, and
- Relocation model – to relocate current service points to optimal locations.

Various GIS software tools are currently on the market with the ability to solve facility location problems, which include TransCAD, ArcGIS with Network Analyst and GRASS.

2.5 REVIEW OF PREVIOUS ACCESSIBILITY STUDIES

This section explores various accessibility studies that were done locally and internationally. The aim was to review and describe methods that have been used in the past to measure accessibility.

2.5.1 ACCESSIBILITY STUDY FOR THE METROPOLITAN CITIES OF JOHANNESBURG AND ETHEKWINI

During 2011 – 2012, the Council for Scientific and Industrial Research (CSIR) was appointed by the DPSA to conduct an accessibility study for the metropolitan cities of Johannesburg and eThekwini in South Africa. The intent of the study was to evaluate the current level of accessibility to different key services within various travel distances. Areas were identified where access is inadequate and intervention strategies were established. The study utilised capabilities of FlowMap (http://flowmap.geo.uu.nl/) to measure accessibility and to identify unserved areas within these two metropolitans. Analysis zones were created for the demand/supply modelling. These zones consisted of hexagons that covered the study areas. Population data from Statistics South Africa were disaggregated from Sub-place level to these hexagons in order to determine population demand and to calculate travel distances to facilities (CSIR 2013).

Since both this research and the CSIR study measures accessibility in South Africa, a few differences and similarities were identified. General differences lie in the overall objective of the two studies as well as the method used to measure accessibility. The objective of this research (as discussed in Chapter 1) is to compare the level of accessibility between urban and rural areas of Limpopo province and to identify optimal locations to increase accessibility in rural areas. The strategic intent of the CSIR study was to measure accessibility of all citizens to different key services and to "promote greater alignment across spheres of government with regards to access standards" (CSIR 2013).

Differences in the method include base data and software. This research uses 2011 population data from Statistics South Africa on a geographic level known as a small area layer, (discussed later in Chapter 3), compared to the disaggregation of 2001 population data into hexagons from the CSIR. Population in Johannesburg and eThekwini are situated in predominantly urban areas, consisting of good infrastructure whereby the majority of people in Limpopo province live in rural areas with less infrastructure and access to services. The derived travel network used in the CSIR study was not described in detail to determine obvious differences.

This research adopted capabilities of TransCAD and Maptitude to measure accessibility and identify optimal locations whereby functionalities of FlowMap were used for the CSIR study.

Common similarities between this research and the CSIR study include the use of a travel network to measure accessibility. Both studies also identified a maximum travel distance threshold to measure accessibility.

2.5.2 CSIR GUIDELINE FOR THE PROVISION OF SOCIAL FACILITIES IN SOUTH AFRICAN SETTLEMENTS

The guideline was published by the CSIR in 2012 and contains various travel distance standards to improve access to social facilities in South Africa (Green & Argue 2012). These facilities include health and emergency services, social and cultural, civic, social services, education and recreation provisions. Based on their research, a maximum travel distance of 15 km in urban areas and 25 km in rural areas is considered acceptable when travelling to Thusong Service Centres (these Centres were categorised under *civic* services). Other significant distance standards that were identified in the CSIR guidelines include those that were established for Police Stations. These standards depict an acceptable travel distance of 8 km in metro areas, 15 km in peri-urban areas and 24 km in other areas.

2.5.3 SITUATIONAL ANALYSIS FOR HEALTH FACILITY PLANNING, GAUTENG DEPARTMENT OF HEALTH

In an article written by Francois Venter from Gauteng Department of Health, gaps in the provision of healthcare facilities were identified for Gauteng province (Venter 2015). In the article, response time of 15 minutes for ambulances was used to measure accessibility to healthcare facilities and to identify gaps. This method differs from the Limpopo province research where physical travel distances (not response time) were used to measure accessibility to Thusong Service Centres and Clusters, similar to the standards discussed in the CSIR guidelines mentioned in 2.5.2.

2.5.4 A NATIONWIDE COMPARISON OF DRIVING DISTANCE VERSUS STRAIGHT-LINE DISTANCE TO HOSPITALS

In this article by Boscoe, Henry and Zdeb (2012), a comparison was done between driving distance (network based) and straight-line distance calculations to community hospitals in fifty states of the United States. The base data includes a centroid point for 66 125 census tracts (origin locations), community hospital locations as destinations and road data. Centroid points from census tracts were snapped to the nearest road vertex, indicating the origin location for each census tract. Straight-line distance, travel time and travel distance were then calculated from each census tract to the nearest community hospital. Results from this study concluded that straight-line distance is an "adequate proxy for travel distance" when applying a detour index value. Boscoe, Henry and Zdeb (2012) also noted the exceptions usually occur with straight-line distance calculations, where large natural barriers are present such as lakes, rivers, mountains and wilderness areas. They also recommended that since the cost of travel distance calculations decreased considerably, the added precision of travel distance calculations should be included.

Similarities between this research and the study by Boscoe, Henry and Zdeb (2012) include the use of centroid points. In this research however, an additional feed-link was created from the centroid point to the nearest road segment. This was done since the polygons (areas) used in the Limpopo research vary considerably in shape and size. In both studies, natural barriers were identified as problematic when calculating straight-line distances.

2.5.5 GEOGRAPHIC ACCESSIBILITY ANALYSIS – METHODS AND APPLICATION

Dahlgren analysed the existing geographic accessibility system of the Swedish National Rural Development Agency (SNRDA) known as the NetRider function library and identified bottlenecks in the accessibility system (Dahlgren 2008). He also explores planning accessibility to rescue services. Dahlgren noted that straight-line distance calculations could be possible and common to use in areas with a dense infrastructure network, but is not optimal for rural areas due to their limited road infrastructure and natural barriers.

A relevant chapter in Dahlgren's study that links to this research includes a description of the accessibility calculation process (Chapter 5). In this chapter, seven important steps are identified that describe the accessibility calculation process. In summary, the first step includes the import of a network into a system and adding a spatial index, followed by a process that creates connecting links between points and the network. The next step includes the creation of a graph structure from the network. The purpose of this step is to connect all nodes and edges (lines) in the network (also known as the creation of spatial topology). The second last step is a generalisation of the network where internal nodes and dangling nodes are removed, followed by the last step that performs the network search. This step calculates the distance between points.

For the purpose of this research, the route network was not generalised as suggested by Dahlgren. All the network nodes were used in the distance calculations. Although the process is more time consuming, the end result contains more accurate distance measurements.

2.5.6 PATTERNS OF ACCESS TO RURAL SERVICE INFRASTRUCTURE: THE CASE OF FARMING HOUSEHOLDS IN LIMPOPO PROVINCE

The travel distance between selected farming households in Limpopo province and nine service infrastructure components, (both economic and social), were calculated in order to identify the current pattern of service infrastructure (Makhura, Wasike 2003). Makhura and Wasike (2003) emphasises the notion that insufficient infrastructure is a challenge in Africa and that infrastructure is required to improve the quality of life of people. The exact method on how the distance between households and the nine service infrastructure components was calculated, was not mentioned.

2.5.7 MODELLING AND UNDERSTANDING PRIMARY HEALTH CARE ACCESSIBILITY AND UTILIZATION IN RURAL SOUTH AFRICA

In this article by Tanser, Gijsbertsen and Herbst (2006), households in Hlabisa, KwaZulu-Natal were interviewed regarding their use of clinics. These homesteads were also geocoded and their distance to clinics was calculated in a GIS to determine the mean travel time to a clinic. Factors such as the quality and distribution of roads as well as natural barriers were considered in the distance calculations. Results from the model were subsequently used to analyse the usage of clinics in urban, rural and peri-urban areas. The study included both travel distance and travel time using the costgrow algorithm in Idrisi Kilimanjaro (Tanser, Gijsbertsen and Herbst 2006).

2.5.8 MEASURES OF SPATIAL ACCESSIBILITY TO HEALTH CARE IN A GIS ENVIRONMENT: SYNTHESIS AND A CASE STUDY IN THE CHICAGO REGION.

This study combines different GIS methods in order to measure spatial accessibility to primary health care in the Chicago region. These methods include a floating catchment area method and a gravity catchment method. Base data includes census tract centroid points to represent population distribution and ZIP-code centroid points for physician locations. "The spatial barrier between residents and physicians" was calculated by travel time and not straight-line distances (Luo & Wang 2003).

Luo and Wang (2003) concluded that "finer resolution data", (or base data on a granular level), combined with travel time calculations, "reveal details of varying spatial accessibility" that could be used to improve the location for health professionals, where current shortages were identified.

2.5.9 RETAIL LOCATION ANALYSIS: A CASE STUDY OF BURGER KING & MCDONALD'S IN PORTAGE & SUMMIT COUNTIES, OHIO

Duggal, 2007 noted that "There has been a growing interest among the academia and the private sector for the use of GIS techniques in the analysis and planning of retail store network" (Duggal 2007). Various spatial techniques that include Thiessen polygons (or areas of influence) and buffers, were used to aggregate variables associated with the catchment area (or trade zone) of each store. These variables were subsequently analysed with regression models to understand how geographic factors impact the performance of stores. ArcGIS software was used for spatial analysis in this study.

Duggal concludes that GIS is becoming a "popular tool in retail industry for the site location analysis" (Duggal 2007). In summary, Duggal managed to identify various relationships between sales revenues and location factors that include socio-economic attributes by utilising spatial techniques in a GIS.

3. ACCESSIBILITY ANALYSIS: METHODOLOGY AND DESIGN

3.1 INTRODUCTION

This chapter provides a detailed description of the methods that were used to statistically model the current geographic accessibility of Thusong Service Centres and Clusters, as well as to identify additional locations that could improve accessibility in Limpopo province. Only secondary datasets were sourced and prepared for this study. Chapter 1 already introduced the three-step methodology. Chapter 3 continues to describe these steps in more technical detail. *Figure 7* shows the three steps that were followed and described in Sections 3.2, 3.3 and 3.4 respectively.

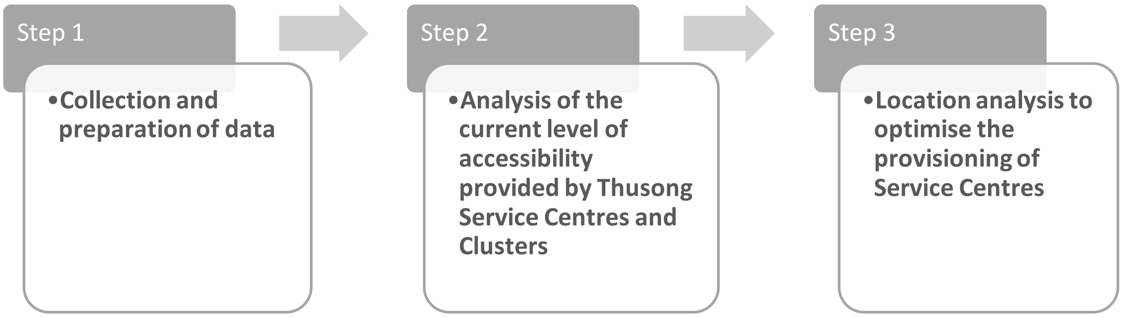


Figure 7: Three-Step methodology

3.2 STEP 1 – COLLECTION AND PREPARATION OF DATA

This step includes the collection of various datasets, as well as preparation of the data for use in a GIS. These comprise settlement typologies for Limpopo province to distinguish between urban and rural areas, location data of Thusong Service Centres (including facility data of departments), population figures and lastly, a routable travel network. In order to determine the distance that people travel to their nearest centre, both the Thusong Service Centre locations and the populated areas, should be connected to the travel network. These four datasets are explained in more detail in subsequent sections.

3.2.1 SETTLEMENT TYPOLOGY

As no single official classification currently exists in South Africa to distinguish between urban and rural spaces (Laldaparsad 2011), for the purpose of this study, the AfriGIS spatial town boundaries were used in a GIS (as an alternative to the census EA type classification described in Chapter 2) to distinguish between urban and rural areas. The South African Geospatial Data Dictionary and Its Application, compiled by South African National Standards (SANS) served as a standard and guide to differentiate urban and rural areas. Urban type classification is based on dominant settlement type (derived from census data) and land use. Cities, towns, townships, suburbs, etc., are typical urban settlements. EAs comprising informal settlements, hostels, institutions, industrial and recreational areas, and small holdings within or adjacent to any formal urban settlement are classified as urban. Rural type is any area that is not classified as urban. *Figure 8* shows urban and rural areas in South Africa based on the AfriGIS town boundaries.

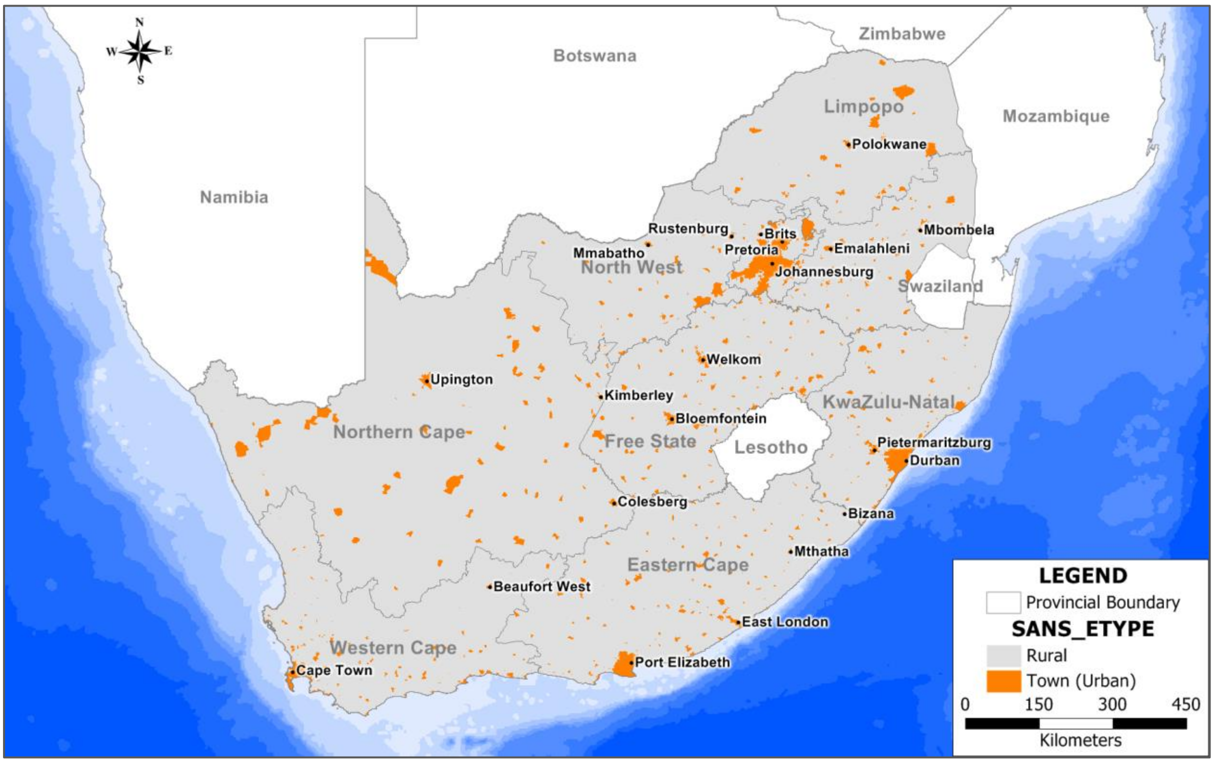


Figure 8: Urban and rural areas in South Africa

3.2.2 THUSONG SERVICE CENTRES AND THUSONG SERVICE CLUSTERS

This research includes both Thusong Service Centres and Thusong Service Clusters in the accessibility calculations. Thusong Service Centres are permanent structures where services of departments are housed under one roof and where services are provided on a daily basis.

As part of the accessibility study commissioned by DPSA (discussed in 1.10), a mapping exercise was done together with provincial managers of the Thusong Service Centre Programme, the DPSA and the Department: GCIS to verify the geographic location of existing Thusong Service Centres. The Thusong Service Centre locations identified in the mapping exercise were also used for this research.

Thusong Service Clusters were introduced by the DPSA. They are also permanent facilities consisting of three or more key departments which are located in close proximity to each other. These serve as de facto Thusong Service Centres.

A Thusong Service Cluster was defined by creating a geographic distance band, (also known as buffers), around key service points identified by the DPSA. These service points include the Department of Home Affairs, Department of Labour, South African Social Security Agency (SASSA) and the South African Police Service (SAPS). Clusters are created when the bands of at least three departments intersect with one another. Most GIS software products have the capability to generate distance bands. For the purpose of this study, a one km radius in urban areas and two km radius in rural areas was used to create distance bands. *Figure 9* displays a map of a Thusong Service Cluster in Seshego, adjacent to Polokwane. This Cluster consists of the following three key departments: Department of Home Affairs, SAPS and SASSA. Spatial data of the various key departments was obtained through DPSA, with permission to use the data for geographic analysis purposes relating to Thusong Service Clusters only. Each dataset contains coordinate information (a latitude and longitude value) that was imported into a GIS and mapped for analysis.

Since intersecting bands of key departments to establish Thusong Service Clusters could cover a large geographical area, a centroid point was created to represent the Cluster location. See *Figure 9*.

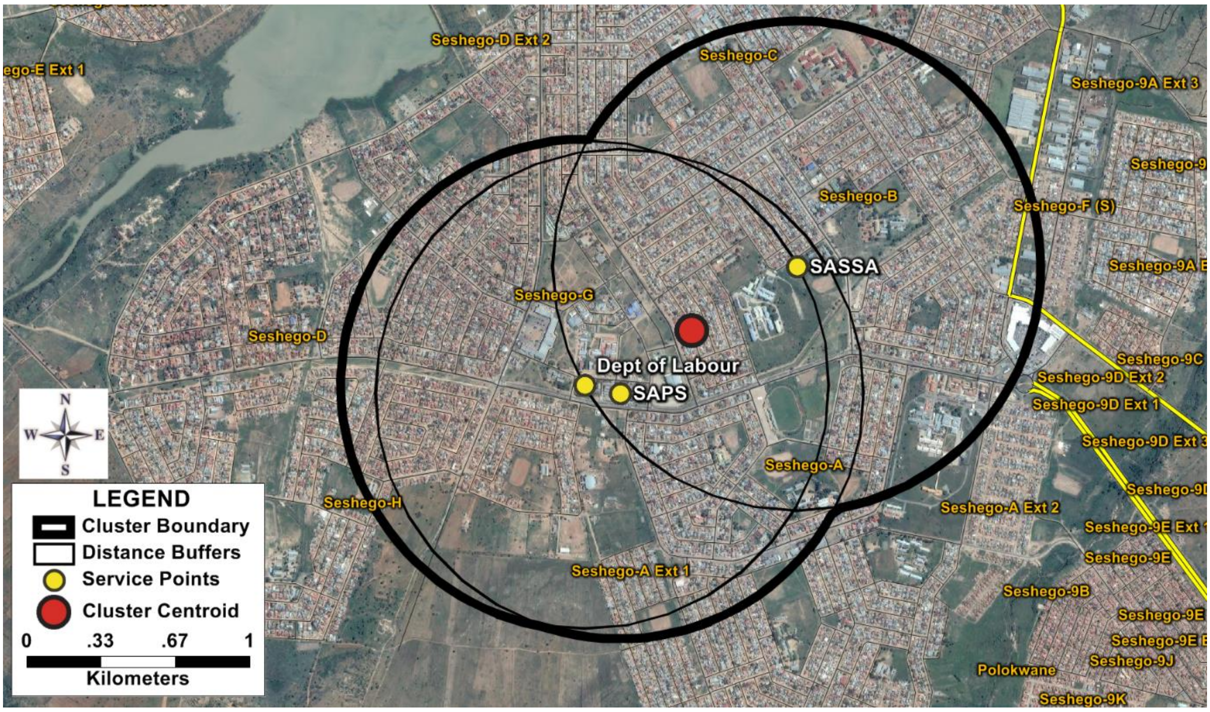


Figure 9: Example of a Thusong Service Cluster

Thusong Service Centres and Thusong Service Clusters in adjacent provinces could also provide access to people in Limpopo province, hence all the Thusong Service Centres and Cluster that are situated in adjacent provinces, close to the Limpopo province border were included as part of the base data. Adjacent provinces include Mpumalanga, Gauteng and North West province. *Figure 10* shows a map of Limpopo province illustrating a distance band (in 5 km intervals) around the southern part of the province. Service Centres that are situated within these bands were also included for the accessibility calculations.

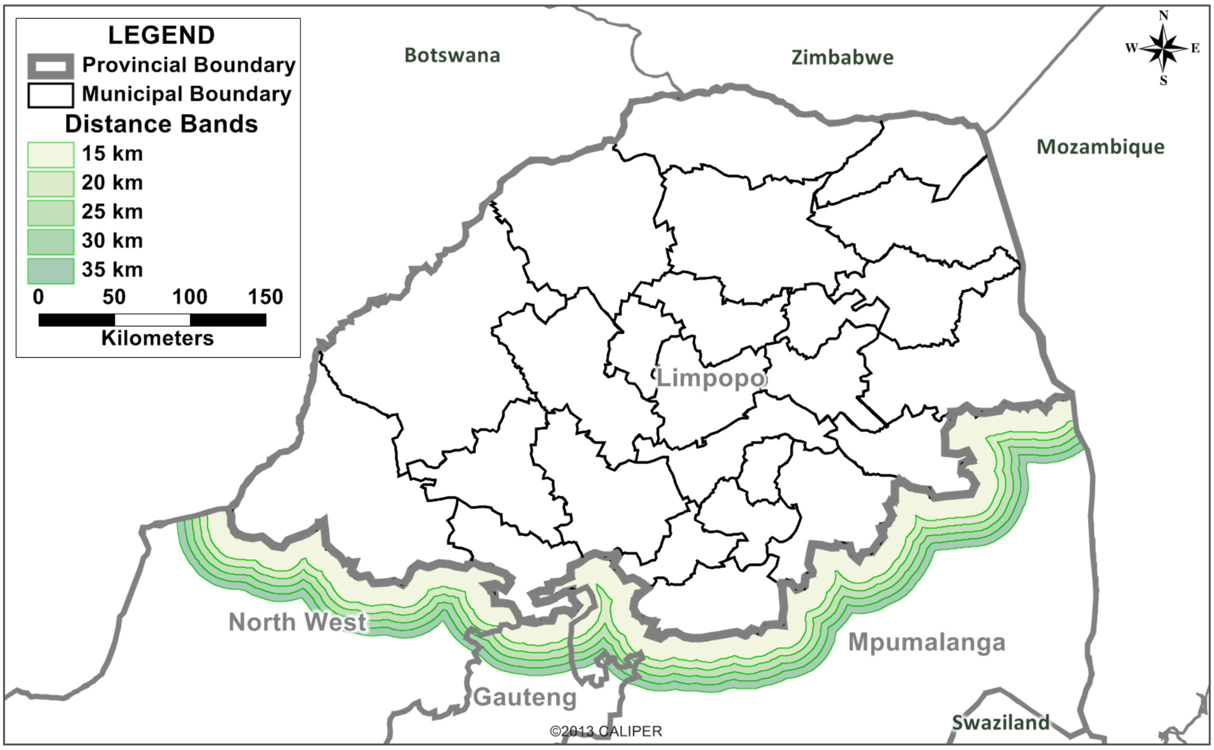


Figure 10: Distance bands in adjacent provinces

3.2.3 POPULATION DATA

The most recent national Census (prior to the start of this research) was held in 2011 (Statistics South Africa 2012a), hence population figures from this census was used to calculate accessibility in Limpopo province. This section explains the method that was followed to create a geographic layer representing population distribution across the province. The method can be divided into three phases:

- Phase 1 – Mapping population data to a small area layer.
- Phase 2 - Disaggregation of large areas into smaller entities.
- Phase 3 – Converting populated areas into centroid points.

3.2.3.1 Phase 1 - Mapping population data to a small area layer

Statistics South Africa released the 2011 Census results in various products and publications. One of these products is called the Census 2011 Community Profiles in SuperCROSS. It is a desktop application that enables users to extract 2011 population data in tabular format and to filter various demographic variables. The population data can be linked to different spatial hierarchies such as provinces, municipalities, main-places (towns), sub-places (suburbs or villages) and a small area layer (SAL). The SAL layer contains the smallest geographical polygons for the entire country that is relationally linked to the Census 2011 Community Profiles in SuperCROSS. Hence these polygons were used to depict population distribution across the province.

Figure 11 displays the cross-tabulation functionality of SuperCROSS. Population figures derived from SuperCROSS can be exported into various external file formats such as Microsoft Excel (.XLS or .XLSX), comma-separated file (.CSV) or a tab delimited file (.TXT). To import and map population figures in a GIS, results from SuperCROSS were saved in a Microsoft Excel file format (.XLSX). Microsoft Excel files are easily imported into GIS systems and linked to spatial layers of points, lines or areas.

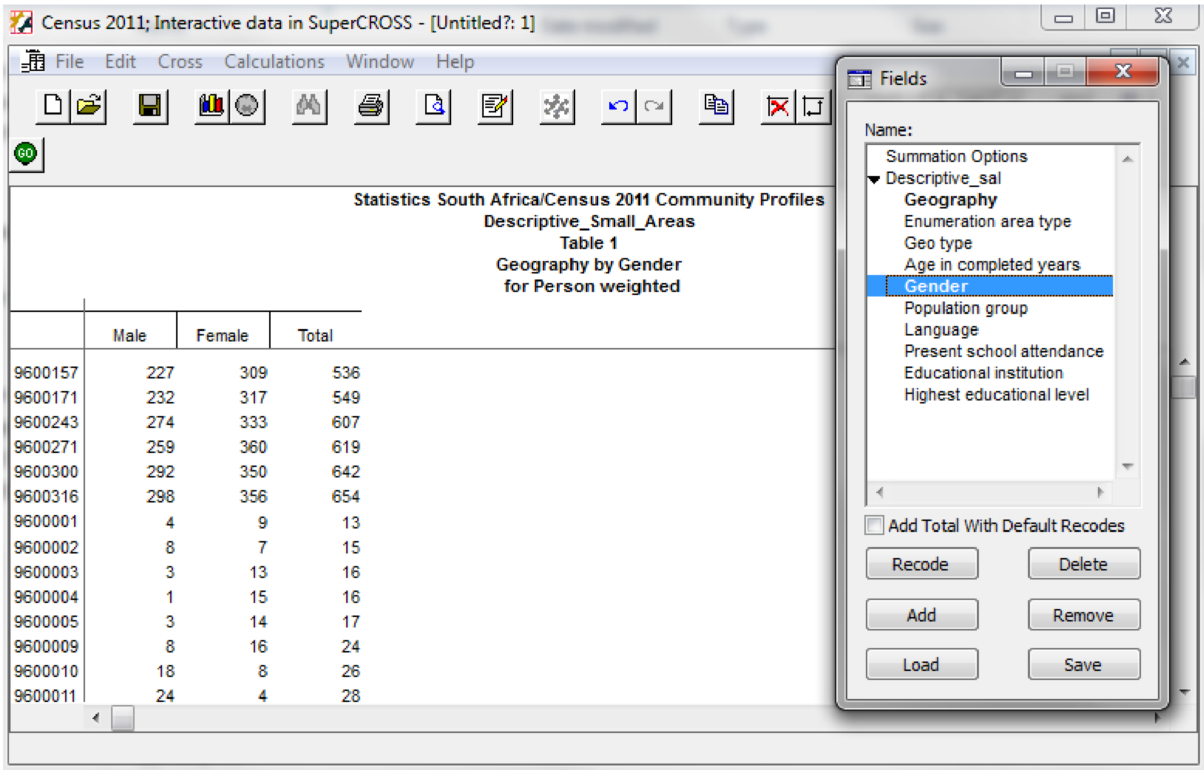


Figure 11: Cross-tabulation functionality in SuperCROSS

Figure 12 shows SAL polygons for a small section in the town Polokwane, that is also the capital of Limpopo province. Polygons are labelled with the total population count that was extracted from the Census 2011 Community Profiles in SuperCROSS. The geographical shape, size and number of people per SAL polygon differ significantly throughout the province, depending on population density as well as the topographic landscape of an area.

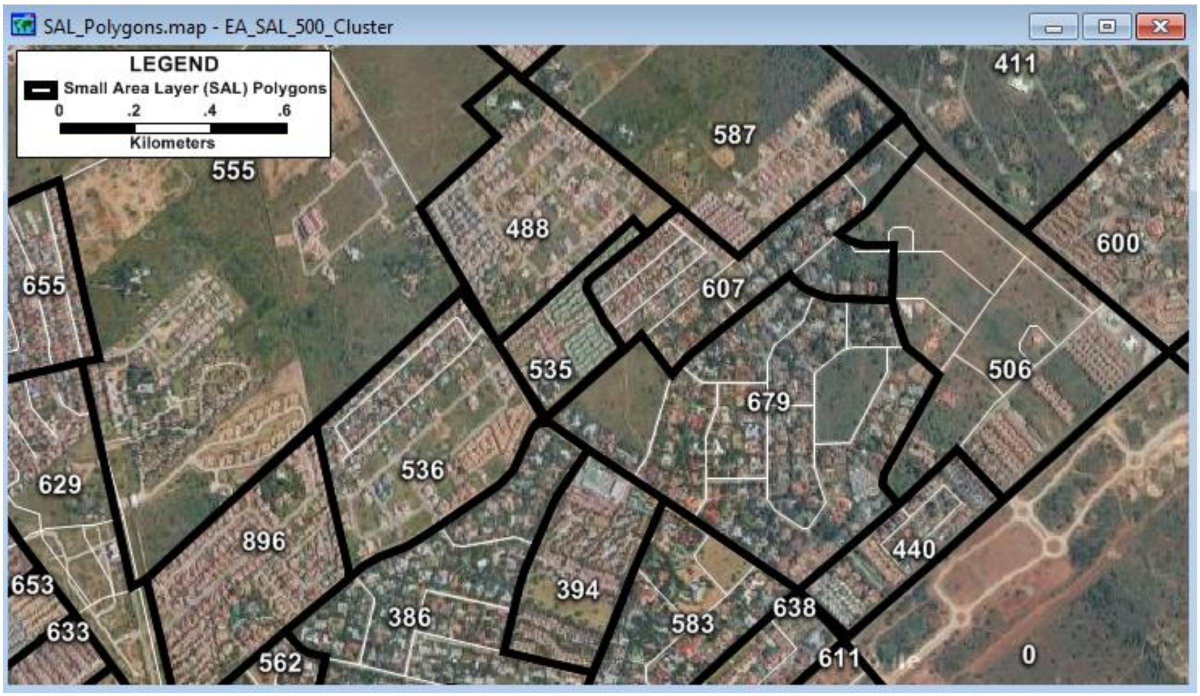


Figure 12: Small areas in Polokwane

The SAL layer was also created by Statistics South Africa. It is an aggregated version of the original EAs where EAs with a population of less than 500 were merged into larger polygons (Statistics South Africa 2001).

3.2.3.2 Phase 2 - Disaggregation of large areas into smaller entities.

Densely populated urban areas usually have several SAL polygons, compared to more sparsely populated (or unevenly populated) rural areas which typically have less SAL polygons and that are larger in size. Measuring accessibility in these rural areas, where the SAL polygons are extremely large could be problematic since population is rarely distributed evenly across SAL polygons. In order to overcome this challenge, a method had to be found that could split large rural SAL polygons into smaller entities. Since SAL polygons were aggregated from smaller EAs, a novel method was used to disaggregate large SAL polygons into the original smaller EAs and to distribute population from SALs to each underlying EA.

Figure 13 shows five EAs within a single SAL polygon in Limpopo province. The estimated population for the SAL polygon based on the Census 2011 Community Profiles in SuperCROSS is 442.

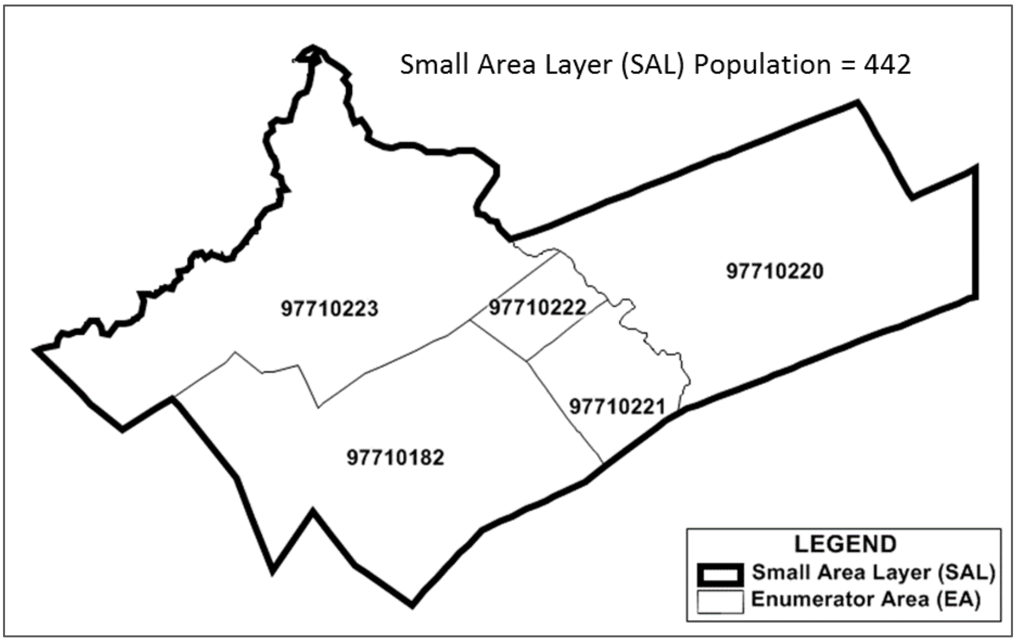


Figure 13: EAs inside a SAL polygon

Various methods to distribute population figures from large SALs to underlying EAs were evaluated and compared. The following section explores three possible methods to sub-divide population from SAL polygons into smaller EAs.

Method 1: Equal distribution. An equal distribution method distributes population from the SAL polygon equally to each EA. A total number of 88.4 people (rounded to 88 people) would be distributed to each of the 5 EAs (shown in *Figure 13*), since they are not weighted.

Method 2: Population distribution based on area size. The following equation shows how area size of EAs are used as a weighting variable to distribute SAL population proportionally across all the EAs inside a SAL.

Inputs

p = SAL population count

A_{ea} = Area size of EA 97710220

A_{sal} = SAL area size

$$x = \left(\frac{Aea}{Asal}\right) \times p$$

$$x = \left(\frac{164.1}{522}\right) \times 442$$

$$x = 139$$

The largest EA will receive the most people and in turn, the least number of people will be assigned to the smallest EA. See *Table 4*. EA 97710223 received the highest population count of 142, followed by 97710220 with 139 people. The least number of people (13) will be in EA 97710222.

Table 4: Population distribution based on areas size

EA	Area (km2)	Population distribution based on Area Size (Rounded)
97710220	164.1	139
97710222	15.8	13
97710221	32.3	27
97710182	142.5	121
97710223	167.4	142
Total	522.0	442

Method 3: Population distribution based on a weighted variable. The count of erf parcels per EA could possibly give an indication of population spread across EAs. After examining this option, erf parcels in rural areas are problematic since most rural areas comprise farms, villages and informal towns or settlements. The villages, informal towns or settlements in rural areas usually do not have spatially captured erf boundaries.

A spatial layer from Stats SA was identified that could be used as a possible weighting variable. The layer consists of more than 13 million dwelling points across the country (that includes both urban and rural areas). It is called the Census Dwelling Frame points and was captured from the EA Summary Books used during Census 2011. The EA Summary Books contain a register of all places to be visited during the census (Statistics South Africa 2014a). Appendix 1 shows the various available categories and descriptions. Only the highlighted categories and feature descriptions were used for this research as they indicate populated areas.

The number of Census Dwelling Frame points per EA served as a weighting variable to distribute population proportionally to each EA.

Equation for EA 97710220:

Inputs

p = SAL population count

C_{ea} = Count of census dwelling frame points per EA

C_{sal} Total count of census dwelling points inside the SAL polygon

$$x = \left(\frac{Cea}{Csal}\right) \times p$$

$$x = \left(\frac{96}{385}\right) \times 442$$

$$x = 110$$

Table 5 displays the population count per EA based on this method.

Table 5: Population distribution based on Census dwelling frame points

Enumerator Area (EA)	Census Dwelling Count	Population Distribution (Rounded)
97710220	96	110
97710222	31	36
97710221	47	54
97710182	74	85
97710223	137	157
Total	385	442

Results from these three methods indicate that the population distribution per EA differ in each method. The chart in *Figure 14* compares the results. Population in EA 97710223 and 97710220 remained highest in both method two (2) and three (3), although a significant difference in the population counts is observed. EAs with the lowest population counts display similar patterns, where both EA 97710222 and 97710221 are rank lowest in method two (2) and three (3).

Major population differences exist between these three methods. Population in EA 97710220 increased from 88 (method 1) to 139 (method 2) and reduced to 110 (method 3). Although each method is based on assumptions derived from spatial queries, they managed to distribute population from a large SAL polygon into smaller EAs.

Method 3 (Census Dwelling Frame points as the weighting factor) was adopted for this study.

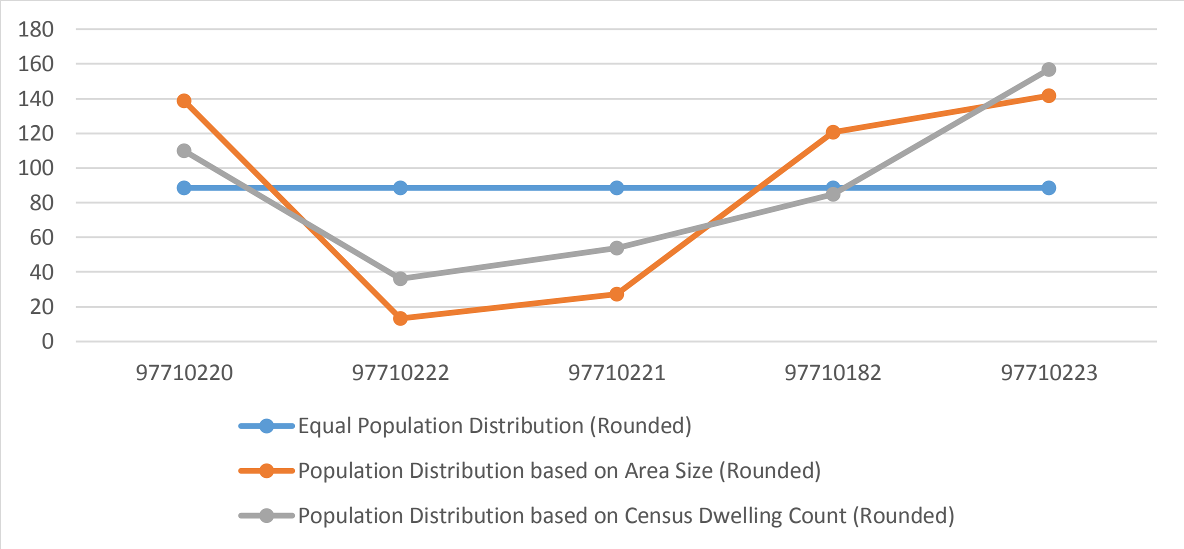


Figure 14: Population distribution based on the three methods

The following section describes the process followed to identify these large SAL polygons in Limpopo province that can be disaggregated into the smaller original EAs.

From the 9 882 SAL polygons in Limpopo province, 89 are > 300 km^2, 42 are > 500 km^2, 11 are > 800 km^2 and only 5 are > 1 000 km^2. For the purpose of this research, SAL polygons larger than 500 km^2 was subdivided into smaller EA areas.

Figure 15 shows a map of SAL polygons in Limpopo province. The SAL polygons are colour-coded based on their different area sizes. The large areas on the eastern side of the province are situated in the Kruger National Park, hence these areas cover a large geographical surface but are very sparsely populated.

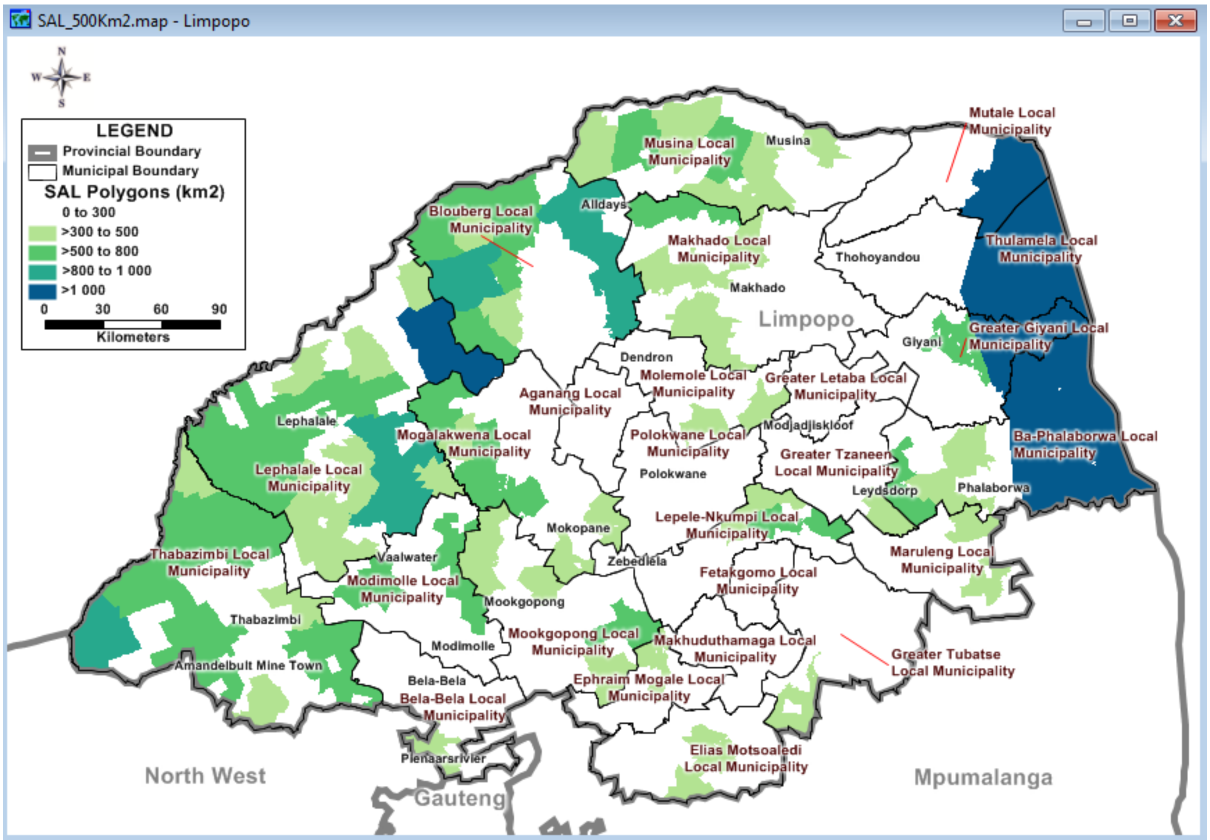


Figure 15: Size of EAs in Limpopo province

3.2.3.3 Phase 3 – Converting populated areas into centroid points.

Currently, population data is represented by polygons (or areas), hence these polygons are not connected to the travel network. For this reason, a centroid point was created for each SAL polygon that can be spatially connected to the travel network. "Every area in a geographic file has an associated point location called the centroid. The centroid is a point located near the geographic center of an area" (Caliper Corporation 2015). *Figure 16* shows the centroid point of SAL polygons in Polokwane. Centroid points are labelled with their respective population count.

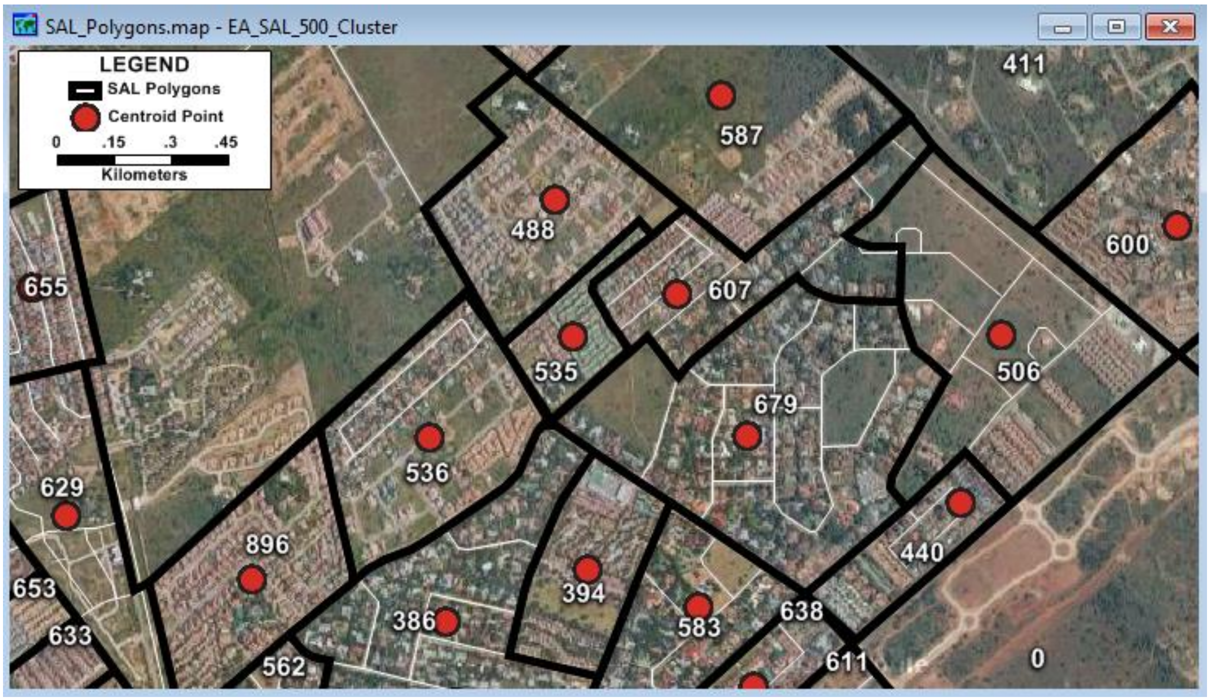


Figure 16: SAL centroid points

Since this research focuses on the geographic accessibility within urban and rural settlement typology types, a spatial tag functionality in Maptitude was used to assign a settlement typology type to each SAL centroid. The settlement typology layer that was discussed in 3.2.1 served as the base layer. This function created an additional column in the SAL centroid layer.

3.2.4 TRAVEL NETWORK

The last dataset required to measure accessibility and to identify optimal locations for Thusong Service Centres includes a comprehensive routable travel network. The travel network was essential to calculate the travel distance between origin (SAL centroid points) and destination (Thusong Service Centres and Clusters) points.

In this research, the travel network comprises of street centrelines, feed-links (or centroid connectivity lines) and a TIN.

3.2.4.1 Street centrelines

Street centrelines consist of line segments (Arcs) that are connected by nodes (Church & Murray 2009). These line segments could have multiple attribute fields such as an indication of one-way streets, average travel speed or simply a street name. The length of each line segment is stored in the GIS allowing distance calculations from one node to the next. The street centreline layer for Limpopo province used in this research was obtained with permission from AfriGIS. The layer was received in vector format and consists of a topological route network that is divided into five categories; highways, main roads, secondary roads, arterial roads, streets and other. *Figure 17* illustrates the line segments (Arcs) and nodes in a travel network.

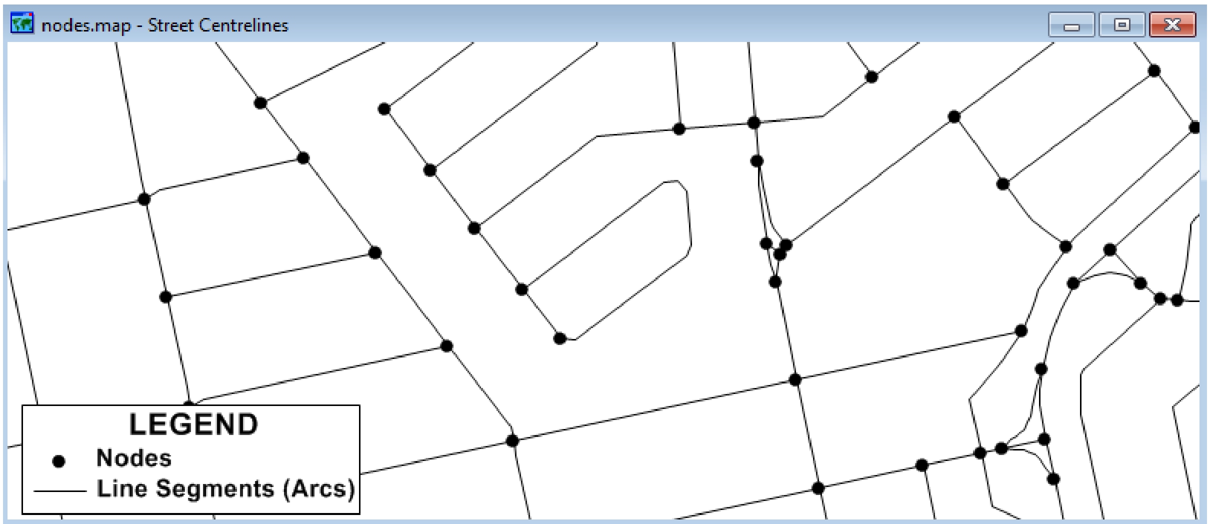


Figure 17: Travel network

3.2.4.2 Feed-links or centroid connectivity lines

In order to include the distance from each SAL centroid point (origin) or Service Centre (destination) to their nearest street segment, a feed-link or centroid connectivity line was created. This line connects the SAL centroids and Service Centres to the travel network. This is particularly relevant in rural areas where SAL centroids and Service Centres are not always close to roads. The distance from the SAL centroid point to the travel network could stretch over kilometres, hence if this distance is not included, a distorted result will be obtained. Spatial capabilities in TransCAD software was used to generate feed-links.

3.2.4.3 Triangular irregular network

Since it is possible, specifically in rural areas for people to travel between settlements on unofficial trails or footpaths, a third extension to the travel network was created. A TIN was created between SAL centroid points that are situated in rural areas. This method generates straight lines between SAL points in non-overlapping triangles. A TIN network is based on a Delaunay triangulation and was created in Maptitude GIS software. The inclusion of a TIN network in this research has strengths and weaknesses. TIN lines enable connectivity between settlements in rural areas that could reduce the overall travel distance between settlements and Service Centres, hence the level of accessibility based on travel distance will improve. On the downside, these lines will not necessarily represent a true reflection of the actual paths or routes that people use between rural settlements. For the purpose of this research these TIN lines were included and form part of the travel network in the province.

Both TIN lines and feed-links were removed via a manual process if they cross natural barriers such as major rivers, dams, nature reserves and steep mountainous areas. This caused a problem in certain areas where SAL centroids are not connected to a travel network. To resolve this problem, another manual exercise was done (by using aerial photography as a guide) to create lines that do not cross natural barriers and links SAL centroid points to the travel network.

The final travel network consists of street centrelines, feed-links (or centroid connectivity lines) that connect SAL centroid points to the road network and a triangular irregular network (TIN) to connect rural settlements in areas that lack sufficient road infrastructure. The travel network requires spatial typology, ensuring that all the line segments are connected to a single network. Various GIS software packages were used to build the routable travel network which includes Maptitude, TransCAD and ArcInfo.

When calculating the distance between origin and destination locations, the following route calculations were used:

- Straight-line distance from an origin location (SAL centroid) to the nearest node in the travel network (feed-links or centroid connectivity lines).
- Distance from the node in the travel network (that includes street centrelines and the TIN network) to the nearest node in the travel network of the destination location (route based).
- Straight-line distance from the destination node to the Service Centre location.

Figure 18 displays the travel network consisting of street centrelines, feed-links (or centroid connectivity lines) and the TIN.

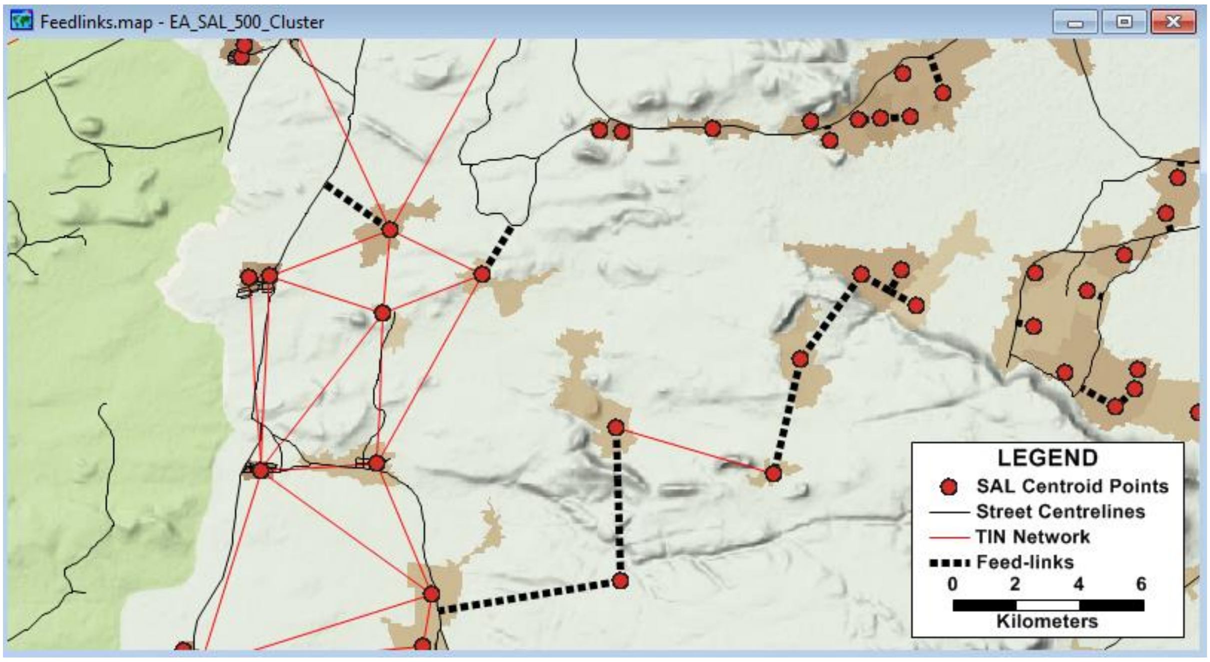


Figure 18: Travel network including TIN lines and feed-links

3.2.5 DATA SUMMARY

For the purpose of this research, the following base datasets were gathered and prepared in a GIS to calculate accessibility in relation to Thusong Service Centres or Clusters and in relation to actual distances travelled in Limpopo province:

- Settlement typology to distinguish between urban and rural areas.
- Population data to determine the geographic distribution of people across the province (origin).
- The location of Thusong Service Centres and Thusong Service Clusters (destination).
- A routable travel network to calculate the distance between populated areas (origin) and Service Centres (destination).

3.3 STEP 2 - ANALYSIS OF THE CURRENT LEVEL OF ACCESSIBILITY PROVIDED BY THUSONG SERVICE CENTRES AND CLUSTERS

The previous section (Step 1) identified and explained the different datasets that was used in the study. Context were also given on the importance of each dataset.

Step 2 explains the methods that were adopted for this research to calculate the distance that people travel along the travel network to their nearest Thusong Service Centre or Thusong Service Cluster. Hence this research determines the actual travel distance between origin and destination points by using a routable travel network in a GIS.

Results from this step depicts the current level of accessibility provided by Service Centres in Limpopo province within various travel distance thresholds. It was assumed for this study that people are more likely to travel to their nearest Thusong Service Centre, hence other factors were not included. Different maximum travel distances were used and tested in this step to determine the level of accessibility.

This section is divided into two separate components. These components include:

- Creating a cost matrix with TransCAD to calculate the travel distance between SAL centroid points (origin) and Service Centres (destination).
- Define and compare the current level of accessibility between urban and rural areas based on results emanating from the cost matrix.

3.3.1 CREATING A COST MATRIX

Various GIS software with the capability to measure the distances between origin and destination locations via a specified travel network exist today. This research adopted the cost matrix capabilities of TransCAD.

TransCAD was developed by Caliper Corporation. The software is designed to analyse and model transportation data (Caliper Corporation n.d.). TransCAD basically requires three spatially referenced datasets (layers) to generate a cost matrix:

1. A point layer with all the origin locations (SAL centroid points).
2. A routable travel network.
3. A point layer that contains all the destination locations (Thusong Service Centres and Thusong Service Clusters).

These three layers were all imported separately into TransCAD. The original street centreline layer received from AfriGIS includes one-way street attributes, therefore the cost matrix calculations will include one-way restrictions.

The two native file formats for TransCAD are a standard geographic file (.dbd) and a compact geographic file (.cdf). The standard geographic file is an editable format where spatial entities can be added, edited, modified or deleted. The compact geographic file is a read only file format. This format is not editable and is also smaller in file size (Caliper Corporation 2015).

Although TransCAD can calculate distances via straight lines or route based, this research focussed on route-based calculations since this approach delivers more accurate results compared to straight line calculations. *Figure 19* displays the *Create Network* dialog box in TransCAD that is required to generate a cost matrix. The network file contains route information in a compact format that increases the processing speed of route based calculations (Caliper Corporation 2007). The travel network includes the street centrelines, feed-links and TIN network as discussed in Step1.

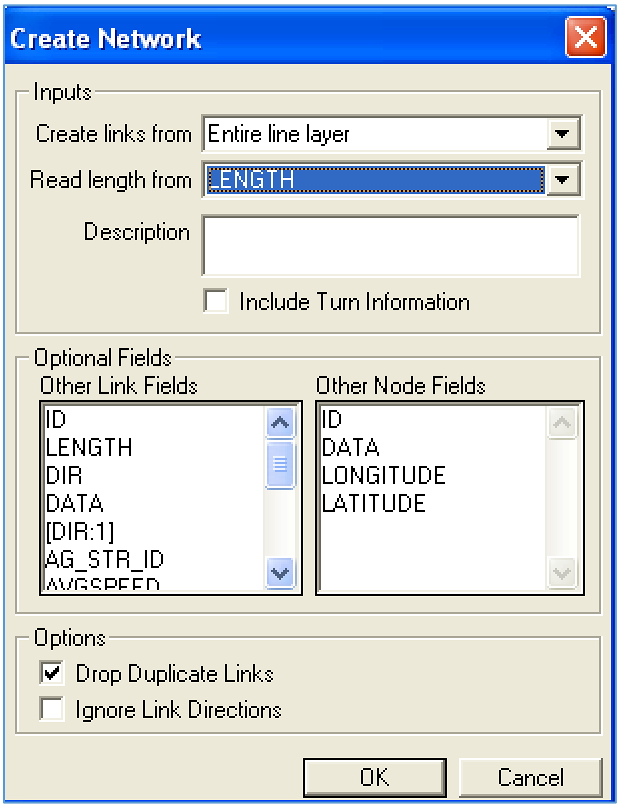


Figure 19: Creating a network in TransCAD

The intention of the cost matrix calculation is to minimise cost. Cost in this research refers to the shortest travel distance between origin and destination locations. Additional cost variables can also be included such as travel time or fuel consumption. The processing time to create a cost matrix can be very lengthy depending on the number of routes that must be calculated.

Both the origin (SAL centroid points) and destination layer (Thusong Service Centres and Clusters) requires a node_id field from the travel network to link both layers to the nearest travel network node. To do this; a spatial tag functionality in TransCAD was used. The tag functionality identifies the nearest travel network node and populates a new field in the origin and destination layers with the unique node_id. *Figure 20* shows the Cost Matrix dialog box. The example shows that the matrix method will be network based and the *LENGTH* between origin and destination layers will be minimised. The node_id field is also visible in both the origin and destination layers.

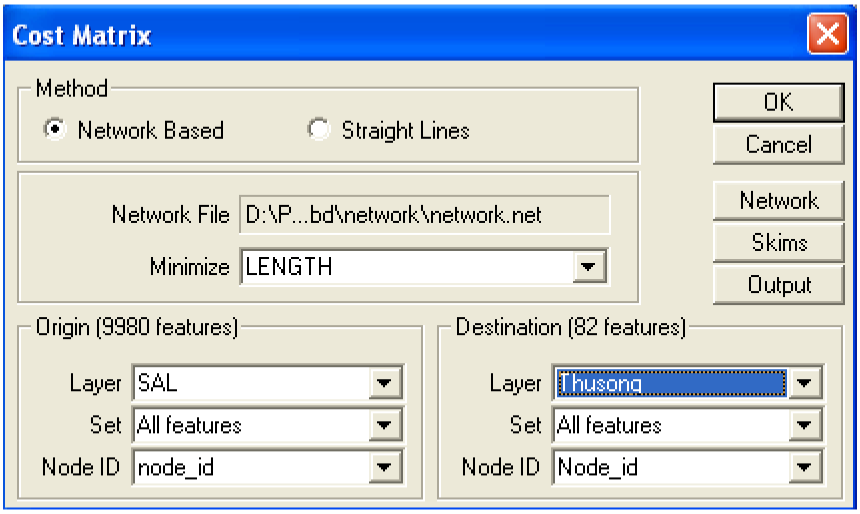


Figure 20: Cost matrix in TransCAD

The output format of the cost matrix is similar to the example in *Table 6*. The table depicts the travel distance between all origin and destination locations. ID fields from both layers were used to uniquely identify each record. The cost matrix result uses a native TransCAD format and needs to be exported into an external database format for additional analysis and data manipulation. Although TransCAD consists of advanced analytical capabilities, Microsoft Access was selected for alphanumeric data analysis.

Table 6: Example of a cost matrix based on travel distance

Matrix1 - Cost Matrix (LENGTH)

	4297	4305	4313	4321	4337	4345	4361	4369
4289	5.31	7.37	4.44	4.90	5.25	4.37	6.77	20.69
4329	3.33	5.38	1.93	0.37	0.15	3.57	2.03	15.95
4353	4.20	6.26	2.81	2.55	2.90	1.07	4.41	18.33
4377	10.67	8.86	11.60	12.06	12.41	14.04	13.93	27.85
4497	16.12	18.17	14.14	13.52	13.26	16.36	11.71	9.97
4553	15.35	17.41	13.38	12.75	12.50	15.59	10.95	10.47
4561	16.65	18.71	14.67	14.05	13.80	16.89	12.25	13.45
4569	17.13	19.19	15.16	14.53	14.28	17.37	12.73	12.68
4601	19.70	21.17	17.72	17.10	16.84	19.94	15.29	17.25
4657	14.27	12.46	15.20	15.66	16.01	17.64	17.53	24.94
4737	16.56	14.75	17.49	17.95	18.30	19.93	19.82	23.09
4745	17.60	15.79	18.53	18.99	19.34	20.97	18.58	21.87
4769	19.86	18.05	19.89	19.27	19.01	22.11	17.47	20.12
4777	20.84	20.24	18.87	18.24	17.99	21.08	16.44	18.69
4969	21.41	23.46	19.43	18.81	18.56	21.65	17.01	17.89
4985	21.53	23.15	19.56	18.93	18.68	21.77	17.13	18.25
5001	21.29	23.35	19.32	18.69	18.44	21.53	16.89	16.41

3.3.2 DEFINE AND COMPARE THE CURRENT LEVEL OF ACCESSIBILITY

The cost matrix was exported to a comma delimited text file (.TXT) format enabling easy import into Microsoft Access database software. Depending on the size and processing requirements, other database software products such as MySQL, Microsoft SQL Server, Oracle or PostGreSQL could be considered. Microsoft Access was adopted since it contains all the necessary functionalities required for this research. *Figure 21* shows the three tables used to calculate the current level of accessibility. *Figure 21* also depicts the table structure as well as the table relationship. The three tables include:

- **SAL Centroid** table that contains attribute information of the SAL Centroid points.
- **Cost Matrix** table with travel distance results between origin (SAL Centroid points) and destination fields (Service Centres).
- **Service Centres** table that contains attribute information of all the Thusong Service Centres and Thusong Service Clusters.

The Origin field in the Cost Matrix table links to the ID field in the SAL Centroid table, whereby the Destination field on the other hand links to the ID field of the Service Centres table.

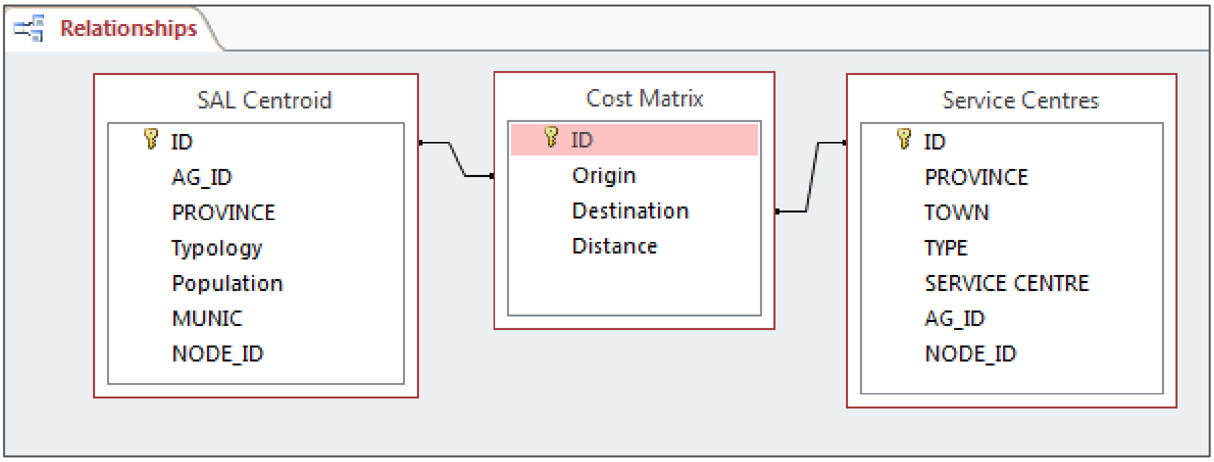


Figure 21: Table relationship in Microsoft Access

Currently the Cost Matrix table includes the travel distance between ALL the origin and destination locations, therefore the following queries were constructed in Microsoft Access to determine the travel distance from each SAL centroid to their NEAREST Service Centre.

Query 1 – MIN DIST: Identifies the shortest travel distance from a SAL centroid point to a Service Centre.

```
SELECT [Cost Matrix].Origin, Min([Cost Matrix].Distance) AS MinOfDistance
FROM [Cost Matrix]
GROUP BY [Cost Matrix].Origin;
```

Query 2 - Nearest Service Centre: Identifies the ID of the nearest Service Centre.

```
SELECT [Cost Matrix].Origin, [Cost Matrix].Destination, [Cost Matrix].Distance
FROM [MIN DIST] INNER JOIN [Cost Matrix] ON ([MIN DIST].MinOfDistance = [Cost Matrix].Distance)
AND ([MIN DIST].Origin = [Cost Matrix].Origin);
```

Query 3: Includes additional attribute information of both the SAL Centroid table and the Service Centres table. Attributes from the SAL centroid points include and ID field, the urban/rural typology type, total population and the distance to the nearest Service Centre. Attributes from the Service Centre table include an ID field of the nearest Service Centre, a town name and the Service Centre type to distinguish between Thusong Service Centres and Thusong Service Clusters.

```
SELECT [SAL Centroid].ID, [SAL Centroid].AG_ID, [SAL Centroid].Typology, [SAL Centroid].Population, [Query 2 - Nearest Service Centre].Distance, [Service Centres].ID, [Service Centres].AG_ID, [Service Centres].TOWN, [Service Centres].[SERVICE CENTRE]

FROM ([SAL Centroid] INNER JOIN [Query 2 - Nearest Service Centre] ON [SAL Centroid].ID = [Query 2 - Nearest Service Centre].Origin) INNER JOIN [Service Centres] ON [Query 2 - Nearest Service Centre].Destination = [Service Centres].ID;
```

Query 3
*
SAL Centroid.ID
SAL Centroid.AG_ID
Typology
Population
Distance
Service Centres.ID
Service Centres.AG_ID
TOWN
SERVICE CENTRE

Results from Query 3 enables geographic accessibility calculation on different travel distance threshold. For the purpose of this research, urban and rural areas were compared within the following travel distance thresholds: 10 km, 15 km, 20 km and 25 km.

Query 4 (see example below) identifies the number of people in urban and rural areas that live within 15 km from their nearest Service Centre. This query was repeated for all the different travel distance thresholds to compare the level of accessibility within each threshold.

```
SELECT [Query 3].Typology, Sum([Query 3].Population) AS SumOfPopulation

FROM [Query 3]

WHERE ((([Query 3].Distance)<=15))

GROUP BY [Query 3].Typology;
```

Results from the cost matrix includes two additional fields in the SAL centroid layer; a distance field, indicating the shortest distance to a Service Centre and an ID field that is populated with the unique ID of the nearest Service Centre.

3.4 STEP 3 – LOCATION ANALYSIS TO OPTIMISE THE PROVISIONING OF SERVICE CENTRES

Step 3 describes the location analysis process that was followed to identify the optimum number and location of additional Service Centres. These additional locations were identified to meet the unserved population demand and to increase the level of accessibility in rural areas to a similar level that currently exists in urban areas (based on the maximum travel distance thresholds identified for both urban and rural areas). In this research, location analysis to identify the optimal number and location of Service Centres accepts the current location of Thusong Service Centres and Thusong Service Clusters (brownfields approach), while determining the minimum number of additional locations that would be required to increase accessibility to a set percentage of population coverage.

Since this analysis is a desktop exercise that utilises the data analysis capabilities of GIS, the optimal locations identified in the study refer to generalised areas and not exact places. The following section describes the methods that were applied to identify optimal locations for the establishment of additional Thusong Service Centres.

3.4.1 IDENTIFY OPTIMAL LOCATIONS

As this study adopted a brownfields approach, optimal locations were identified to improve accessibility of people situated in predominantly rural areas.

These locations were identified through GIS processes that include Density Mapping and *Facility Location* procedures in TransCAD. The goal of the Facility Location procedure was to identify locations that will minimise the average cost of service. Cost of service refers to the travel distance between population and Service Centres. An example of the facility location procedure in TransCAD is shown in *Figure 22*. The average cost (distance) was set to 20 km.

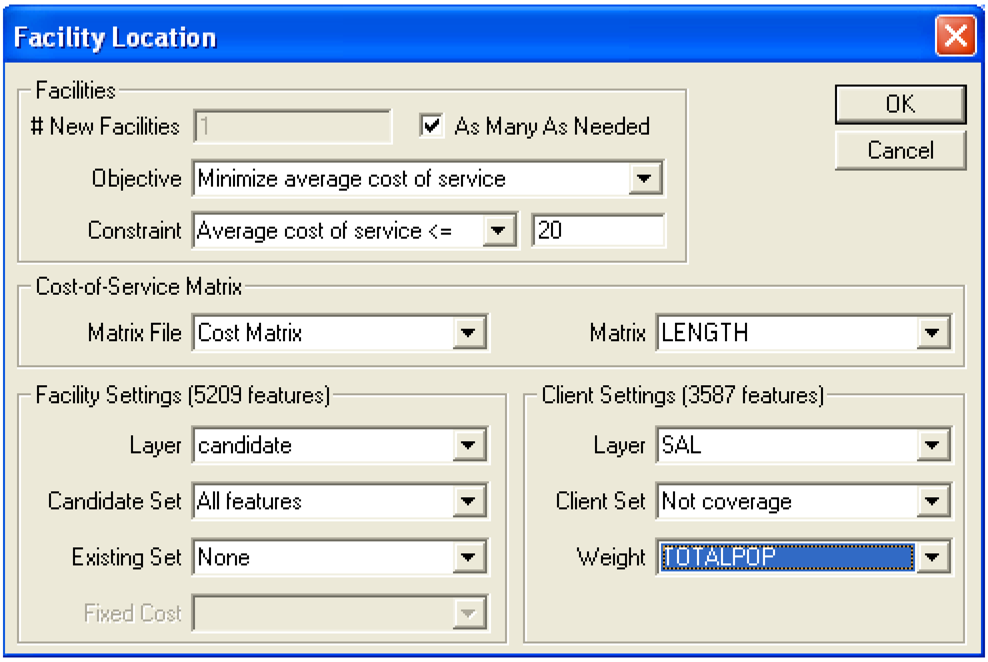


Figure 22: Facility Location model

The Facility Location model includes the following input layers:

- A candidate layer (or list of possible locations for Service Centres)
- A client layer (SAL centroids with population counts),
- A cost matrix containing the travel distance between all the client and candidate locations.

The candidate layer is a subset of the SAL centroid layer that excludes sparsely populated areas. Population count per SAL centroid point served as a weighting factor in order to prioritise areas with excessive population demand.

Optimal locations derived from the facility location procedure were saved into a separate geographic layer consisting of coordinate information (latitude and longitude values) and a unique identifier (AG_ID) that corresponds with the ID fields of the original candidate layer. Future analysis could include a Greenfields approach where optimal locations are identified for the entire province regardless of the current footprint of Thusong Service Centres or Clusters. A comparison between current and optimal locations could be significant to validate current locations against optimal locations.

3.4.2 RANKING OF OPTIMAL LOCATIONS

The next objective was to select the least number of optimal locations that will improve accessibility and increase population coverage in rural areas to an acceptable percentage coverage. This was done by ranking optimal locations based on their respective catchment population. The catchment population was calculated by assigning population to their nearest optimal location. People that already have access to existing Service Centres (within the maximum travel distance thresholds for urban and rural areas) were excluded. People that are situated close to multiple locations were allocated to the nearest one. The following steps describe the ranking process:

Firstly, a full cost matrix that calculates the distance between all the SAL centroid points and optimal locations was created. The resulting table includes an origin ID (SAL centroid unique identifier), a destination ID (unique identifier for proposed optimal locations) and a distance field (measured in kilometres) that displays the travel distance between each origin and destination location. Since the resulting table has the potential to be gigantic, records with a distance measurement above 50 km were excluded. Secondly, all the SAL centroid points that already have access to existing Service Centres within the maximum allowed travel distance were excluded from the results table, providing a smaller table of SAL centroid points.

Thirdly, population from the SAL centroid layer were assigned and aggregated to their nearest optimal location (based on travel distance results from the cost matrix), providing a list of all the optimal locations with their respective catchment population.

The least number of optimal locations that could increase the level of accessibility to a set population coverage percentage were added to the current mix of Thusong Service Centres and Thusong Service Clusters.

These optimal locations were subsequently analysed based on their proximity to current key departments used in this research (Department of Labour, the Department of Home Affairs, SAPS and SASSA). The number of key departments in close proximity to these locations will influence recommendations regarding the proposed facility type. If services of at least two key departments are offered close to optimal locations, the expansion of services to create a Thusong Service Cluster would be more cost effective than to establish a new, fully functional Thusong Service Centre.

3.4.3 POTENTIAL LEVEL OF ACCESSIBILITY

Finally, a new cost new matrix was created to calculate the travel distance between all SAL centroids and Service Centres (these include the current footprint of Thusong Service Centres and Service Centre Clusters, as well as the selected optimal locations). This was done to measure and compare the improved level of accessibility for Limpopo province confirming that the inclusion of optimal locations would improve accessibility in rural areas to the set percentage coverage target.

The catchment population of Service Centres (Thusong Service Centres, Clusters and optimal locations) was also determined to identify population demand at each centre.

4. FINDINGS IN RELATION TO THE CURRENT ACCESSIBILITY OF THUSONG SERVICE CENTRES AND CLUSTERS

4.1 INTRODUCTION

Chapter 4 provides details on the current level of geographic accessibility in relation to Thusong Service Centres and Clusters in Limpopo province. These results are analysed and compared within urban and rural settlement types. The chapter focuses on the following core objectives:

1. Population distribution within urban and rural settlement typology types.
2. Current location of Thusong Service Centres and Thusong Service Clusters.
3. Analysis of the current level of geographic accessibility within urban and rural settlements (research questions 3 and 4).

Results are analysed in relation to the research statement (or hypothesis) arguing that access to Thusong Service Centres is uneven across different settlement typologies. People in rural areas need to travel significantly further to Service Centres compared to those living in urbanised areas.

4.2 POPULATION DISTRIBUTION

The national SAL that was used to represent populated areas in the province consists of 84 907 polygons (areas) with an average area size of 13.5 km^2. Limpopo province comprise 9 882 polygons (or 11.6% of the total number of polygons in the country). The average area size is 11 km^2. Forty-two (42) of these polygons exceeded 500 km^2 and were subsequently divided into smaller EAs to provide more accurate travel distance calculations. As an example, the SAL polygon (9780077) in the rural areas of Lephalale consisting of 503 people was divided into nine smaller EAs. Seven SAL polygons in the province that are larger than 500 km^2 consist of only one EA, hence these polygons could not be subdivided. Additional EAs increased the total number of polygons in the province from 9 882 to 9 980 (a total increase of 98 polygons) affecting only 15 000 people in the province.

Settlement Typology

Based on the settlement typology types that were derived from the AfriGIS town boundaries, Limpopo province consists of 31 urban towns that are distributed across the province with rural areas in between. From the 5.4 million people in the province (Statistics South Africa 2012a), close to 4.3 million (or 79.2%) people reside in rural areas. The remaining 20.80% of the population live in urban areas. Thohoyandou, Polokwane, Phalaborwa, Mokopane, Bela-Bela, Lephalale, Musina and Modimolle are some of the urban areas situated in Limpopo province. *Figure 23* highlights urban and rural areas in the province.

The number of rural population (79.2%) is slightly lower compared to 82.1% derived from the Census 2011 Community Profiles in SuperCROSS. See Chapter 2.

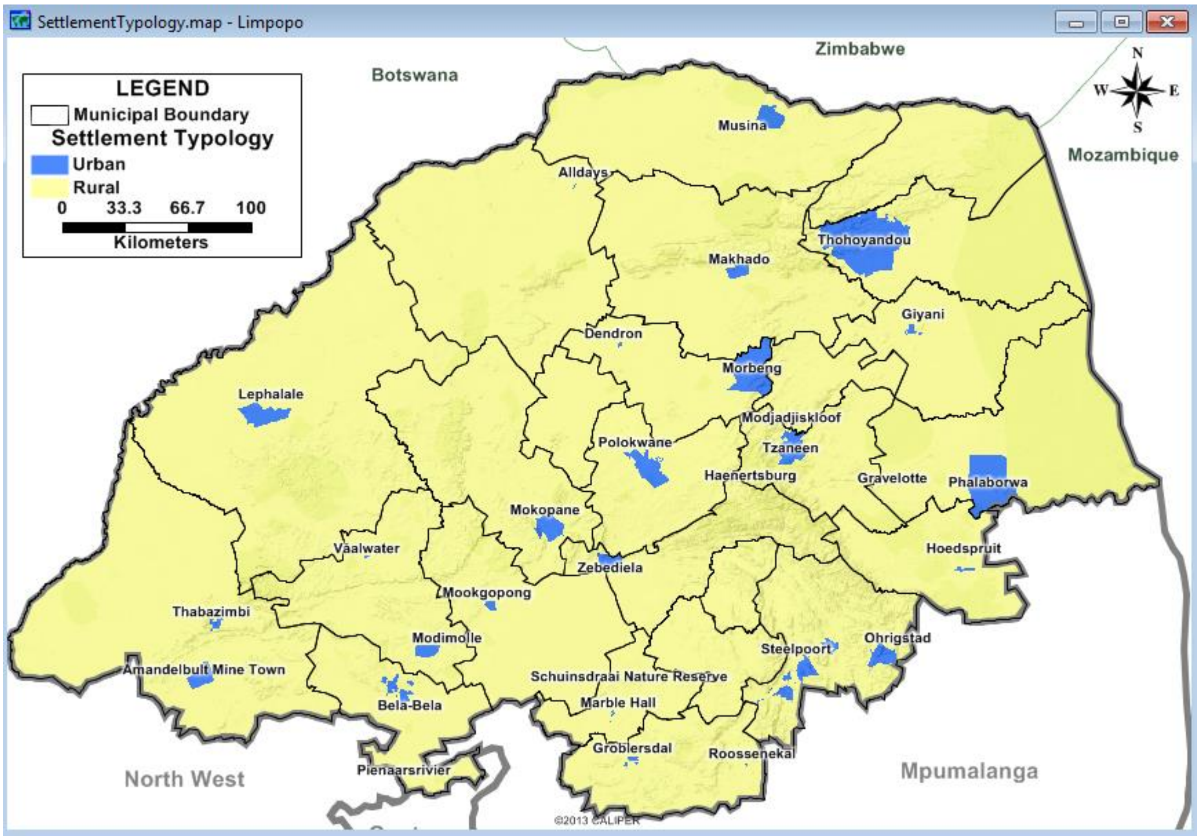


Figure 23: Urban and rural areas in Limpopo province

The following map (*Figure 24*) depicts the distribution of people across the province based on a kernel density grid. Additional applications for kernel density modelling are also described by Mathison et al. (2013), Okabe, Satoh and Sugihara (2009) and Yao, Murray and Agadjanian (2013).

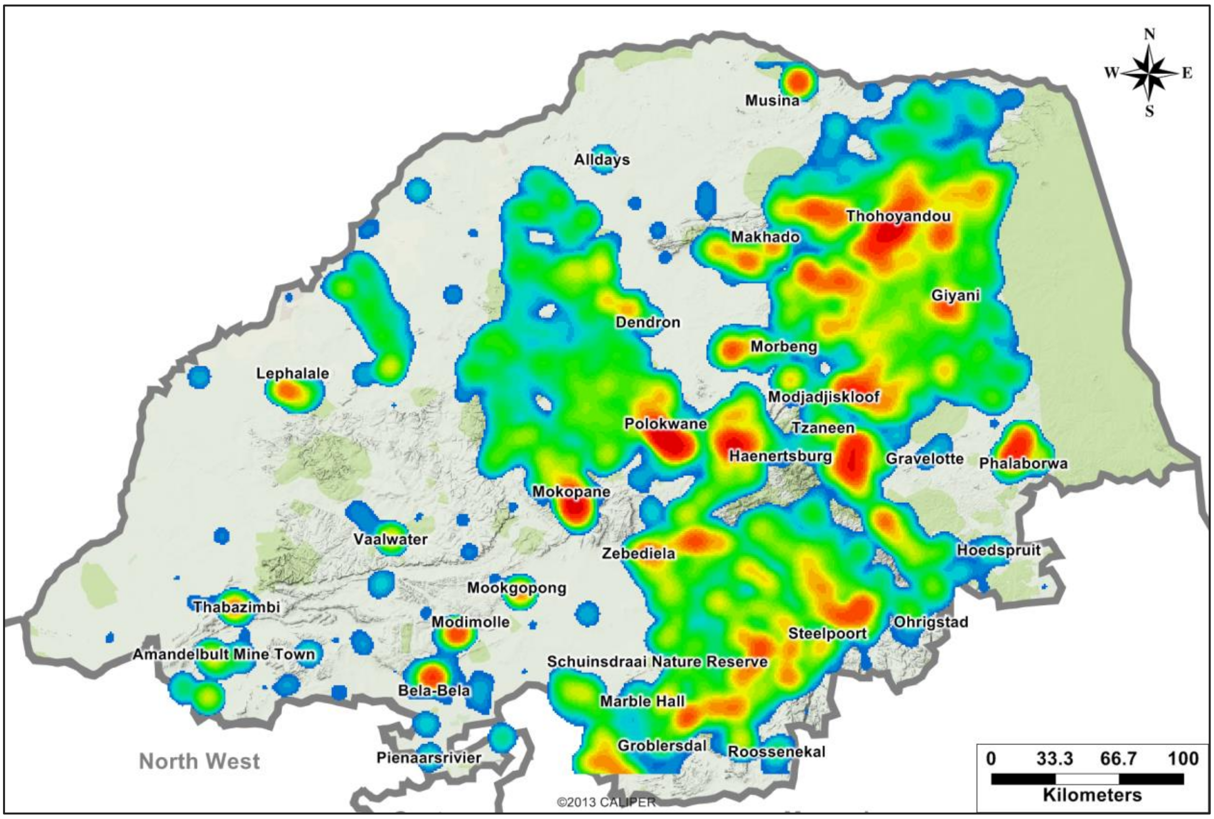


Figure 24: Population distribution based on a kernel density model

4.3 CURRENT LOCATION OF THUSONG SERVICE CENTRES AND THUSONG SERVICE CLUSTERS

Forty-one (41) Service Centres were identified in Limpopo province. These include 22 Thusong Service Centres and 19 Thusong Service Clusters. Greater Tzaneen Local Municipality has the highest number of Service Centres in the province consisting of four Thusong Service Centres and two Thusong Service Clusters. Greater Tubatse Local Municipality, Mogalakwena Local Municipality, Polokwane Local Municipality and Thulamela Local Municipality are ranked second with three Service Centres respectively. Two municipalities (Aganang Local Municipality and Ephraim Mogale Local Municipality) have no Service Centres.

The 19 Thusong Service Clusters in Limpopo province consist of services from multiple government facilities. These include 18 facilities of Department of Home Affairs, 11 of Department of Labour, 18 of SAPS and 17 facilities from SASSA.

Most Thusong Service Clusters are located in town centres. This occurrence is part of the legacy of previous town planning initiatives. All the Thusong Service Centres are situated in rural areas corresponding to the initial objective of the Thusong Service Centre programme to provide services in rural communities (GCIS n.d.-b).

Twelve (12) Thusong Service Centres and eight Thusong Service Clusters in adjacent provinces were also identified that could impact the level of accessibility in the province. Hence these Service Centres were included in the distance analysis. See *Figure 25*.

4.4 ACCESSIBILITY CURRENTLY PROVIDED BY THUSONG SERVICE CENTRES AND THUSONG SERVICE CLUSTERS

This section answers research questions 3 and 4 by comparing the current level of accessibility between urban and rural areas, based on the following three measures: Firstly, the average travel distance to a nearest Service Centre is compared between urban and rural areas, the second measure includes a travel distance comparison within various travel distance bands and thirdly, accessibility in urban and rural areas is compared based on different maximum travel distance thresholds.

4.4.1 AVERAGE TRAVEL DISTANCE COMPARISON

Based on results from this research, the average distance that people travel to their nearest Service Centre in Limpopo province is 19.2 km. This calculation is based on the consideration that people will travel to their nearest Service Centre. People in rural areas travel on average 21.7 km compared to only 9.9 km for those living in urban areas. This implies that the average travel distance in rural areas is more than double compared to urban areas. The map in *Figure 25* displays the geographic location of Thusong Service Centres and Thusong Service Clusters that are within and adjacent to Limpopo province. Travel distances to the nearest Service Centre are divided into 5 km intervals.

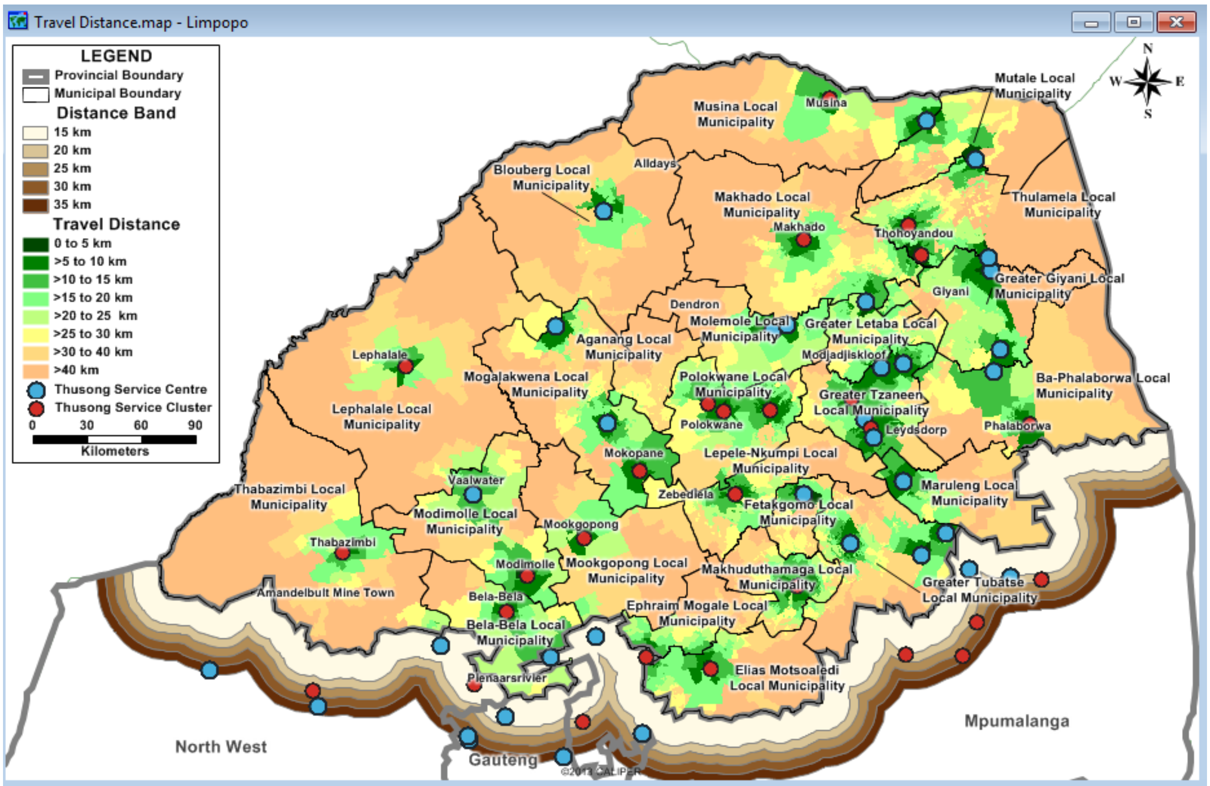


Figure 25: Geographic location of Thusong Service Centres and Thusong Service Clusters

4.4.2 COMPARISON WITHIN DIFFERENT TRAVEL DISTANCE BANDS

Results from this measurement indicate that the majority of people in **urban** areas (439 320 people) travel less than 5 km to a Service Centre. Only 14 851 need to travel further than 40 km. See *Table 7*. Results for **rural** areas are significantly different. The majority of people (629 511) travel between 15 and 20 km to a Service Centre. The 20 to 25 km travel band is second highest, with 568 922 people. 428 156 People need to travel more than 40 km to a Service Centre compared to only 14 851 that are living in urban areas. *Table 7* shows the number of people per travel distance band for both urban and rural areas.

Table 7: Urban and rural comparison per travel distance band

Settlement Typology	0-5 km	>5-10 km	>10-15 km	>15-20 km	>20-25 km	>25-30 km	>30-40 km	>40 km	Total
Urban	439 320	292 578	121 314	129 069	54 330	50 724	21 306	14 851	1 123 492
Rural	479 571	542 303	542 405	629 511	568 922	537 011	552 652	428 156	4 280 531
Total	**918 891**	**834 881**	**663 719**	**758 580**	**623 252**	**587 735**	**573 958**	**443 007**	**5 404 023**

The following graph in *Figure 26* shows a regression analysis for both urban and rural areas within the different travel distance bands. The purpose of this comparison is to explore the overall relationship between different variables (Montgomery, Peck & Vining 2006). These variables include the number of people and the distance that they travel to their nearest Service Centre. The correlation between travel distance and the number of people in urban areas are best represented by an exponential trendline (regression line) where the R-Squared value is 0.97, indicating a close to 100% fit. This means that there is a very strong correlation between the volume of people and the distance they travel to a Service Centre. The number of people that travel less than 5 km is high and then reduces gradually as the travel distance to a Service Centre increases.

Rural areas on the other hand display a vastly different pattern. The correlation between travel distance and number of people are best represented by a polynomial trendline (regression line) where the R-Squared value is 0.79.

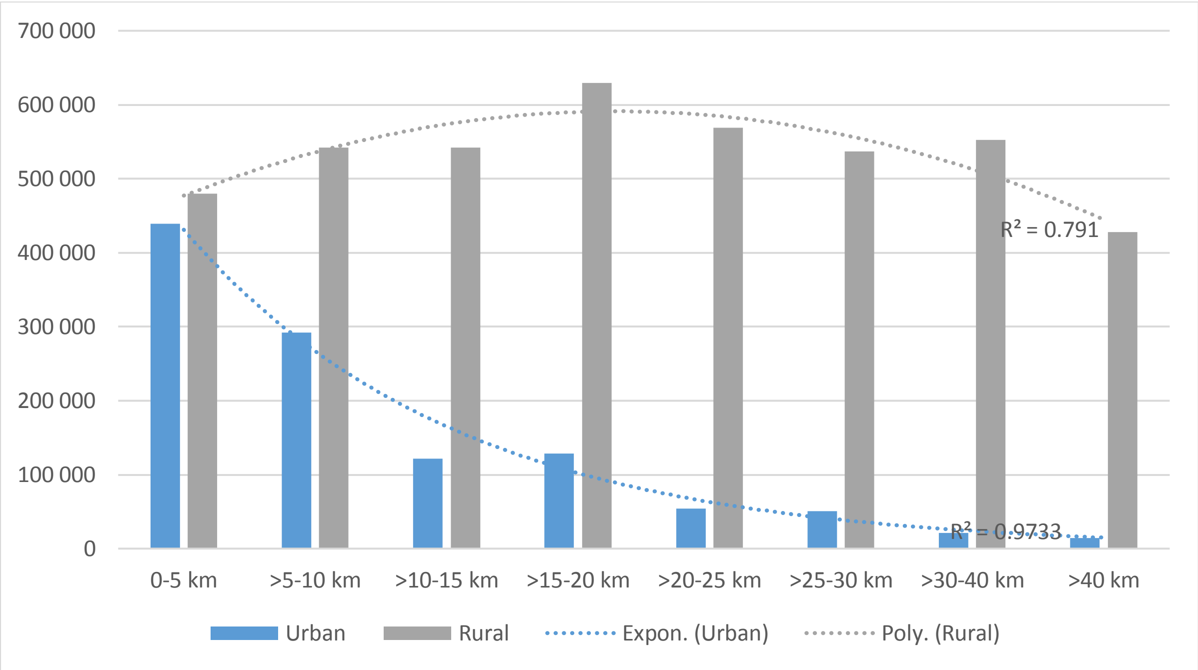


Figure 26: Urban and rural regression analysis

Population increases gradually as the travel distance to a Service Centre increases and peak at 15 – 20 km. The number of people decreases after 20 – 25 km with a spike at 30 – 40 km. These results indicate that different accessibility patterns exist between urban and rural areas.

4.4.3 COMPARISON BASED ON DIFFERENT TRAVEL DISTANCE THRESHOLDS

The following tables highlight levels of accessibility currently provided by Thusong Service Centres and Thusong Service Clusters, in both urban and rural areas, based on different travel distance thresholds. These thresholds include 10 km, 15 km, 20 km and 25 km.

The first table (*Table 8*) displays results for urban areas only. These results show that 65.14% (or 731 898 of the population) live within 10 km from a Thusong Service Centre or Cluster. This figure increases to 92.27% if the maximum travel distance is increased to 25 km, implying that only 86 881 will not have adequate access to a Service Centre.

Table 8: Population coverage in urban areas

URBAN AREAS				
Urban Population	Less than 10 km	Less than 15 km	Less than 20 km	Less than 25 km
Population Covered	731 898	853 212	982 281	1 036 611
Not Covered	391 594	270 280	141 211	86 881
Total Population	1 123 492	1 123 492	1 123 492	1 123 492
Percentage Coverage	**65.14%**	**75.94%**	**87.43%**	**92.27%**

Only 23.87% of the people that live in rural areas currently have access to a Service Centre within 10 km. Sixty-four point five four percent (64.54%) have adequate access within 25 km. See *Table 9*.

Table 9: Population coverage in rural areas

RURAL AREAS				
Rural Population	Less than 10 km	Less than 15 km	Less than 20 km	Less than 25 km
Population Covered	1 021 874	1 564 279	2 193 790	2 762 712
Not Covered	3 258 657	2 716 252	2 086 741	1 517 819
Total Population	4 280 531	4 280 531	4 280 531	4 280 531
Percentage Coverage	**23.87%**	**36.54%**	**51.25%**	**64.54%**

The following figures (*Figure 27* to *Figure 30*) provide a geographic view of areas that are covered by Thusong Service Centres and Thusong Service Clusters within 25 km, 20 km, 15 km and 10 km travel distance thresholds.

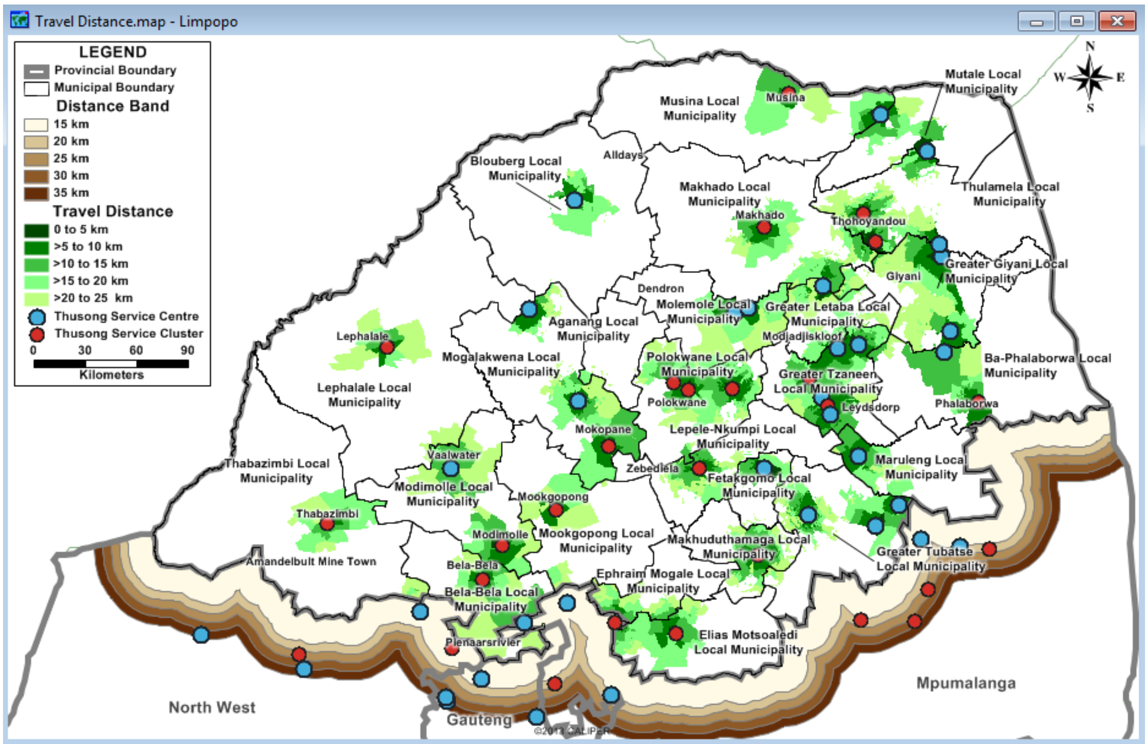


Figure 27: Population coverage within 25 km to a nearest Service Centre

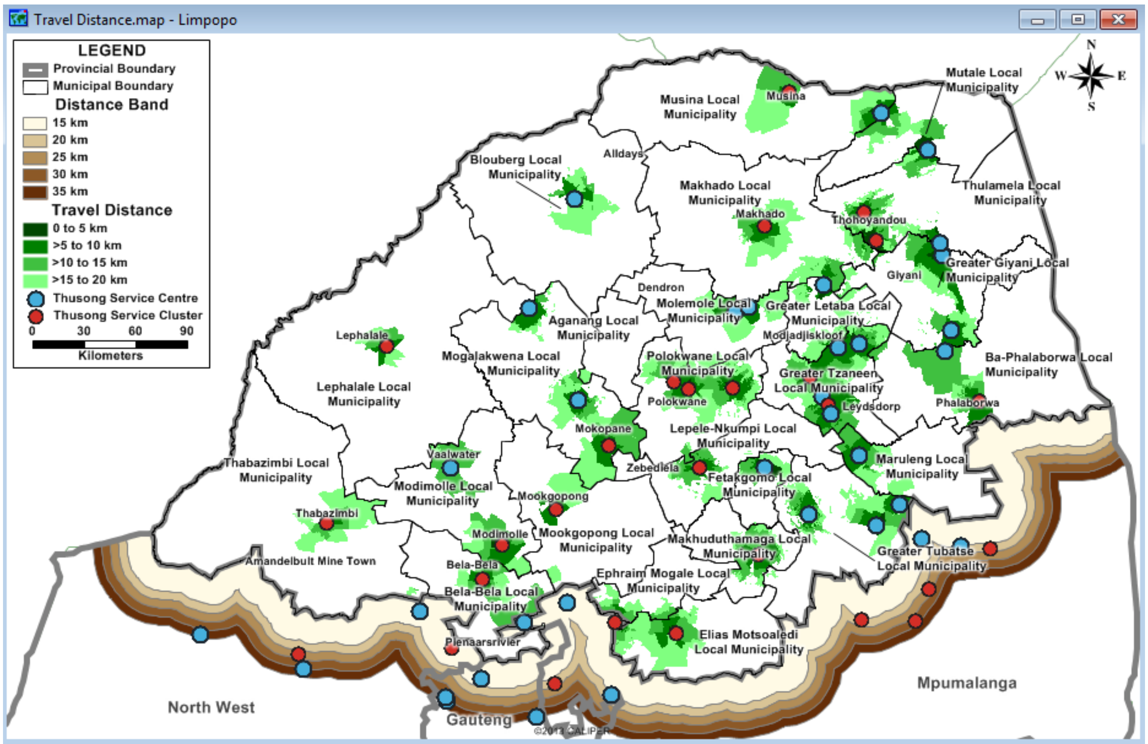


Figure 28: Population coverage within 20 km to a nearest Service Centre

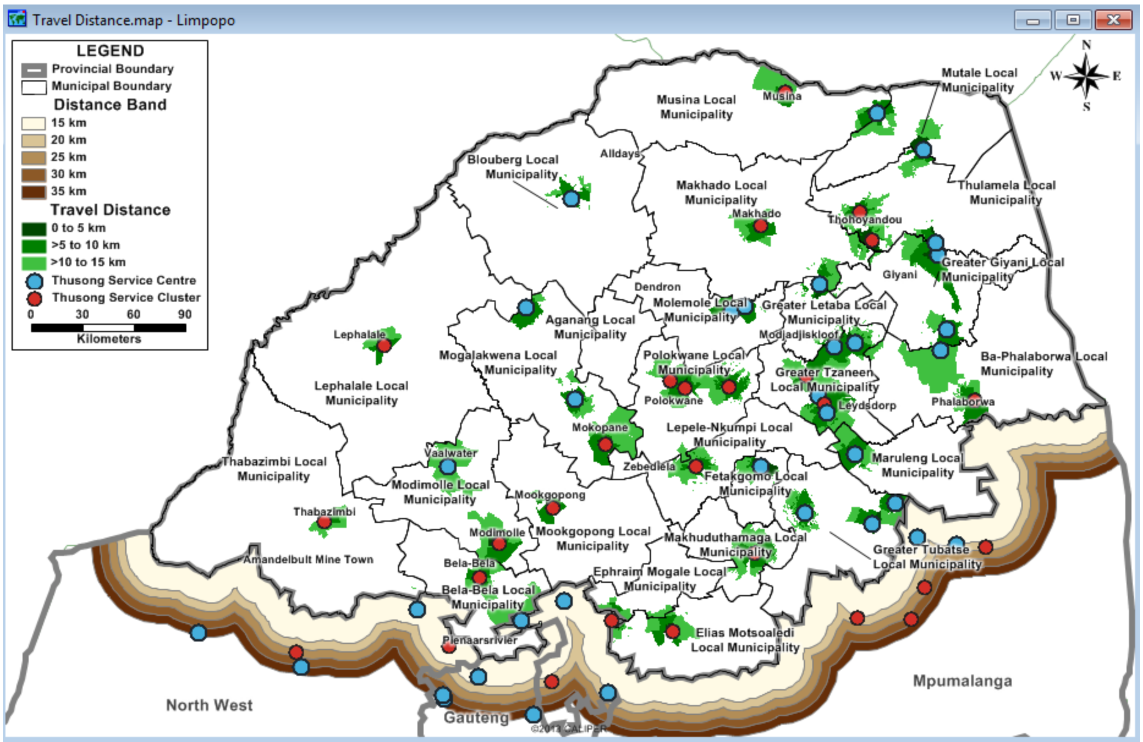


Figure 29: Population coverage within 15 km to a nearest Service Centre

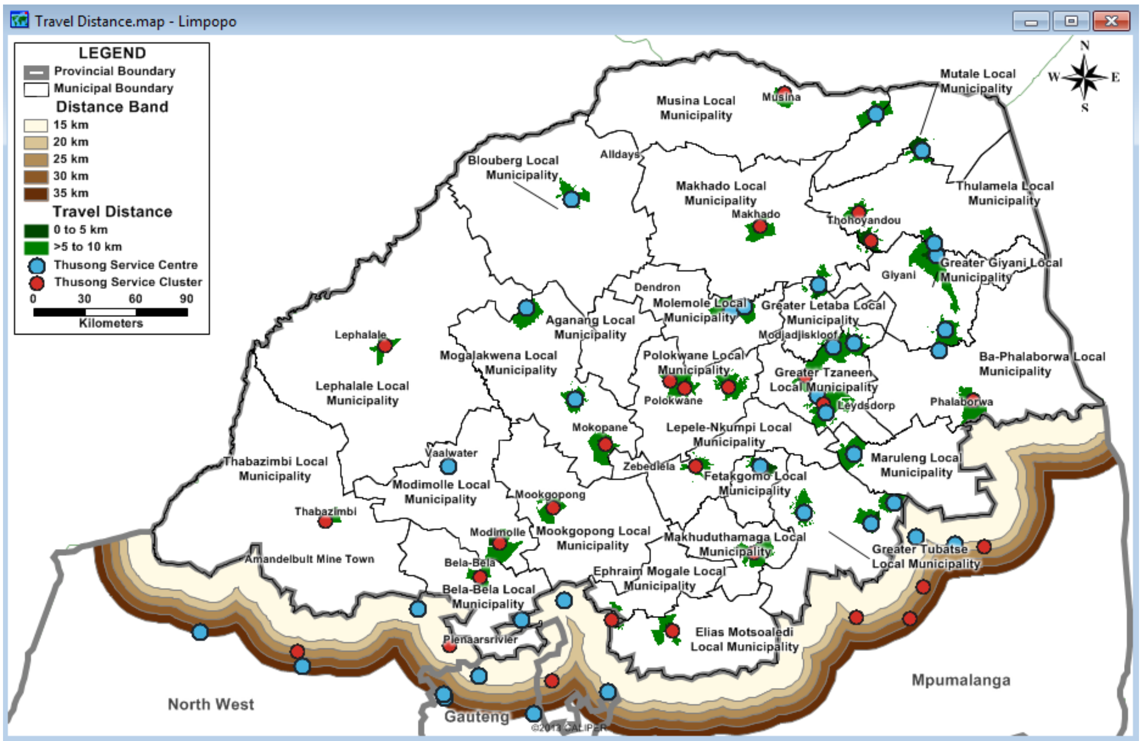


Figure 30: Population coverage within 10 km to a nearest Service Centre

4.4.4 SUMMARY OF FINDINGS

Based on results of the current level of accessibility in Limpopo province, geographic access to Thusong Service Centres and Clusters is uneven across the province and additional Service Centres will be required to increase accessibility in rural areas.

By looking at Limpopo province in general, 3 615 924 people (or 66.9%) currently have access to a Thusong Service Centre or Cluster based on the 15 and 25 km travel distance thresholds for urban and rural areas. The remaining 1 788 099 or 33.1% of the people in the province are not covered.

The CSIR guidelines for the provision of social facilities in South African settlements, (discussed in chapter 2), recommend 15 km access distance to a Thusong Service Centre or Cluster, with a maximum distance of 25 km for peri-urban or rural areas (Green & Argue 2012). By adopting similar travel distance thresholds for this research; 75.94% of the population living in urban areas has access to Thusong Service Centres and Thusong Service Clusters within 15 km. Only 64.54% of the rural population will have access to a Service Centre within the 25 km threshold.

Based on these results, accessibility between urban and rural areas differs by 11.4%. This implies that in order to increase accessibility in rural areas to a similar level that currently exists in urban areas (based on the 15 and 25 km thresholds), additional Service Centres are required. These additional Service Centres should provide access to approximately 450 000 people in rural areas that currently live further than 25 km from their nearest Service Centre. The number of people required to increase accessibility in rural areas from 64.54% to 75% can be calculated based on the following equation:

Inputs

p = Number of rural population that currently have coverage

z = Current percentage coverage in rural population

y = Difference between the current and target coverage

$$x = \left(\frac{p}{z}\right) \times y$$

$$x = \left(\frac{2\ 762\ 712}{64.54\%}\right) \times 10.46\%$$

$$x = 447\ 686.25$$

The map in *Figure 31* displays areas in Limpopo province that are currently covered by Thusong Service Centres and Clusters within the defined maximum travel distance thresholds used for urban and rural areas.

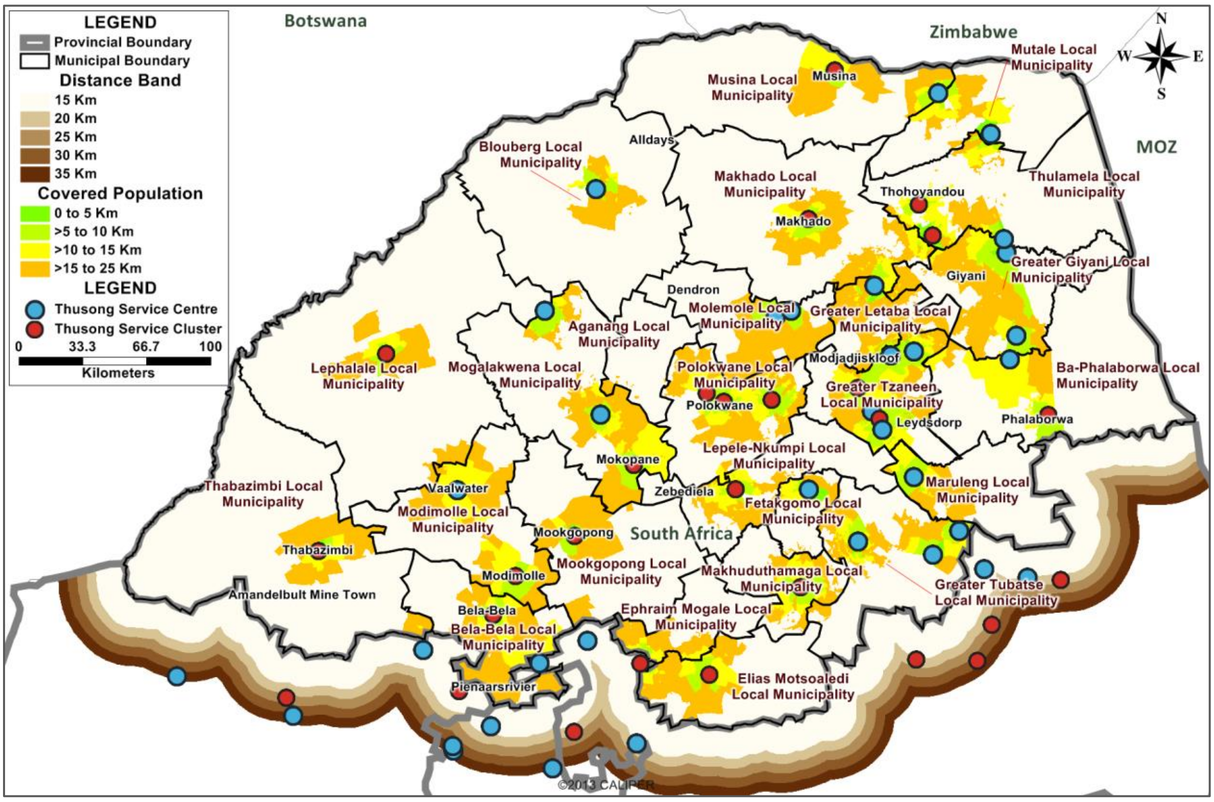


Figure 31: Current level of accessibility in Limpopo province based on the defined travel distance thresholds for urban and rural areas

Table 10 highlights the number of Service Centres, as well as the current level of accessibility in each local municipality within urban and rural areas respectively. The level of accessibility is represented as a percentage of population coverage.

Accessibility is worse in Makhado Local Municipality where close to 240 000 people rural areas are not covered by Service Centres. Thulamela Local Municipality is ranked second with 133 000 people that are not covered. Blouberg Local Municipality is ranked third, followed by Aganang Local Municipality.

Two Municipalities, Aganang Local Municipality and Ephraim Mogale Local Municipality have no Service Centres within their boundaries.

Local Municipality	Code	Number of Service Centres	Urban				Rural			
			Total Population	Population Covered within 15 km	% Coverage	Not Covered	Total Population	Population Covered within 25 km	% Coverage	Not Covered
Greater Giyani Local Municipality	LIM331	2	28 417		0.00%	28 417	215 772	137 845	63.88%	77 927
Greater Letaba Local Municipality	LIM332	1	1 815		0.00%	1 815	210 854	175 238	83.11%	35 616
Greater Tzaneen Local Municipality	LIM333	6	19 061	19 061	100.00%		371 010	364 507	98.25%	6 503
Ba-Phalaborwa Local Municipality	LIM334	2	132 980	63 780	47.96%	69 200	17 634	11 705	66.38%	5 929
Maruleng Local Municipality	LIM335	1	2 846		0.00%	2 846	91 994	78 119	84.92%	13 875
Musina Local Municipality	LIM341	2	42 681	42 681	100.00%		25 678	9 735	37.91%	15 943
Mutale Local Municipality	LIM342	1					91 810	32 474	35.37%	59 336
Thulamela Local Municipality	LIM343	3	299 893	194 456	64.84%	105 437	318 439	185 043	58.11%	133 396
Makhado Local Municipality	LIM344	1	25 350	25 350	100.00%		490 604	251 649	51.29%	238 955
Blouberg Local Municipality	LIM351	1	2 988		0.00%	2 988	159 627	39 174	24.54%	120 453
Aganang Local Municipality	LIM352	0					131 131	11 628	8.87%	119 503
Molemole Local Municipality	LIM353	2	9 902	3 036	30.66%	6 866	98 400	65 762	66.83%	32 638
Polokwane Local Municipality	LIM354	3	215 996	215 996	100.00%		412 856	378 473	91.67%	34 383
Lepele-Nkumpi Local Municipality	LIM355	1	864		0.00%	864	229 460	160 441	69.92%	69 019
Thabazimbi Local Municipality	LIM361	1	36 022	27 783	77.13%	8 239	49 203	4 327	8.79%	44 876
Lephalale Local Municipality	LIM362	1	44 056	18 958	43.03%	25 098	71 701	3 006	4.19%	68 695
Mookgopong Local Municipality	LIM364	1	20 031	20 031	100.00%		15 607	8 070	51.71%	7 537
Modimolle Local Municipality	LIM365	2	54 921	54 921	100.00%		13 587	9 732	71.63%	3 855
Bela-Bela Local Municipality	LIM366	1	45 701	44 998	98.46%	703	20 773	14 151	68.12%	6 622
Mogalakwena Local Municipality	LIM367	3	118 051	118 051	100.00%		189 613	141 068	74.40%	48 545
Ephraim Mogale Local Municipality	LIM471	0	1 700		0.00%	1 700	121 921	58 060	47.62%	63 861
Elias Motsoaledi Local Municipality	LIM472	1	6 431	4 110	63.91%	2 321	242 912	124 157	51.11%	118 755
Makhuduthamaga Local Municipality	LIM473	1					274 308	210 393	76.70%	63 915
Fetakgomo Local Municipality	LIM474	1					93 771	50 142	53.47%	43 629
Greater Tubatse Local Municipality	LIM475	3	13 786		0.00%	13 786	321 866	237 846	73.90%	84 020
Total		**41**	**1 123 492**	**853 212**	**75.94%**	**270 280**	**4 280 531**	**2 762 745**	**64.54%**	**1 517 786**

Table 10: Overview of Thusong Service Centres and Cluster per local municipality

5. OPTIMUM PROVISIONING AND LOCATION OF THUSONG SERVICE CENTRES

5.1 INTRODUCTION

Chapter 5 provides a critical analysis of the optimal locations that were identified for the establishment of additional Thusong Service Centres or Clusters to improve accessibility in the province (research question 5). The chapter also compares results from various facility location models that were tested and evaluated in this research to find the least number of optimal locations that would maximise accessibility in rural areas.

5.2 FACILITY LOCATION RESULTS

Various facility location iterations were tested in this research to identify the least number of additional locations that could improve the level of accessibility in rural areas. These iterations include different sets of candidate (possible) locations, as well as different cost of service constraints. Total population per SAL centroid (depicting population demand) was also added as a weighting factor in each iteration.

At first, all the derived SAL centroid points were considered as candidate (possible) locations for Thusong Service Centres. These comprise 9 980 points across the province. SAL centroid points with low population counts were eventually removed from the list of candidate locations, allowing better facility location results. The final set of candidate locations that were used in the facility location model consists of 5 207 SAL centroid points, each with a population density above 1 000.

Based on the reduced number of candidate locations, facility location models were tested with two different constraints to minimise the average cost of service. These constraints were selected based on the maximum travel distance threshold of 25 km that was set for rural areas in this research.

The first cost of service constraint was set to 25 km, resulting in 15 optimal locations across the province. Each location was subsequently ranked based on their potential catchment population. The catchment population consists of people that are not currently covered by existing Service Centres and who are situated within the catchment area of each proposed location. Given the overall objective to identify the least number of proposed locations that will cover approximately 450 000 unserved population from predominantly rural areas to achieve 75% coverage, only five of these locations were required to meet the objective.

A second facility location model was tested with a 20 km cost of service constraint. Results from this model produced 21 proposed locations. Again, only five of these locations were required to meet the population coverage objective.

Although results from both models identified a minimum number of five optimal locations to increase accessibility in rural areas to the set percentage coverage, the geographic spread of these optimal locations differ slightly. Three of the five locations from both models are situated in similar areas, whereby the remaining two are situated at entirely different locations.

Figure 32 and *Figure 33* show the geographic spread of proposed optimal locations derived from both models. The top five locations are ranked and numbered based on their derived catchment population.

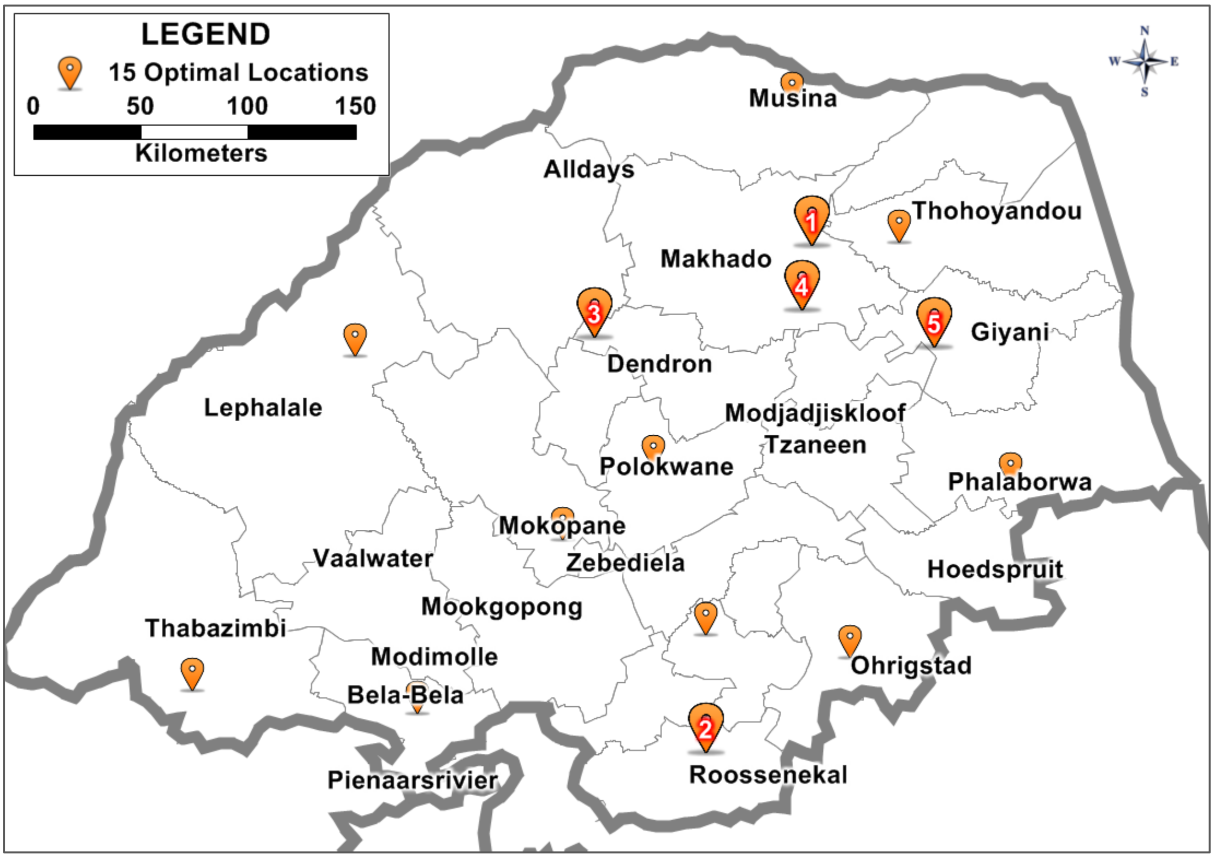


Figure 32: Optimal locations based on a 25 km cost of service constraint

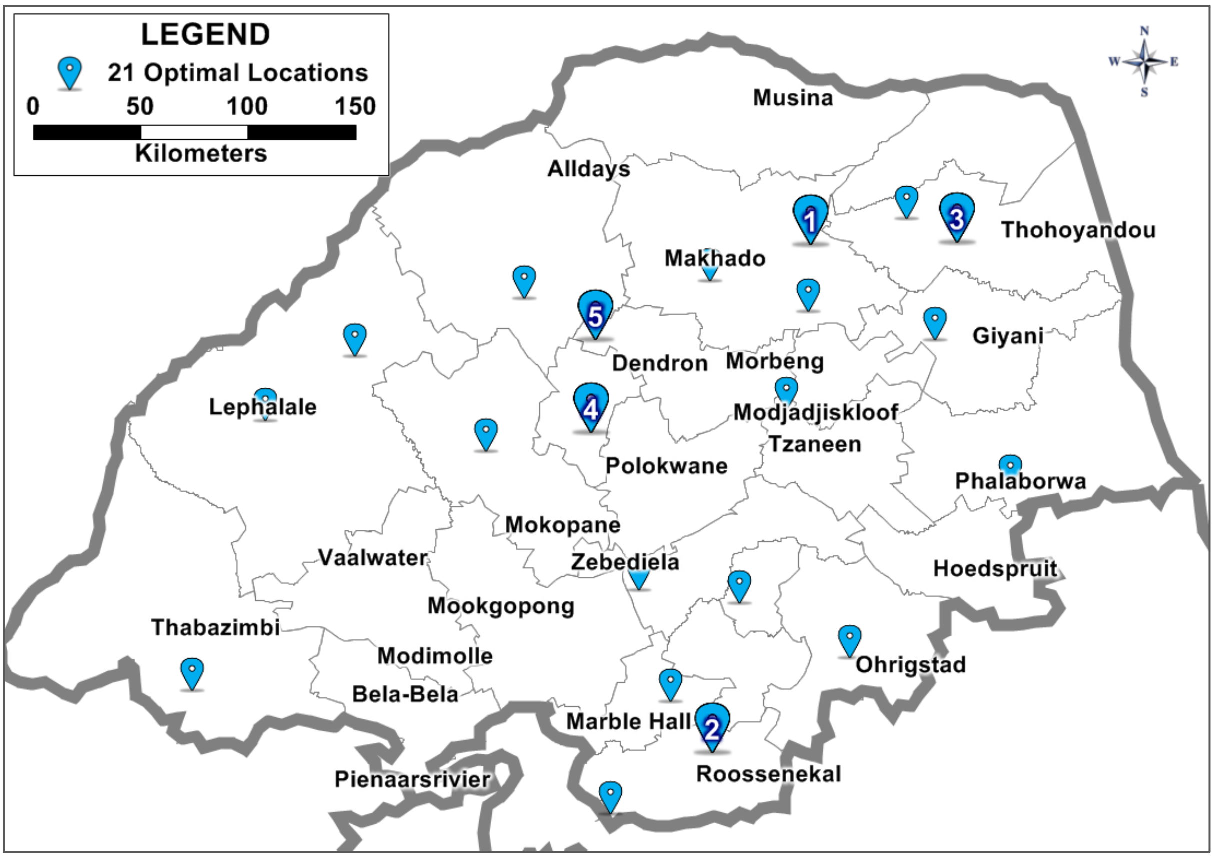


Figure 33: Optimal locations based on a 20 km cost of service constraint

The following section compares results from both models, and proposes a best-fit scenario for the optimal provisioning of Service Centres.

Optimal locations are compared based on their potential catchment population only (*Table 11*). The table shows the total catchment population per proposed optimal location derived from both models.

Table 11: Comparison of optimal locations based on a 25 and 20 kilometre cost of service constraint

Optimal locations based on the 25 km cost of service constraint				**Optimal locations based on the 20 km cost of service constraint**			
Rank	Catchment Population	Rural	Urban	Rank	Catchment Population	Rural	Urban
1	138 722	138 722		1	138 293	138 293	
2	114 972	114 972		2	100 984	100 984	
3	84 421	84 421		3	92 650	89 873	2 777
4	79 373	79 373		4	86 019	86 019	
5	92 496	64 079	28 417	5	84 721	84 721	
Total	**509 984**	**481 567**	**28 417**	**Total**	**502 667**	**499 890**	**2 777**
6	61 902	61 902		6	83 364	83 364	
7	49 587	49 587		7	92 496	64 079	28 417
8	47 048	40 676	6 372	8	62 633	62 633	
9	35 295	27 056	8 239	9	60 059	60 059	
10	59 018	16 461	42 557	10	49 587	49 587	
11	1 117	1 117		11	46 209	45 594	615
12	34 300	114	34 186	12	96 077	44 717	51 360
13	0	0	0	13	47 048	40 676	6 372
14	0	0	0	14	38 734	38 734	
15	0	0	0	15	34 151	34 151	
				16	28 511	28 511	
				17	35 295	27 056	8 239
				18	23 567	23 567	
				19	22 432	22 432	
				20	32 521	114	32 407
				21	25 098	0	25 098

The top five proposed locations from the 25 km cost of service constraint could potentially increase population coverage in the province by 509 984 people. This includes 481 567 people living in rural areas, and 28 417 people from urban areas.

The top five optimal locations derived from the 20 km cost of service constraint have the potential to cover 502 667 people. Although this figure is slightly less than the results from the first model, rural population will benefit most from this model where 499 890 people could gain access, compared to only 481 567 people in the first model.

Table 12 shows the recalculated figures of only the top five locations for both models. This was done to determine if the catchment population of these locations would change if the remaining locations were removed.

Table 12: Comparison of the top five optimal locations based on a 25 km and 20 km cost of service constraint

Top 5 optimal locations based on the 25 km cost of service constraint			
Rank	Catchment Population	Rural	Urban
1	138 722	138 722	
2	114 972	114 972	
3	84 421	84 421	
4	79 373	79 373	
5	92 496	64 079	28 417
Total	**509 984**	**481 567**	**28 417**

Top 5 optimal locations based on the 20 km cost of service constraint			
Rank	Catchment Population	Rural	Urban
1	138 293	138 293	
2	111 580	111 580	
3	92 650	89 873	2 777
4	86 019	86 019	
5	85 222	85 222	
Total	**513 764**	**510 987**	**2 777**

25 Km cost of service constraint

The catchment population of the top five locations derived from the first model, (25 km cost of service constraint), remained unchanged in both urban and rural areas, even if the remaining locations were excluded. Optimal locations that are ranked fourth, (situated just south of Makhado), and fifth, (situated close to Giyani), are unique to the 25 km constraint model and not proposed in the 20 km model. The optimal location south of Makhado, (ranked fourth), could only cover 79 373 people. Current services that are offered close to this location include those that are offered by SAPS.

Giyani (ranked fifth), could cover a total of 92 496 people, from which only 64 079 reside in rural areas. Current services include SAPS, Department of Labour and SASSA. Based on the methodology described in Chapter 3, these key departments are situated to far from one another to be considered as a Cluster.

20 Km cost of service constraint

Contrary to the first model, a catchment population increase was observed for the top five locations of the second model, (20 km constraint), when the remaining 16 locations were removed. The total catchment population increases from 502 667 to 513 764, a total increase of 8 320 people, residing in predominantly rural areas.

Conclusion

Since the top five proposed locations derived from the second model (20 km cost of service constraint) will cover a higher number of unserved population compared to the first model, these locations were selected as the final set of optimal locations to improve accessibility in rural areas to the set percentage coverage of 75%.

Although both locations, ranked fourth and fifth from the first model, are relevant and could increase the level of coverage significantly, for the purpose of this research they were excluded based on their catchment population (specifically in rural areas) that were less than those identified in the second model.

Lastly, the final set of optimal locations were analysed in relation to the level of road infrastructure, as well as the presence of current key departments that are in close proximity to these locations. If a proposed optimal location was in proximity to an existing key department, the location of the key department was used as the optimal location. The number of key departments in close proximity to these locations will influence recommendations regarding the proposed facility type. If services of at least two key departments are offered close by, the expansion of services to create a Thusong Service Cluster (described in Chapter 3) would be more cost effective than to establish a fully functional Thusong Service Centre.

5.3 IMPROVED ACCESSIBILITY RESULTS BASED ON THE CURRENT LOCATION OF THUSONG SERVICE CENTRES AND THUSONG SERVICE CLUSTERS INCLUDING THE FIVE OPTIMAL LOCATIONS

The provisioning of services at these five optimal locations would increase the total number of Thusong Service Centres (including Clusters) in Limpopo province from 41 to 46. *Figure 34* provides a geographic view of the five proposed optimal locations; these are situated in densely populated rural areas of the province. Very steep terrain in the north of the province and the scattered distribution of some densely populated settlements made it difficult to identify optimal locations for additional Service Centres.

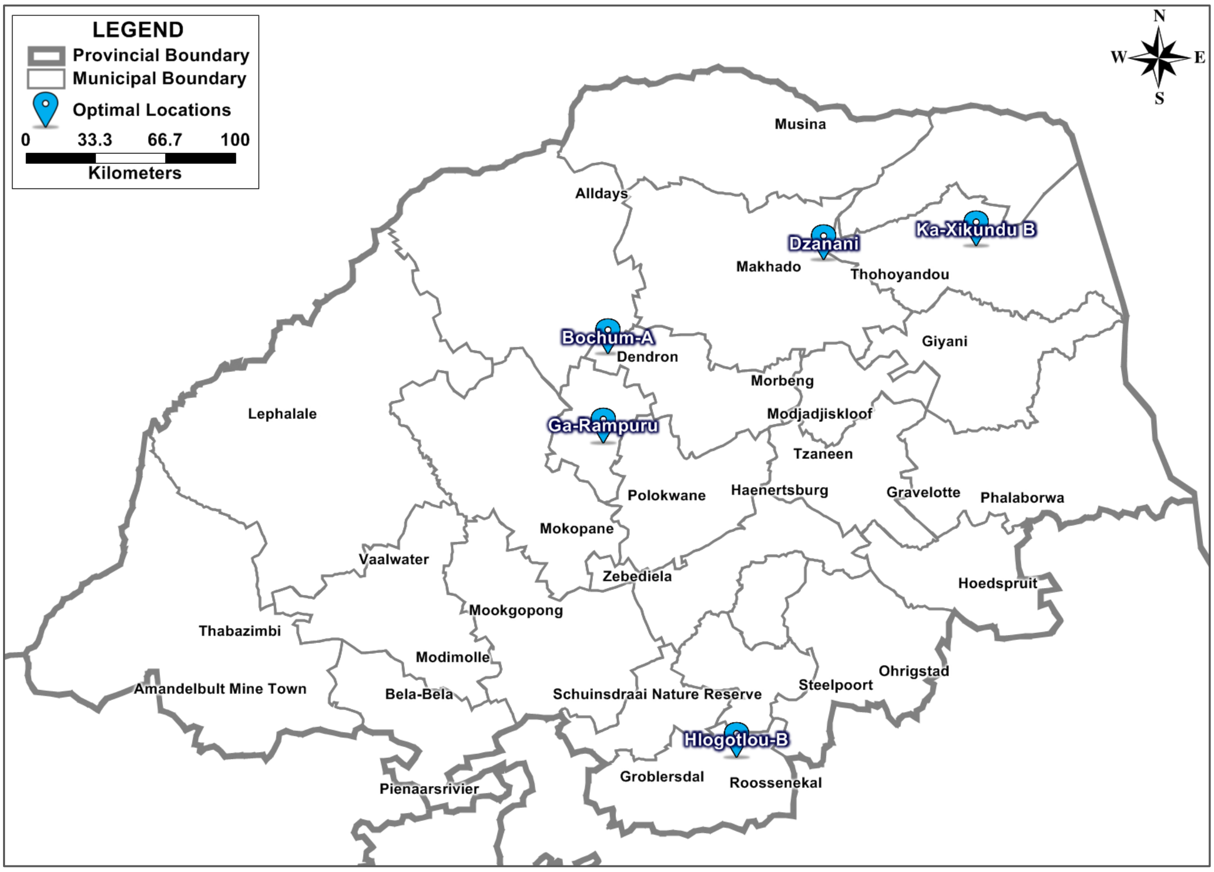


Figure 34: Final list of proposed optimal locations

Table 13 provides details about the five optimal locations that include the proposed facility type (Thusong Service Centre or Cluster), the derived catchment population and the number of nearby key departments. Populated areas that are situated close to multiple Service Centres (including current or proposed) were allocated to the nearest one, hence areas already covered by existing centres could now be allocated to a proposed location.

Table 13: Proposed optimal locations including catchment population

Rank	Town	Suburb	Existing services in close proximity to each other	Catchment Population	Rural Population	Urban Population	Proposed Centre Type
1	Makhado Rural	Dzanani	Home Affairs and SASSA	140 346	140 346	0	Thusong Service Cluster
2	Elias Motsoaledi Rural	Hlogotlou-B	SAPS	138 183	138 183	0	Thusong Service Centre

Rank	Town	Suburb	Existing services in close proximity to each other	Catchment Population	Rural Population	Urban Population	Proposed Centre Type
3	Thulamela Rural	Ka-Xikundu B	SAPS	129 042	129 042	0	Thusong Service Centre
4	Aganang Rural	Ga-Rampuru	SASSA	95 008	95 008	0	Thusong Service Centre
5	Blouberg Rural	Bochum-A	SAPS	85 222	85 222	0	Thusong Service Centre

Based on the results from *Table 13*, a Thusong Service Cluster could potentially be established at one proposed location since two key departments are already situated in the area. Thusong Service Centres could be established at the remaining four locations.

5.3.1 DESCRIPTION OF EACH PROPOSED OPTIMAL LOCATION

5.3.1.1 Dzanani, Makhado Rural

The proposed location is situated in Dzanani (in the Makhado Local Municipality), close to the Soutpansberg mountain range and between the towns of Louis Trichardt and Thohoyandou. A Thusong Service Cluster in Dzanani could potentially provide access to approximately 140 000 people. The Department of Home Affairs and SASSA currently provide services in the Dzanani area. Services from SAPS or the Department of Labour are required to establish a Service Cluster. A service point from SAPS is situated in Siloam, approximately 5 km from Dzanani. This location is too far from the current Department of Home Affairs and the SASSA to establish a Cluster.

5.3.1.2 Hlogotlou, Elias Motsoaledi Rural

Hlogotlou is part of Elias Motsoaledi Local Municipality and is situated next to the R579, approximately 45 km east of Groblersdal. The area is characterised by densely populated traditional residential settlements. A Thusong Service Centre is proposed in Hlogotlou that could provide access to more than 100 000 people currently situated more than 25 km from their nearest Service Centre. SAPS currently provides services in the area.

5.3.1.3 Ka-Xikundu B, Thulamela Local Municipality

A Thusong Service Centre in Ka-Xikundu B could provide access to approximately 85 000 people that are living in predominantly rural areas. Ka-Xikundu B is situated in Thulamela Local Municipality roughly 50 km east of Thohoyandou. Current services close to Ka-Xikundu include those that are offered by SAPS.

5.3.1.4 Ga-Rampuru, Aganang Local Municipality

In Aganang Local Municipality, which is characterised by rural settlements, close to 120 000 people do not have sufficient access to a Service Centre. Hence, the municipality is ranked fourth highest in the province based on the total number of unserved population. A Thusong Service Centre is proposed in Ga-Rampuru, close to the R567 arterial road to increase accessibility in the municipality. Current services in the vicinity of Ga-Rampuru include those that are offered by SASSA.

5.3.1.5 Bochum, Blouberg Rural Local Municipality

Currently just over 123 000 people lack adequate access to a Service Centre in Blouberg Local Municipality. A Thusong Service Centre is therefore proposed in Bochum, close to the rural town of Dendron.

The proposed Thusong Service Centre in Bochum will provide access to 85 000 people in Blouberg Local Municipality, Molemole Local Municipality and a portion of Aganang Local Municipality. These municipalities include populated areas such as Mohodi-A, Ha-Madikana and Dilaeneng. SAPS is situated close to Bochum.

5.3.2 POTENTIAL IMPROVEMENT IN POPULATION COVERAGE

The addition of the five optimal locations to the existing 41 Thusong Service Centres and Thusong Service Clusters in the province could potentially improve accessibility in the province from 66.9% to 76.25%.

Accessibility in rural areas would increase from 64.54% to 76.33%, providing access to more than 500 000 people who previously travelled further than the defined 25 km threshold to their nearest Service Centre. The improved level of accessibility to 76.33% is well above the 75%

target that was set for this research. Accessibility in urban areas remains unchanged at 75.94% within a 15 km travel distance. See *Table 14* and *Table 15*.

Table 14: Accessibility in urban areas based on the optimal provisioning and location of Service Centres

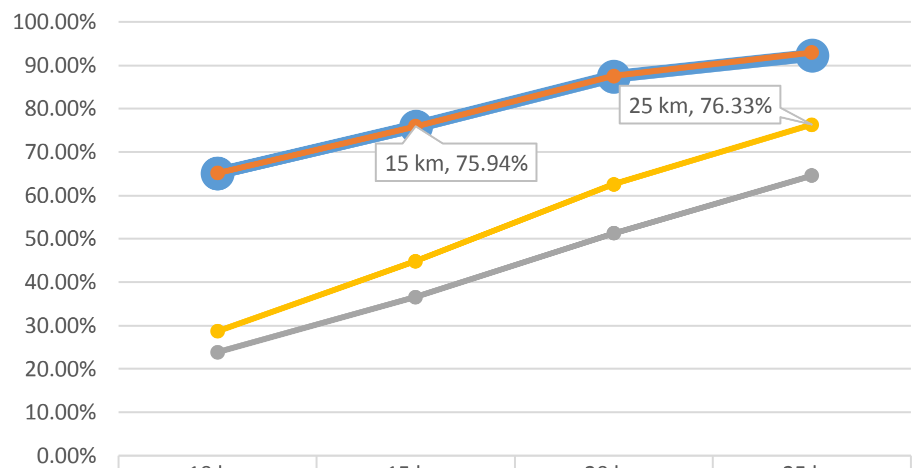
URBAN AREAS				
Urban Population	Less than 10 km	**Less than 15 km**	Less than 20 km	Less than 25 km
Population Covered	731 898	**853 212**	983 402	1 043 976
Not Covered	391 594	**270 280**	140 090	79 516
Total Population	1 123 492	**1 123 492**	1 123 492	1 123 492
Percentage Coverage	**65.14%**	**75.94%**	**87.53%**	**92.92%**

Table 15: Accessibility in rural areas based on the optimal provisioning and location of Service Centres

RURAL AREAS				
Rural Population	Less than 10 km	Less than 15 km	Less than 20 km	**Less than 25 km**
Population Covered	1 228 078	1 919 250	2 677 173	**3 267 371**
Not Covered	3 052 453	2 361 281	1 603 358	**1 013 160**
Total Population	4 280 531	4 280 531	4 280 531	**4 280 531**
Percentage Coverage	**28.69%**	**44.84%**	**62.54%**	**76.33%**

The graph in *Figure 35* compares the current and potential level of accessibility that could be achieved by adding the five optimal locations. Accessibility is compared within four travel distance thresholds; 10 km, 15 km, 20 km and 25 km. Minor changes occurred in urban areas where the percentage population within 10 km and 15 km from a Service Centre remained unchanged.

In rural areas, accessibility improved significantly within each defined travel distance threshold. The greatest improvement occurred within the 25 km threshold where accessibility improved from 64.54% to 76.33% compared to urban areas where only a minor improvement was observed.



	10 km	15 km	20 km	25 km
Current coverage in urban areas	65.14%	75.94%	87.43%	92.27%
Potential coverage in urban areas	65.14%	75.94%	87.53%	92.92%
Current coverage in rural areas	23.87%	36.54%	51.25%	64.54%
Potential coverage in rural areas	28.69%	44.84%	62.54%	76.33%

Figure 35: Accessibility comparison between urban and rural areas based on the optimal provisioning and location of Service Centres

Figure 36 displays a map of Limpopo province. Areas that are covered by current Service Centres or proposed optimal locations are highlighted. These areas are within the maximum travel distance thresholds of 15 and 25 km that were defined for urban and rural settlements respectively.

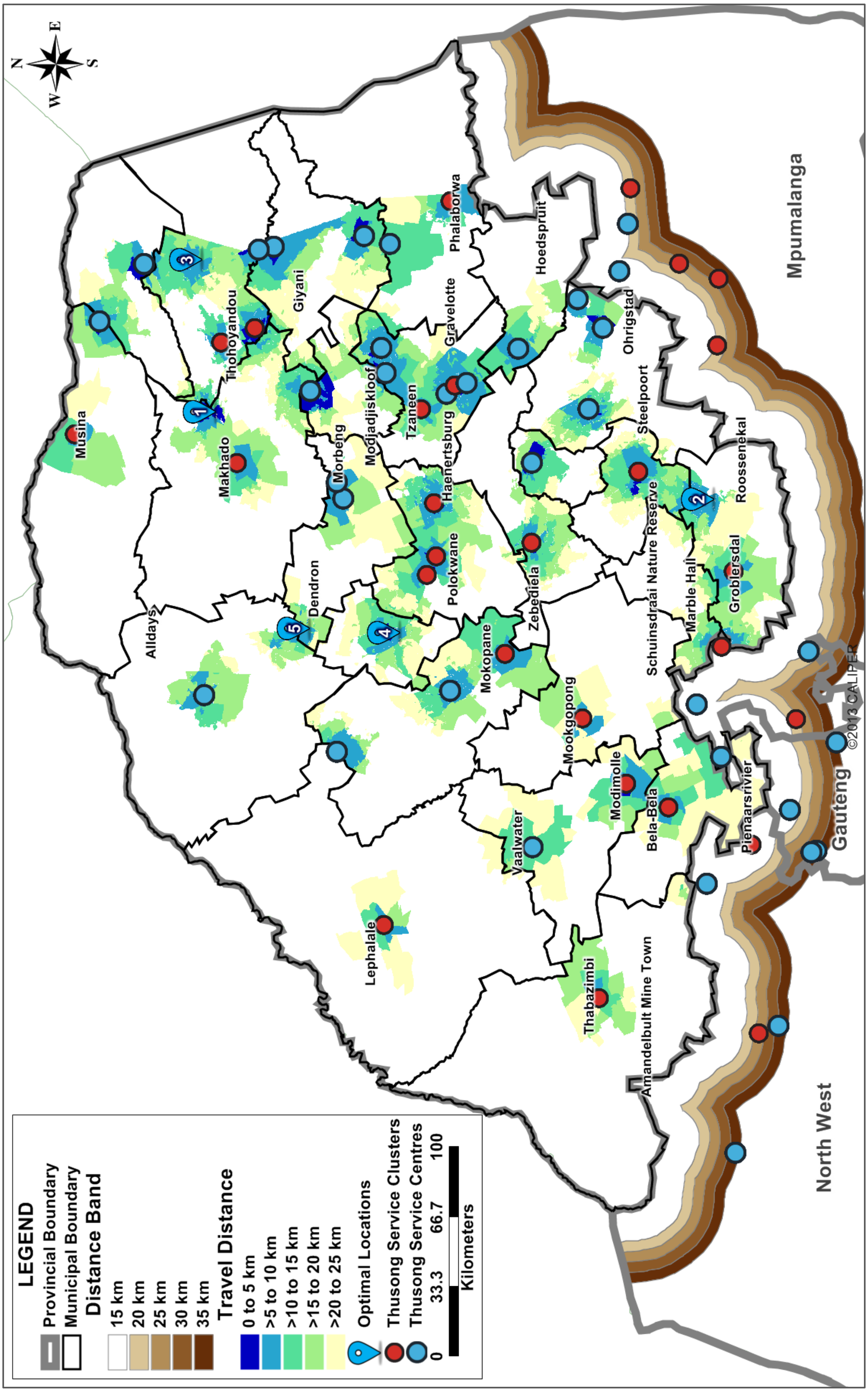


Figure 36: Thusong Service Centres and Clusters in relation to the five optimal locations in Limpopo province

5.3.3 POTENTIAL REDUCTION IN TRAVEL DISTANCES

The additional five optimal locations would reduce the average travel distance to Service Centres from 19.2 km to 16.20 km. The average travel distance in rural areas reduces from 21.7 km to 17.88 km (a total improvement of 3.82 km). In urban areas, the average travel distance reduces by 0.13 km. See *Table 16*.

Table 16: Average travel distance improvement

Settlement Typology	Average travel distance to nearest Service Centre (km)	Average travel distance to nearest Service Centre (km), including proposed optimal locations	Improvement (km)
Urban	9.92	9.79	0.13
Rural	21.7	17.88	3.82
Total	19.25	16.20	3.05

Further location analysis will be required to determine most suitable sites for the establishment of the five additional Service Centres. Location analysis should ideally include a physical location assessment and feasibility study to recognise the practicality of each location.

6. CONCLUSION

6.1 SUMMARY OF FINDINGS

This section provides a summary of findings with reference to the five research questions presented in this study.

6.1.1 Question 1 – How is accessibility measured?

Various methods and procedures have been documented in previous literature to measure geographic accessibility in relation to public and private facilities. In summary, accessibility is typically measured by calculating the shortest distance between locations based on either straight-lines (Euclidean distance) or a travel network, whereby the latter produces more accurate results. The level of accessibility can be measured as complete coverage or maximal coverage whereby complete coverage is reached when all the people are within a defined maximum travel distance standard. Maximal coverage (which was adopted in this research) finds the least number of facilities to maximise accessibility to a satisfactory level.

GIS is widely recognised throughout the literature as a tool to calculate travel distances and to measure accessibility due to its ability to compute large volumes of spatially referenced data. Using GIS as a tool to measure accessibility proved to be an invaluable mechanism in this research. The ability to analyse high volumes of data with GIS software enables location insights that would otherwise not have been exposed. Additional benefits from GIS applications include high quality map visualization capabilities.

6.1.2 Question 2 – How can accessibility be measured in rural areas with limited road infrastructure and where footpaths are not mapped?

Urban and rural classifications are complex, specifically within the South African context, hence no standard classification is currently available for the country. Classification methodologies from Statistics South Africa uses a combination of land use and economic activity to distinguish between urban and rural areas. Other methodologies also include population counts and densities to classify areas. This research adopted urban and rural classification from the AfriGIS town boundaries where urban areas are classified based on dominant settlement type, (derived from census data), as well as land use.

Accessibility, for the purpose of this research was measured by calculating the travel distance from populated urban and rural settlements to their nearest Thusong Service Centre or Thusong Service Cluster based on a derived travel network. Since it is possible, specifically in rural areas of Limpopo province that people travel between settlements on unofficial trails or footpaths due to limited road infrastructure, a novel method was used to establish a travel network between these settlements. A TIN was created between settlements in rural areas that represents trails or footpaths. This method generates straight lines between settlements in non-overlapping triangles while also considering natural barriers such as major rivers, dams or mountains.

These TIN lines create connectivity routes between settlements in rural areas that could reduce the overall travel distance calculation between settlements and Service Centres, hence the level of accessibility based on travel distance could improve. On the downside, these lines will not necessarily represent a true reflection of the actual footpaths or routes that people use between rural settlements.

The use of TIN lines in this research to represent trails and footpaths in rural areas, proved to be valuable for the overall measurement of accessibility as well as for the positioning of optimal locations for additional Service Centres. The removal of lines that intersects with major natural barriers such a dams, rivers and mountain ranges resulted in a number of settlements that were not connected to the road network, hence connections to the road network were created manually with the aid of aerial photography. This process proved to be tedious and extremely time consuming.

6.1.3 Question 3 – What is the current level of access provided by Thusong Service Centres and Thusong Service Clusters in the Limpopo province?

Forty-one (41) Service Centres were identified in Limpopo Province. These include 22 Thusong Service Centres and 19 Thusong Service Clusters. An additional 12 Thusong Service Centres and eight Thusong Service Clusters in adjacent provinces were also identified that could impact the level of accessibility in the province. Based on the results from this study, the average distance that people travel to their nearest Service Centre in Limpopo province is 19.2 km. Based on the defined maximum travel distance thresholds of 15 km in urban areas and 25 km in rural areas, 3 615 924 people (or 66.9%) of the population in the province have access to a Thusong Service Centre or Thusong Service Cluster.

6.1.4 Question 4 – How does the level of accessibility differ between urban and rural areas?

People in rural areas travel on average 21.7 km compared to only 9.9 km for those living in urban areas. This implies that the average travel distance in rural areas is more than double compared to urban areas. Results show that 65.14% of urban population live within 10 km from a Thusong Service Centre or Cluster. This figure increases to 92.27% if the maximum travel distance is increased to 25 km. Only 23.87% of the people that live in rural areas currently have access to a Thusong Service Centre or Cluster within 10 km. Sixty-four point five four percent (64.54%) have adequate access within 25 km.

Based on the CSIR guidelines for the provision of social facilities in South African settlements (which recommend a maximum travel distance of 15 km for urban areas and 25 km for peri-urban or rural areas), 75.94% of urban population have access to a Service Centre and only 64.54% of the rural population. This implies that accessibility between urban and rural areas differ by 11.4% and that additional Service Centres are required to increase accessibility in rural areas to a similar level that currently exists in urban areas (based on these maximum travel distance thresholds).

6.1.5 Question 5 – How can accessibility be optimised in the province?

Optimal locations were identified through facility location procedures in TransCAD. These procedures rely on a spatially referenced candidate layer (or list of possible locations), a client layer (population demand) and a cost matrix containing the travel distance between al the client and candidate locations. The goal of the facility location procedure was to identify the least number of additional locations, (while considering the current location of Service Centres), which would ensure equal accessibility to public Service Centres in both urban and rural areas, within defined maximum travel distance thresholds.

Optimum locations for additional Service Centres have been identified in five populated areas where access is currently inadequate. These areas include Dzanani, Hlogotlou, Ka-Xikundu B, Ga-Rampuru and Bochum. The inclusion of these five proposed optimal locations to the current mix of Thusong Service Centres and Clusters could improve accessibility in rural areas from 64.64% to 76.33%. This implies that accessibility of more than 500 000 people in rural areas who previously travelled further than the set 25 km to a Service Centre would be improved.

From the five optimal locations, a Thusong Service Cluster could be established at one of these locations since current services of key departments are already offered there. Thusong Service Centres could be established at the remaining four locations.

Since this was a desktop study and no physical site visits were done, further location analysis is recommended to determine most suitable sites for the establishment of the five additional Service Centres. Location analysis should include a physical location assessment and feasibility study to recognise the practicality of each location.

6.2 RESEARCH LIMITATIONS

Various limitations were identified in this research. These limitations are significant to note since future research could benefit from the lessons learnt.

The spatial datasets used in this research were obtained with permission from external sources. These datasets were captured at a specific moment in time, hence updates or modifications could have occurred, subsequent to this analysis.

At commencement of this research, the Census 2011 survey from Stats SA was the most updated and official dataset that provides population figures on a geographic level smaller than a suburb level. Population changes could have occurred subsequent to this survey influencing the level of accessibility as well as the identification of optimal locations for Thusong Service Centres.

In addition to this, the accessibility study relies on the accurate geographic location of service points. Inaccurate service point locations could potentially influence the number of Thusong Service Clusters and in turn this could influence the coverage figures, as well as the calculations to identify the optimum number and location of facilities for meeting the unserved population demand.

The establishment of Thusong Service Centres across the country is an ongoing initiative, hence additional Thusong Service Centres could have been opened prior to the inception of this research.

The classification of urban and rural settlement typologies in South Africa remains a challenge since no official classification currently exists. Although various guidelines were used in this study to distinguish between urban and rural spaces in the province, it remained a limitation.

Other accessibility factors such as possible modes of transport, road conditions, traffic patterns or the operational effectiveness of Thusong Service Centres were not included in this study. Although these are important factors to consider, they could be included in future studies relating to the Thusong Service Centre Programme. It is also assumed that people will most likely travel to their nearest Service Centre, although this is probably not the case in certain instances.

6.3 FURTHER RESEARCH AND SCOPE FOR FUTURE STUDIES

The study identified the need for further research in respect of the following:

- Profiling the population catchment areas of all Thusong Service Centres in relation to their demographic, socio-economic, environmental and infrastructural characteristics.
- Reviewing the current mix of services that are provided at Thusong Service Centres. Services should speak to the needs of service beneficiaries and the prevailing socio-economic realities, in particular, youth unemployment and multi-dimensional deprivation. Communities should be consulted in order to define these challenges more clearly and to identify appropriate and coordinated responses from departments.
- Collection of user statistics and other operational and facilities data to assess the performance of Service Centres and to quantify the need(s) for certain services.
- Maintenance and updating of the database of Thusong Service Centres.
- Possible utilisation of the South African Postal Services facilities and the deployment of Mobile Services within sparsely populated areas.
- Since this research focused on a brownfields analysis that accepts the current location of Service Centres, future studies could compare the full list of optimal locations to the current location of Services Centres with the possibility to relocating current centres that are not optimally located.
- Factors such as possible modes of transport, road conditions, traffic patterns or the operational effectiveness of Thusong Service Centres could be included in future studies relating the Thusong Service Centre Programme.

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8. APPENDICES

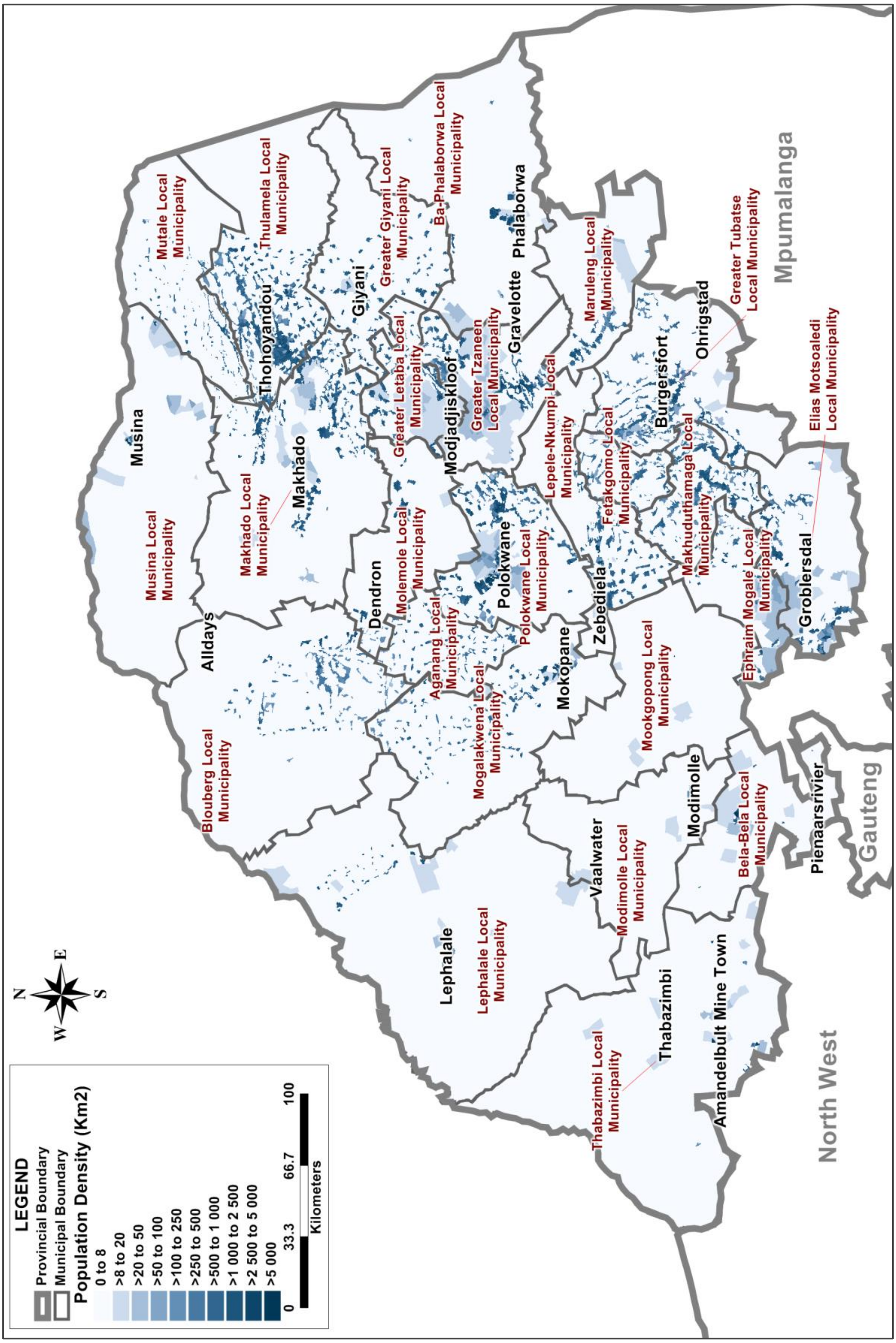
8.1 APPENDIX 1 - CENSUS DWELLING FRAME POINTS

Feature Number	DB Abbreviation	Feature description	Category	Count
	<IS NULL>			157 128
1	DU	Dwelling Unit	Residential	10 815 385
2	VD	Vacant Dwelling	Residential	272 694
3	NDUC	Dwelling under construction	Residential	113 629
4	DEM	Demolished structure	Residential	109 153
5	UNOCC	Unoccupied Dwelling	Residential	471 545
6	OTH	Other	Other	446 316
7	VS	Vacant stand/plot	Other	217 544
8	VL	Vacant Land	Other	111 576
9	PARK	Park	Recreation	3 226
10	GAR	Garage	Business	22 856
11	OFF	Offices	Business	28 981
12	BUS	Business	Business	80 102
13	PO	Post Office	Business	3 467
14	SHOP	Shop	Business	47 198
15	SCH	School	Community Services	28 262
16	FACT	Factory	Business	18 361
17	BANK	Bank	Business	655
18	PLSN	Police station (Police cells)	Community Services	828
19	FLSN	Filling station	Business	1 511
20	BS	Bottle store	Business	2 245
21	CEM	Cemetery	Community Services	3 899
22	CH_MSQ	Church or other place of worship	Community Services	45 750
23	CL	Day clinic	Community Services	1 191
24	OVAL	Sports oval, stadium	Recreation	5 810
25	HALL	Community Hall	Community Services	4 916
26	OSUC	Other Structure Under Construction	Other	1 204
27	SDI/HOTEL	Non-residential Hotel/ Motels/B&Bs/Lodges/Guesthouses	Business	8 467
28	SDI/HOSP	Hospital/ Frail Care Centre/Nursing Homes	Community Services	1 139
29	SDI/STRESS	Students' Residence	Residential	726
30	SDI/HOME	Home for the aged (other than Frail Care Centre)	Residential	4 656
31	SDI/CCARE	Child Care Institution/ Orphanage	Residential	1 663
32	SDI/WHOST	Workers' Hostel	Residential	2 543
33	SDI/SHOST	Boarding School Hostel	Residential	1 048
34	SDI/INIT	Initiation School	Community Services	204
35	SDI/CON	Convent/ Monastery/ Religious Retreat/ Reformatories	Community Services	168

Feature Number	DB Abbreviation	Feature description	Category	Count
36	SDI/BARR	Defence Force Barracks/ Camp/ Ship in Harbour	Residential	254
37	SDI/PRSN	Prison/ Correctional Institution/ Police Cells	Community Services	363
38	SDI/HALL	Community/ Church Hall (in cases of refuge for disaster)	Community Services	372
39	SDI/SHEL	Refugee Camp/ Shelter for the Homeless	Residential	356
40	MARK	Market	Business	1 059
				13 038 450

8.2 APPENDIX 2 – ORIENTATION MAP OF LIMPOPO PROVINCE

8.3 APPENDIX 3 – POPULATION DENSITY MAP OF LIMPOPO PROVINCE



8.4 APPENDIX 4 – TOTAL POPULATION PER SERVICE CENTRE

Appendix 4 shows the catchment population of each Thusong Service Centre, Thusong Service Cluster and proposed optimal location. The list of Service Centres include those that are situated in Limpopo province as well as Service Centres from adjacent provinces that provide access to people in Limpopo province.

Number	Town	Total Population	Rural	Urban	Suburb	Thusong Service Centre Name	Type
1	Aganang Rural	95 008	95 008		Ga-Rampuru		Proposed Optimal Location
2	Ba-Phalaborwa Rural	14 319	14 319		Ga-Selwana	Selwane	Thusong Service Centre
3	Bela-Bela	52 370	7 372	44 998	Bela-Bela		Thusong Service Cluster
4	Blouberg Rural	85 222	85 222		Bochum-A		Proposed Optimal Location
5	Blouberg Rural	38 036	38 036		Eldorado	Eldorado	Thusong Service Centre
6	Dr JS Moroka Rural	93 145	93 145		Siyabuswa-B		Thusong Service Cluster
7	Dr JS Moroka Rural	4 991	4 991		Mmantlole	Mmametlhake	Thusong Service Centre
8	Dr JS Moroka Rural	11 579	11 579		Marapyane	Marapyana	Thusong Service Centre
9	Elias Motsoaledi Rural	138 183	138 183		Hlogotlou-B		Proposed Optimal Location
10	Fetakgomo Rural	57 023	57 023		Fetakgomo Rural	Fetakgomo-Atok	Thusong Service Centre
11	Greater Giyani Rural	36 106	36 106		Muyexe	Muyexe	Thusong Service Centre
12	Greater Giyani Rural	35 280	35 280		Ka-Makhuva	Makhuva	Thusong Service Centre
13	Greater Letaba Rural	195 224	195 224		Naledi B 2	Mokwakwaila	Thusong Service Centre
14	Greater Tubatse Rural	21 588	21 588		Kgautswana	Kgautswane	Thusong Service Centre
15	Greater Tubatse Rural	163 511	163 511		Ga-Ragopola	Mapodile	Thusong Service Centre
16	Greater Tubatse Rural	11 123	11 123		Leboeng	Leboeng	Thusong Service Centre
17	Greater Tzaneen Rural	56 574	56 574		Myakayaka	Bulamahlo	Thusong Service Centre
18	Greater Tzaneen Rural	78 543	78 543		Khujwana	Lesedi	Thusong Service Centre
19	Greater Tzaneen Rural	80 975	80 975		Lenyeenyee-A		Thusong Service Cluster

Number	Town	Total Population	Rural	Urban	Suburb	Thusong Service Centre Name	Type
20	Greater Tzaneen Rural	119 801	119 801		Thako	Relela	Thusong Service Centre
21	Greater Tzaneen Rural	113 444	113 444		Runnymede	Runnymede	Thusong Service Centre
22	Groblersdal	78 868	74 758	4 110	Groblersdal		Thusong Service Cluster
23	Hammanskraal	1 788	1 788		Hammanskraal	Hammanskraal	Thusong Service Centre
24	Lepele-Nkumpi Rural	163 083	163 083		Lebowakgomo-S		Thusong Service Cluster
25	Lephalale	21 360	2 402	18 958	Lephalale		Thusong Service Cluster
26	Makhado	95 921	70 571	25 350	Makhado		Thusong Service Cluster
27	Makhado Rural	140 346	140 346		Dzanani		Proposed Optimal Location
28	Makhuduthamaga Rural	221 681	221 681		Jane Furse		Thusong Service Cluster
29	Maruleng Rural	74 926	74 926		Maruleng Rural	Maruleng	Thusong Service Centre
30	Modimolle	45 068	3 188	41 880	Modimolle		Thusong Service Cluster
31	Modimolle Rural	20 189	7 148	13 041	Vaalwater	Mabatlane	Thusong Service Centre
32	Mogalakwena Rural	84 180	84 180		KwaKwalata	Mapela	Thusong Service Centre
33	Mogalakwena Rural	34 632	34 632		Ga-Taueatswala	Babirwa	Thusong Service Centre
34	Mokopane	150 107	32 056	118 051	Mokopane		Thusong Service Cluster
35	Molemole Rural	24 425	21 389	3 036	Makwetja	Festus Mothudi	Thusong Service Centre
36	Molemole Rural	44 681	44 681		Sefene	Botlokwa	Thusong Service Centre
37	Mookgopong	27 268	7 237	20 031	Mookgopong		Thusong Service Cluster
38	Moretele Rural	803	803		Lebotlwane	Leretlhabetse	Thusong Service Centre
39	Musina	44 566	1 885	42 681	Musina		Thusong Service Cluster
40	Musina Rural	29 413	29 413		Madimbo	Madimbo	Thusong Service Centre
41	Mutale Rural	21 531	21 531		HaMakuya	Makuya	Thusong Service Centre
42	Phalaborwa	64 160	380	63 780	Phalaborwa		Thusong Service Cluster

Number	Town	Total Population	Rural	Urban	Suburb	Thusong Service Centre Name	Type
43	Polokwane	230 023	108 796	121 227	Seshego-B		Thusong Service Cluster
44	Polokwane	111 645	16 876	94 769	Bendor Ext 69		Thusong Service Cluster
45	Polokwane Rural	239 249	239 249		Mankweng-B		Thusong Service Cluster
46	Thabazimbi	31 307	3 524	27 783	Thabazimbi		Thusong Service Cluster
47	Thohoyandou	254 892	67 891	187 001	Thohoyandou-F		Thusong Service Cluster
48	Thulamela Rural	129 042	129 042		Ka-Xikundu B		Proposed Optimal Location
49	Thulamela Rural	160 142	152 687	7 455	Phaphazela, Ka-Mulamula		Thusong Service Cluster
50	Thulamela Rural	42 205	42 205		Mtititi	Mtititi	Thusong Service Centre
51	Tzaneen	31 037	11 976	19 061	Arbor Park		Thusong Service Cluster
Total		4 120 583	3 267 371	853 212			

8.5 APPENDIX 5 – LETTER OF APPROVAL FROM THE DPSA

the **dpsa**
Department:
Public Service and Administration
REPUBLIC OF SOUTH AFRICA
Private Bag X916, Pretoria, 0001 Tel(012) 3361000

Inquiry : Ms Brenda J Hendricks
Telephone : 012-336 1570
Email address : Brenda@dpsa.gov.za

Dear Mr. Lourens Snyman

Your letter requesting permission to use the Department to conduct research has reference.

1. The Department has considered your application and grants approval to your request on the following conditions.

   a) You shall not use or refer to any information classified as confidential, secret or top secret and that
   b) You will not use or refer to any information of a personal nature without the consent of the affected individual reflection of the comply with the provisions of all laws , which regulate the protection of personal data, including but not limited to the protection pf Personal Information Act 2013 and the Electronic Communications and Transaction Act 2002.

2. That you submit the final research paper to DPSA before it is submitted to the University.

The Department takes this opportunity to wish you well in your studies. Please contact Ms. Brenda J Hendricks, brenda@dpsa.gov.za for any further assistance required.

Kind regards

Mr Mashwahle Diphofa
DIRECTOR – GENERAL
DATE: 06/07/2016

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8.6 APPENDIX 6 – LETTER OF APPROVAL FROM AFRIGIS

A F R I G I S
everything about everywhere.

REQUEST TO USE AFRIGIS DATASETS FOR MY STUDIES AT THE UNIVERSITY OF PRETORIA

LETTER OF REQUEST TO USE AFRIGIS DATASETS FOR MY STUDIES AT THE UNIVERSITY OF PRETORIA

To: Charl Fouche

Director: AfriGIS

From: Lourens Snyman

PURPOSE OF USE

I am currently enrolled at the University of Pretoria for my MA. My studies focus on the Geographic Accessibility in relation to Thusong Service Centres in Limpopo province. I am kindly requesting the following AfriGIS datasets for my research:

- AfriGIS town boundaries to distinguish between urban and rural settlements.
- AfriGIS municipal and provincial boundaries for visual display purposes.
- AfriGIS rivers and dams
- AfriGIS street centrelines
- AfriGIS derived slope layer

CW Fouché: [signature]
Date: 17/1/2017
A F R I G I S | everything about everywhere.

Regards,

[signature]

Lourens Snyman

Approved by Charl Wilhelm Fouche

Signature [signature]

Rigel Park Block A, 446 Rigel Avenue South, Erasmusrand, 0181, Pretoria, South Africa PO Box 14134, Hatfield, 0028, South Africa
Tel: +27 87 310 6400, Fax: +27 87 310 6448, products@afrigis.co.za, www.afrigis.co.za

Directors: CW Fouché, D Liebenberg, PF Mpangase, IM Rademeyer (Managing)
AfriGIS (Pty) Ltd Reg. No. 1997/006716/07 VAT No. 4920166123