

GIS-Based Analysis of Spatial Accessibility: An Approach to Determine Public Primary Healthcare Demand in Metropolitan Areas

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DECLARATION

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Date: February 2015

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“And whatever you do, in word or deed, do everything in the name of the Lord Jesus, giving thanks to God the Father through him” Colossians 3:17

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ABSTRACT

It is important for health planners to provide health services as effectively and equitably as possible for the development of quality living environments. The provision of adequate healthcare services, particularly in metropolitan areas, is becoming more difficult because of three developments: slow economic growth; the rapid growth of metropolitan areas and their subsequent increases in population. It is thus a challenge to provide what is considered a fair or socially just distribution of healthcare services to a population with changing healthcare needs.

The spatial distribution of people and their varying need for healthcare services is a long-standing interest in the field of service planning, and provides a classic issue well suited for Geographical Information Systems (GIS) to analyse. Access is an important aspect in healthcare service planning. GIS-based accessibility analysis is a logical method that can be applied to test the degree to which access is obtained. Such successful applications of GIS-based analysis have been useful in indicating the accessibility of an existing or potential service. This has provided a good basis for the planning of healthcare services. However, it has been increasingly realised that there is a growing need for a paradigm shift in the planning process.

In South Africa, primary healthcare (PHC) is a dual system made up of private and public healthcare facilities. Private PHC is expensive and only affordable to people with medical insurance. These people, most currently belonging to the middle and high income brackets, are theoretically also healthier than the rest of the population. But a small proportion of the population in the low income bracket also has medical aid or insurance. Hence, it is quite difficult to make a clear distinction of the low, middle and high income uninsured population when measuring access to public primary healthcare services.

In this study, three different scenarios to calculate the uninsured population were generated and tested using a GIS-based form of catchment area analysis. The results from the catchment area analysis were compared with actual public PHC demand in the form of headcounts and further analysis of the origins of the patients was undertaken using a patient register. Results indicate that there is no significant difference in the spatial extent of the catchment areas of the facilities across the three demand scenarios but that there are significant differences in demand visits per scenario. A patient register and facility headcounts, both based on actual visits to public PHC facilities, were compared to the results of the catchment area analysis. The comparison results show that almost 45% of the patients did not use their closest facility as a first point of contact. The total allocated demand visits in scenario 3 was strongly in line with the total number of headcounts of the area, and thus is considered the most suitable calculation of uninsured population for implementation in a GIS-based accessibility analysis.

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LIST OF ACRONYMS

| | |
|----------------|---|
| CASE | – Community Agency for Social Enquiry |
| CD | – Compact Disk |
| CHC | – Community Health Centre(s) |
| CSIR | – Council for Scientific and Industrial Research |
| DHIS | – District Health Information System |
| DHS | – District Health System |
| DPSA | – Department of Public Service and Administration |
| ETR | – Electronic Tuberculosis Register |
| GHS | – General Household Survey |
| GIS | – Geographical Information Systems |
| GPDH | – Gauteng Provincial Department of Health |
| HA | – Hectares |
| ID | – Identity |
| IDP | – Integrated Development Plan |
| JDA | – Johannesburg Development Agency |
| KM | – Kilometres |
| PHC | – Primary Healthcare |
| SBC | – Spot Building Count |
| StatsSA | – Statistics South Africa |
| TB | – Tuberculosis |

GLOSSARY OF SIGNIFICANT TERMS

The following set of accessibility modelling definitions is based largely on their use in the context of this study.

| | |
|---------------------------------|--|
| Access standards: | Standards used to determine the size, location and number of service points to be provided. They include population thresholds and access distances. |
| Accessibility: | An aggregate measure of how accessible a place is to all relevant places for engaging in a particular type of activity. It is thus also a measure of activity or interaction opportunities. |
| Capacity: | Facility parameter indicating the minimum and maximum number of people that can be served in a particular time period. |
| Catchment area analysis: | An analysis procedure used to allocate origins to the nearest destination and thus defining catchments. |
| Catchment area: | Proportion of the origins (population or demand) allocated to the destinations (facilities) in question. |
| Demand: | The need for a particular service or good. Demand occurs at the origin. |
| Destination: | The place where a trip ends. In this study it is usually the health facility represented as zones (hexagons). |
| Geocoding: | The process that is used to convert street addresses, zip codes or other locations into geographical coordinates which can then be entered into a global positioning system device or geographical software. |
| Insured population: | Proportion of the population covered by medical aid schemes or insurance. |
| Origin: | The place or location where a trip starts. In this study it's usually the home or residential area represented as zones (hexagons). |
| Uninsured population: | This is an adjustment of the total population to the number assumed to be dependent on services in the public health sector. |
| Supply: | The availability of services or goods at facilities. |

CHAPTER 1

1 PRIMARY HEALTHCARE

1.1 Introduction

The provision of quality healthcare services is important as it contributes to the improvement of people's lives and leads to conditions that favour economic development and the general functioning of areas. An improvement in the health status (mental, physical and social) of the population enables people to contribute towards economic production; this in turn leads to social advancement and economic progress. It is for this reason that Magawa (2012:1) states that the goal of any healthcare system is to provide universal access to appropriate, efficient, effective and quality healthcare services in order to improve and promote people's health. Indeed, good health status is essential as this can highly influence enhanced productivity, especially for people in the labour force.

The provision of adequate healthcare services, particularly in metropolitan areas, is becoming more difficult because of three developments. Amongst these three developments is the rapid growth of cities and their population (Amer; 2007:3). This results in a situation where the carrying capacity of current service delivery systems declines with the increase in service demand. This therefore burdens facilities which already have limited healthcare resources and results in, for example, long queues and increased waiting times. These challenges, amongst others, stress the need for service delivery systems to constantly anticipate continuous change in population growth, and in turn adapt to this change (Amer; 2007:7).

Apart from challenges related to service operation, poor access levels to healthcare services by the population have become a major concern in developing countries. According to the South African Department of Public Services and Administration (DPSA, 2011) people often face great inconvenience, travel long distances and visit more than one service point to obtain the healthcare services they require from government facilities. This is especially true for the poor and marginalised people who experience low levels of service availability and quality while their mobility is usually determined by their economic conditions (Green *et al.*, 1997:1).

Be that as it may, the way in which access is looked at will differ depending on the development context of a country. Gulliford and Morgan (2003:1) state that in developing countries problems of access concern the availability and accessibility of basic services such as the ability to visit a doctor or to receive healthcare during pregnancy and delivery. Whereas in developed countries basic services are generally accessible, questions of access concern the degree of

comprehensiveness that can be offered by healthcare systems, the extent to which equity is achieved, and the timelessness and outcomes of care (Gulliford & Morgan, 2003:1).

The spatial distribution of people and their varying need for healthcare services is a long-standing interest in the field of service planning, and provides a classic issue well suited for Geographical Information Systems (GIS) to analyse. GIS and related spatial analytic techniques provide a set of tools for analysing the spatial provision of services, such as healthcare, by examining its relationship to healthcare access and outcomes, and for exploring how healthcare provision can be improved (McLafferty, 2003:25).

The availability of GIS in organisations has increased rapidly in recent years with the growing recognition of geographical barriers to healthcare access. This increased use of GIS has allowed for the spatial planning of healthcare services by identifying suitable locations for a given number of facilities in a defined territory in such a way that the healthcare needs of a spatially dispersed population can be served in an optimal way (Amer, 2007:31). However, decisions have to be made about the nature and range of services to be provided as well as their distribution (Amer, 2007:11). Hence, the location and operation of these services often involve large amounts of investment, and thus needs to be carefully planned (Ribeiro & Pais Antunes, 2002:553).

From a planning perspective, measuring the accessibility of healthcare services in a geographic area is one of the useful approaches in the planning process. GIS-based accessibility analysis is a logical method which is applied to measure the degree to which geographical access is obtained. It has recently been used to approximate the degree of healthcare need and / or forecast healthcare demand in a number of studies (e.g. McGrail, 2012; Al-Taiar *et al.*, 2010; Apparicio & Séguin, 2006; Bagheri *et al.*, 2005 & Lin *et al.*, 2005).

1.2 Background and Research Problem

Metropolitan areas have the greatest variation in healthcare needs. This is because they have the highest population densities and populations with varying socio-economic profiles. In addition, people are not spread evenly across these areas and resources are also not equally accessible and available to all individuals. In South Africa, primary healthcare providers are fragmented into public and private service sectors. The public service sector is mostly used by the uninsured population, which means that they do not belong to medical aid schemes or cannot afford to pay out-of-pocket for healthcare services provided by the private sector (Ramela, 2009:3). The majority of the people who use services provided by the private sector are insured by medical aid schemes or pay out-of-pocket. These people, most of which currently belong to the middle and high income brackets, are theoretically also healthier than the rest of the population; the so-called health-income gradient (Econex Health Reform Note 15, 2011:7). But a small proportion of the population in the low income bracket also has medical aid or insurance. Hence it is quite difficult to make a

clear distinction of which part of the population is uninsured based on income levels when measuring access to public primary healthcare services.

1.3 Aim and Research Objectives

The overall aim of this research was to evaluate whether GIS-based accessibility modelling is an appropriate method for determining public primary healthcare demand. In order to address the aim the following objectives were realised:

- I. Determine the actual demand for primary healthcare.
- II. Calculate the uninsured population.
- III. Measure access to primary healthcare facilities using the uninsured population.
- IV. Compare results from the uninsured population analysis with the actual demand.

1.4 Research Area

Johannesburg is a good example of a city with a great variation in healthcare needs due to its population density and socio-economic profile. The choice of study area was influenced by this as well as the availability of data, existing knowledge of the area, and the apparent contrasts within the study area in terms of levels of development, population densities, socio-economic profiles and the provision of primary healthcare facilities.

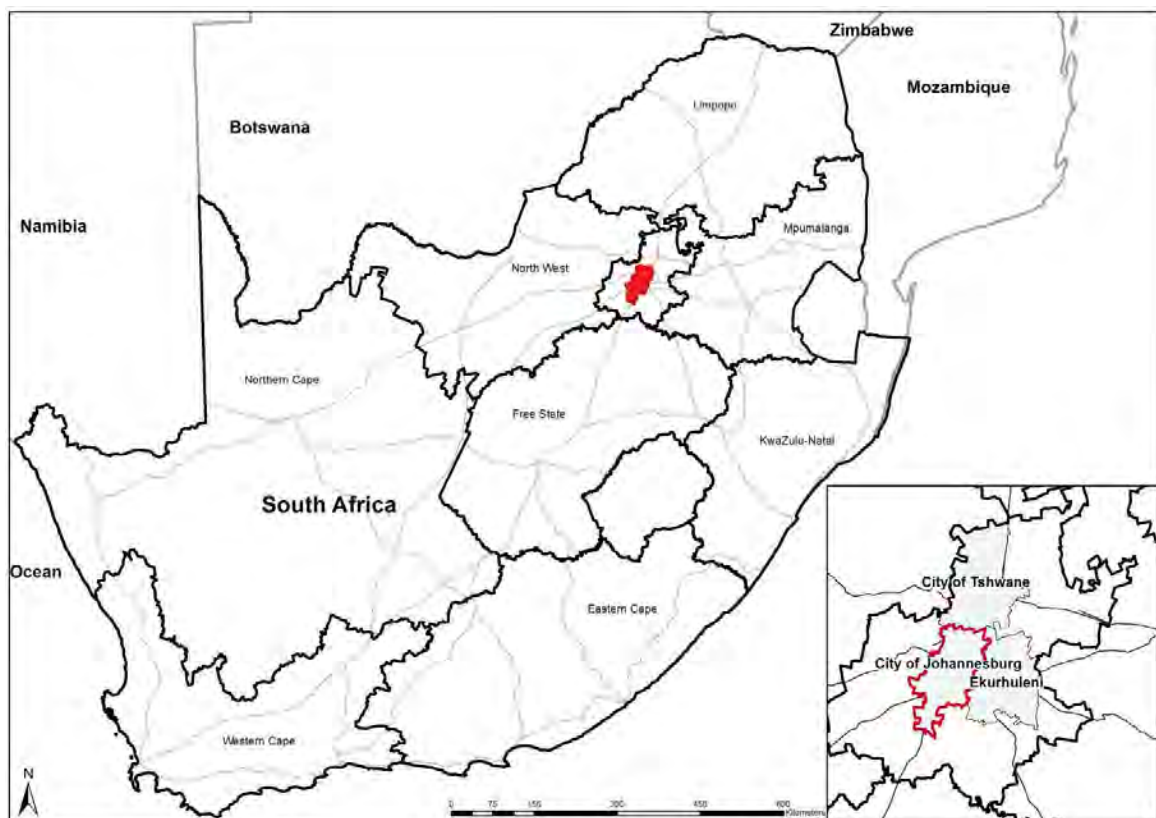


Figure 1.1: City of Johannesburg's location within Gauteng Province (le Roux, 2012:2)

As shown in Figure 1.1 the City of Johannesburg is centrally located in the province of Gauteng. It stretches from its north side boundary with the City of Tshwane to the south side boundary of Emfuleni Local Municipality. Its eastern and western boundaries stretch towards the metropolitan municipalities of Ekurhuleni and Mogale City respectively. The City is geographically divided into seven administration regions; labelled from A to G. The core administration, falling under the Office of the City Manager, incorporates these seven regions and sets the strategic direction for the city with respect to service delivery (Richards *et al.*, 2006:17).

Figure 1.2 (A) and (B) on the following page shows the distribution of the City's population within the seven administration regions. According to Census 2011, the City had a total of 4 434 827 people made up primarily of a young population aged between 30 and 39 years. This total population translates roughly into 1.3 million households (City of Johannesburg Integrated Development Plan, 2011:8). Census 2011 also indicated that between the years 2001 and 2011 the City's population increased by 27%, with household projections showing an increase from about 1.3 million in 2010 to about 1.5 million in 2015 (City of Johannesburg Integrated Development Plan, 2011:8). This shows that the City of Johannesburg remains one of the fastest growing metropolitan areas (Ahmad *et al.*, 2010:5).

According to the Johannesburg Development Agency (2013), rapid population growth in the City has been attributed to in-migration. The City of Johannesburg is viewed as the leading metropolitan gateway by migrants from other provinces in South Africa as well as international migrants (Johannesburg Development Agency, 2013). Hence, as an economic hub, it is the first choice of destination by job seekers with areas such as Hillbrow and Yeoville experiencing a great influx of people and rapid occupancy by migrants seeking employment. The visible results of this urban growth occur in the form of substandard housing and overcrowding (Ahmad *et al.*, 2010:30).

Linked to issues of migration is that of employment. High unemployment rates contribute significantly to poverty and high inequality levels within the City. With youth unemployment as a major challenge nationally, the City faced a high unemployment level of 21.8% in 2009 (City of Johannesburg Integrated Development Plan, 2011:8). Employment in the City is made up of 90.1% formal employment and 9.9% informal employment (City of Johannesburg Integrated Development Plan, 2011:9). Employment by sector figures are 22% for financial and business services, 20% manufacturing, 19% trade, 18% community and social services, 8% construction, 5% public administration, 6% transport and communication (Johannesburg Development Agency, 2013). The City's economy reflects strong successive waves of development and decline, which have seen the City move away from mining and industry towards an economy based on services, trade and high-value manufacturing (Johannesburg Development Agency, 2013).

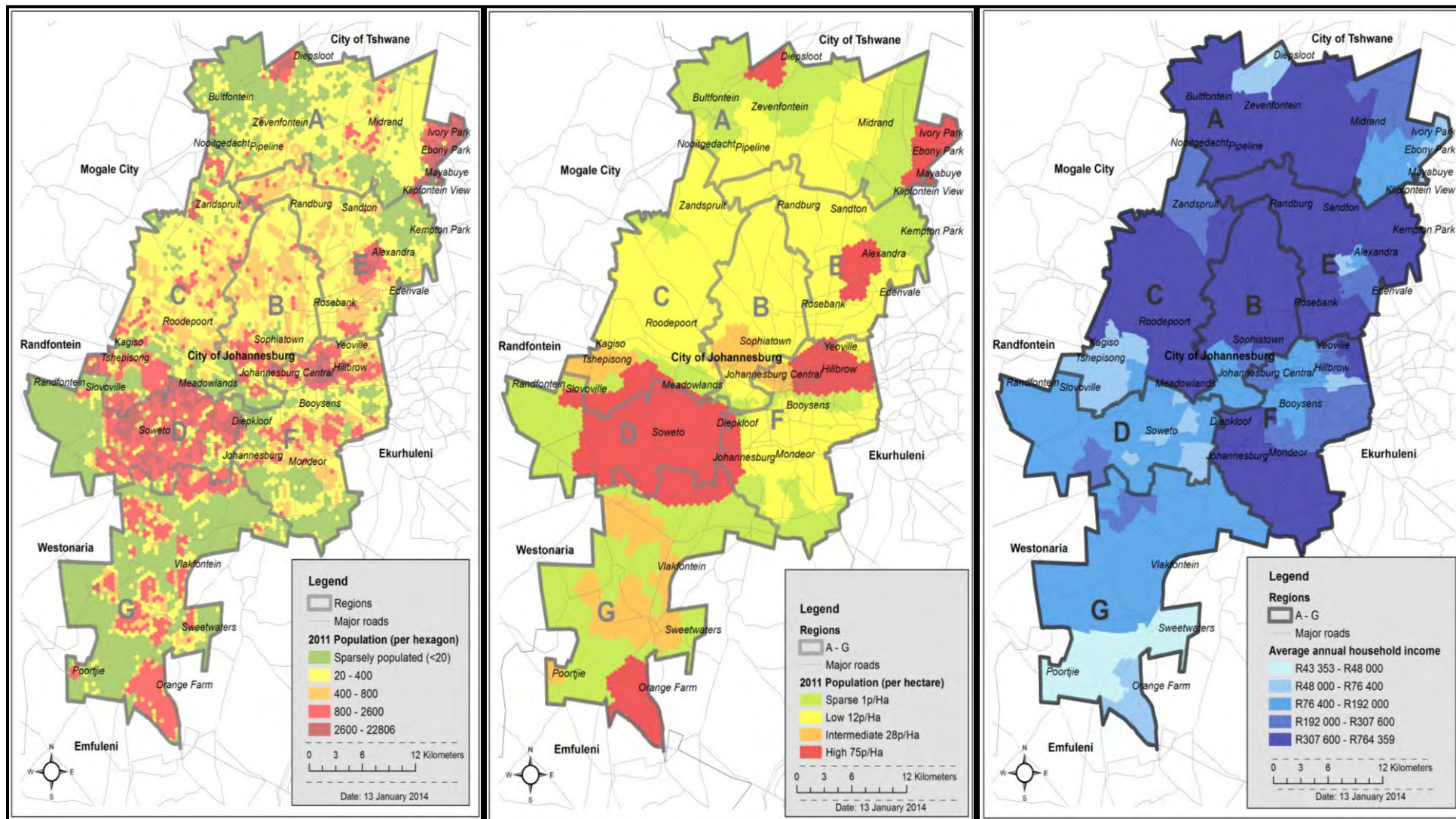


Figure 1.2: (A) 2011 population distribution

(B) 2011 population density zones

(C) 2011 average annual household income

In a context of rapidly shifting settlement dynamics, the City of Johannesburg faces the challenge of providing quality services at affordable rates to all residents (Van Rooyen *et al.*, 2009:65). As illustrated in Figure 1.2 (C) on the preceding page, the high and middle income groups live largely in the areas of Randburg, Rosebank, Sandton and Midrand which are located in the centre of the City and towards the north. The densely populated areas of the southern suburbs and the north periphery house the low income population; these are areas such as Soweto, Ivory Park, Diepsloot and Alexandra. These areas host extremes of poverty, informal trade and high density informal settlements which lack proper roads, access to piped water and have poor sanitation (Ahmad *et al.*, 2010:5).

Apart from the rising unemployment and poverty rates that the City of Johannesburg faces, access to basic services and housing for the poor are key challenges for the City. The successful delivery of basic services such as healthcare depends primarily on the availability of suitable infrastructure, adequate funding and trained staff and an appropriate delivery structure (Abbot, 1996:1).

In the City of Johannesburg, healthcare services are more prominent in the inner-city than outlying areas which are provided with more government support programmes such as home-based care (Richards *et al.*, 2006:35). In 2011, the City had 132 public PHC facilities distributed throughout the seven administrative regions. Most of these facilities operate for eight hours straight during week days while a few are open for 24 hours seven days per week. Ramela (2009:3) states that there is no bypass fee to be paid by patients if they wish to visit the clinics outside their region borders. They are free to visit any clinic of their choice and this makes healthcare services difficult to render because certain of the clinics become overcrowded (Ramela; 2009:3). The capacity of the City to provide basic health services needs to be improved to cater for increased population growth.

1.5 Research Design and Methods

The research strategy that was used to evaluate whether GIS-based accessibility modelling is an appropriate method for determining primary healthcare demand is that of a comparative study. Mills *et al.* (2006:621) describe a comparative study as a broad term that includes comparison of social entities in a search for similarity and variance. The purpose of such comparison in this study is to analyse the research problem in the light of there being very few studies to which one can refer for information about the problem. At the outset of this study the following work outline was developed as the framework to be adhered to when conducting the research:

- i. Preliminary literature review.
- ii. Identifying a research problem.
- iii. Further literature review.
- iv. Identification of data needed to solve the problem.
- v. Data collection.

- vi. Data preparation.
- vii. Data analysis.
- viii. Developing conclusions.

A two-part approach was chosen with regards to the literature review. A preliminary literature review was undertaken to obtain a good understanding of the notion of access particularly in the context of healthcare service planning. In addition, a further literature review looking at the different methods of measuring accessibility was also undertaken. This review follows the work of international and local literature. Following this, the research problem was identified. To address the research problem four objectives were realised. The four objectives are interrelated in such a way that the third and fourth objective cannot be achieved without the outputs of the preceding objective as illustrated in Figure 1.3. These four objectives guided and also informed the type of data required and how the data should be prepared for analysis. The basic analysis steps followed were:

Step 1: Collect the specific types of data needed from a variety of sources. This involves collecting secondary data and other relevant information at various levels of aggregation. Clean and prepare each dataset to serve as input into the analysis.

Step 2: Determine the actual demand for PHC services by using actual patient visits recorded for each facility in the form of headcounts. To supplement the headcounts, geo-code a patient register with residential addresses and use the data to determine the origins of the actual demand.

Step 3: The target population demand for public PHC services was considered to be those people who do not have healthcare insurance. Determine equations to calculate the uninsured population which take into consideration the socio-economic status of the population.

Step 4: Use the uninsured population to measure access to a PHC facility based on a GIS form of catchment area analysis. Determine the allocated demand at each facility.

Step 5: Compare the allocated demand from the uninsured population analysis with the facility headcounts. Identify the facility choice patterns that emanate from analysing the origins of the actual demand. Discuss findings. Make a decision on which of the selected equations for calculating the uninsured population is most suitable for implementation in a GIS-based accessibility analysis.

Step 6: Draw conclusions and recommendations. Following this, identify gaps which can be potentially addressed by future research.

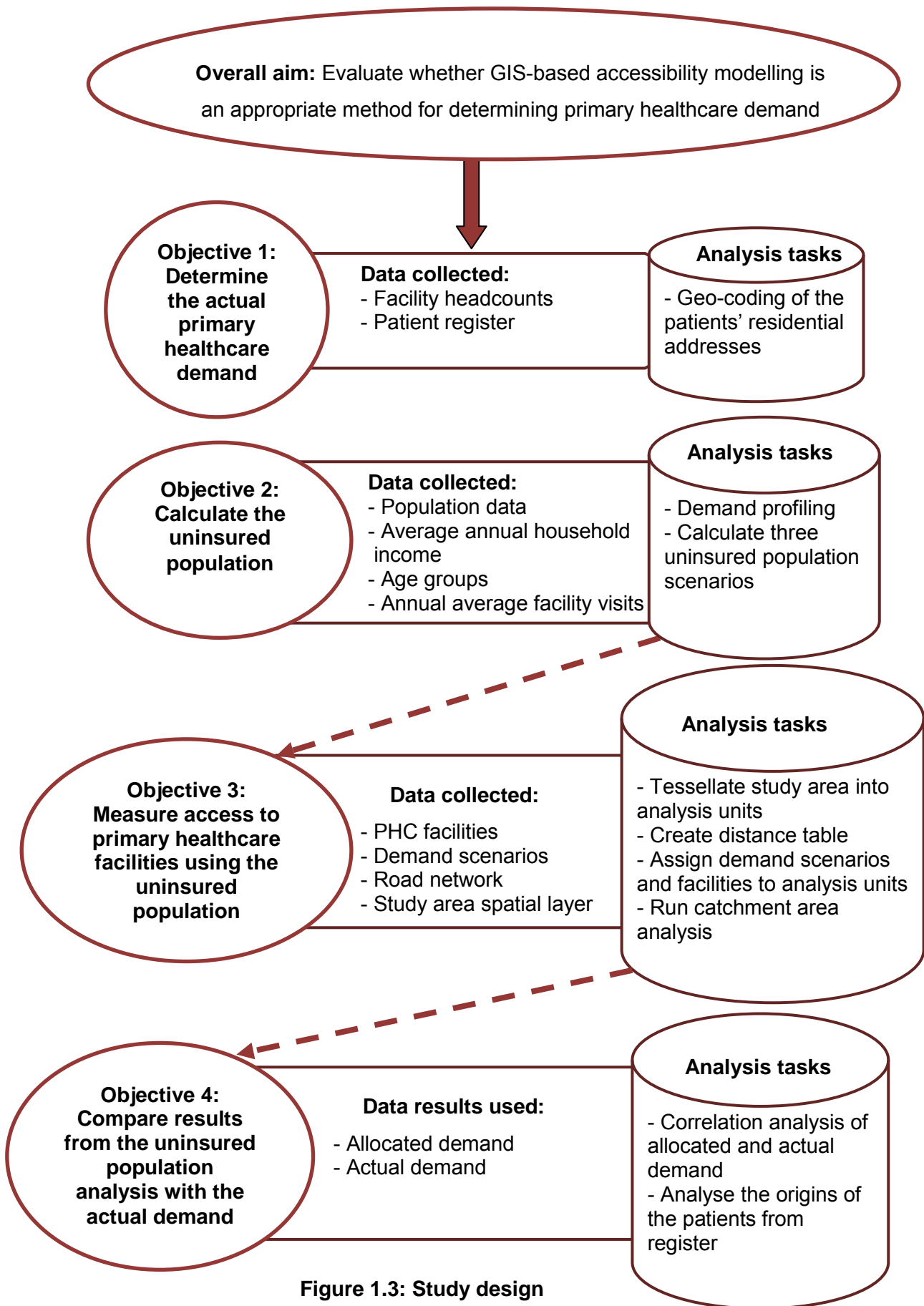


Figure 1.3: Study design

1.6 Research Assumptions

The research was carried out under the following assumptions:

- The target population was considered to be those people that are most likely to use public healthcare facilities, that is the uninsured population and not the entire city's population. This is because it was considered that the medically insured population would use private healthcare facilities which were not covered in this study.
- For the GIS-based form of catchment area analysis, access to facilities was measured following the shortest path from place of residence. People were assumed to initially access the closest primary healthcare facilities from their place of residence and not, for example, place of work. A good employment dataset of the entire City's population did not exist.

1.7 Significance of the Research

Research in South Africa over the last twenty to thirty years has added knowledge to the subject of the spatial planning of healthcare services. However, very little seems to have been done in terms of improved methods for determining demand for healthcare services. Healthcare planning is a demand-driven process; service provision in this sector should respond to the existing or potential demand. The planning process needs, therefore, to be largely seen from the perspective of the patient whose use becomes the most important consideration. The spatial realities and dynamics of a changing population with changing spatial health needs require regular and logical measures to evaluate and improve service provision. Up to this point, quantitative accessibility indicators at facility level have been used to evaluate and plan for the provision of health services. The research undertaken intends to demonstrate the ability of GIS to incorporate service utilisation data for improving efficiency and equity in the spatial planning of healthcare services. Relevant patterns of service utilisation, for example, can be discovered to serve as input to accessibility modelling based on realistic assumptions rather than assuming that people are spatially rational. Thereby adding value in a variety of ways to current research relating to accessibility planning approaches that are continuously developed and incorporated in the GIS suite of decision support tools. This research supports planning for service provision in relation to actual demand and usage by improving current service provision access to areas with the greatest need.

1.8 Ethics

The data obtained for the study was handled with the strictest confidentiality and used only for the purpose of this research and not redistributed nor disclosed to any unauthorised person in any manner whatsoever. With regards to the patient database, only the street and suburb names of each record were used in the analysis. No personal details of individuals such as names or identity numbers were included in any of the analyses nor disclosed to any unauthorised person in any

manner whatsoever. Also see addendum D for the faculty assessment of ethics in research projects.

1.9 Outline of the Dissertation

Chapter 1: Primary Healthcare

The current chapter provides a brief discussion of some of the challenges in planning for healthcare services and the need for improvement in service delivery planning. The overall research aim and research objectives are discussed.

Chapter 2: Access to Healthcare

In this chapter clarification of the meaning of the term access is made. This is done by reviewing definitions and aspects of the concept of access. This forms the conceptual foundation of the entire research.

Chapter 3: GIS-Based Measures of Spatial Accessibility

This chapter reviews accessibility measures for their ability to evaluate access. The focus here is GIS-based measures in the context of healthcare, especially those that have taken a spatial perspective. The chapter provides an overview of the application of such measures found in both international and local literature.

Chapter 4: Data Preparation and Analysis

This chapter discusses and justifies the data collection procedures that are adopted and adapted in order to carry out the analysis for this research. The chapter also describes data sources and the preparatory work. A framework of analysis is also discussed.

Chapter 5: Results and Findings

It is in this chapter that the main outputs of the analysis and main findings are discussed.

Chapter 6: Discussion

This chapter discusses the overall analysis approach and reflects on the strengths and weaknesses of the data used.

Chapter 7: Conclusions and Recommendations

This chapter reflects on the overall aim and set of objectives. The findings are summarised in relation to the specific set of objectives. Details of the recommendations and future work are provided.

Chapter 8: References

This chapter contains an alphabetical listing of the sources referred to in this dissertation. The Harvard system of referencing was used (author-date system).

CHAPTER 2

2 ACCESS TO HEALTHCARE

2.1 Introduction

A decision to locate any public facility in a geographic area is essentially a decision to distribute a certain type of public service among different groups of people. Such decision making is intended in some way to provide equitable access to services for various groups in the population. Basic to this decision making is the concept of access. Although access is in the first instance a spatial condition, it is now a key concept in service planning. However, as current deliberations have indicated, there has been considerable confusion about what the concept of access means. While improving access is a major focus in service planning, this key concept has taken on a variety of definitions and meanings (Halden *et al.*, 2005:1).

Penchansky and Thomas (1981:127) state that access is used synonymously with terms such as 'accessible' and 'available' which are themselves ill-defined. Indeed, the priority being given to achieving access raises questions about the meaning of the term (Gulliford *et al.*, 2002:186). The definitional problem with regard to access may be related to the various disciplinary perspectives of individual authors or their use of the concept (Khan & Bhardwaj, 1994:62). Given this, the term then becomes defined and operationalised in more than a few ways for different contexts.

Despite some serious past attempts to answer such questions and provide formalised empirical definitions of access, most authors (Halden *et al.*, 2005; Khan & Bhardwaj, 1994; Thomas & Penchansky, 1984; Penchansky & Thomas, 1981 and Aday & Andersen, 1974) agree that the term is still not well-defined. This area of confusion should be clarified at the outset so that the concept can be operationalised in the context of this study.

The study within this review will examine what is meant by access to provide the reader with an understanding of the notion of access by examining its definitions, dimensions and its use as a performance measure. Additionally, a short discussion on planning for health care access will be explored to form a foundation for measuring accessibility for planning of public services to achieve equity. This chapter does not in any way aim to be comprehensive but particularly focuses on spatial access in the healthcare context. However, at the end of this chapter the reader will be better informed in these areas.

2.2 The Notion of Access

The concept of access is continually used in a variety of research fields such as urban planning, marketing and transport. Among road engineers, the term access is often used to refer to access from adjoining infrastructure onto a road. For those who are concerned with transport, access is the extent to which transport systems enable individuals to reach activities or destinations by means of transport modes. Access, for planners, describes the ease or difficulty of reaching services in a particular place. The concept has potential applications in urban planning ranging from identifying the most accessible locations for retail to identifying residential locations that are accessible to job opportunities (Morojele *et al.*, 2001:165). These contextual meanings have created an area of confusion as access related terminology is employed inconsistently from one study to another, and thus complicating the task of synthesizing research results into meaningful conclusions (Thomas & Penchansky, 1984:554). But what does access to healthcare mean? Moreover, how can it be measured and what methods should be used to evaluate it (Aday & Andersen, 1974:208)?

The term has been considered to take on a variety of meanings including “the amount of effort for a person to reach a destination” or “the number of activities which can be reached from a certain location” by Geurs and Van Eck (2001:33). Penchansky and Thomas (1981:128) have defined access as the general concept which summarizes a set of more specific areas of fit between the patients and the healthcare system, while Cromley and McLafferty (2012:304) view access as a multidimensional concept that describes people’s ability to use services when and where they are needed. It can therefore be concluded that the definition of access used depends on the goal of the study or its context.

To clarify matters, it can be recognised within the context of this study that access is in the first instance a condition that is experienced at a specific geographic location (Green *et al.*, 1997:4) while another term, accessibility, is an aggregate measure of how accessible a specific geographic location is. The latter is thus a measure of activity or interaction opportunities; therefore the concept of accessibility can be viewed as a performance measure by which a service delivery system can be evaluated.

Three primary components make up accessibility as illustrated in Figure 2.1. These three primary components can be characterised in terms of four questions of ‘who’, ‘what’, ‘where’ and ‘how’. ‘Who gets what, where and how’, being the welfare approach keywords (Amer, 2007:17).

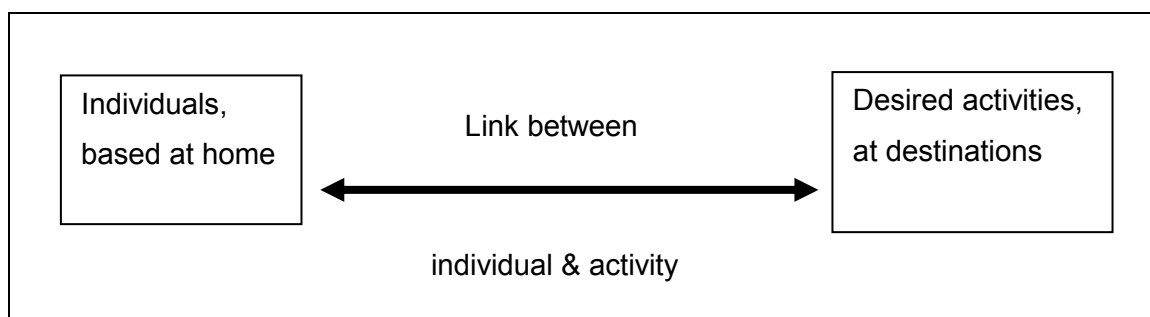


Figure 2.1: Primary components of accessibility (adopted from Halden *et al.*, 2005:2)

According to Halden *et al.* (2005:3) all definitions of accessibility include some reference to these questions, such that:

- The ‘who’ or ‘where’ is being considered – accessibility is an attribute of people or places.
- While the ‘what’ are the opportunities being reached – the land uses, activity supply points or resources (including people) that allow people or places to satisfy their needs.
- And the ‘how’: the factors that separate the people and places from the supply points –
- these can be distance, time, cost, information and other factors that act as deterrents or barriers to access (Halden *et al.*, 2005:2).

In this study, for example, a proxy for ‘how’ is travel distance and is used to determine how far the facilities are to the uninsured population in the study area, taking into account travel resources. The degree to which the uninsured population can access the facilities is an indicator of overall accessibility and the degree to which these facilities are accessible is an indicator of performance. Thus accessibility has been used here to refer to:

“When considering people, accessibility is about “the ease with which any individual or group of people can reach an opportunity or defined set of opportunities”; this is often referred to as origin accessibility. When considering service providers, accessibility is “the ease with which a given destination can be reached from an origin or set of origins” (David Simmonds Consultancy, 1998); this is usually referred to as destination accessibility, catchment accessibility or facility accessibility.” Halden *et al.* (2005:3)

Two main viewpoints can be identified from the above definition: that of the individual (-origin) and that of the service provider (-destination) (Halden *et al.*, 2005:3). Please see relative definitions of origin and destination in the glossary. In terms of the individual, Aday and Andersen (1974:209) state that some researchers tend to equate access with characteristics of the population such as family income, insurance coverage, attitudes towards medical care, etc.; or, of the delivery system such as the distribution and organisation of manpower and facilities. Others argue that access relates to potential entry into or use of the health service system (-destination). For this reason

then access is seen to describe either the potential or the actual entry of a given individual or population group into the healthcare system (Gulliford *et al.*, 2002:186). The extent to which the individual or population group gains access depends on a set of dimensions; availability, accessibility, accommodation, affordability and acceptability. These dimensions have been identified to represent closely related phenomena of access by a number of studies (e.g. Bagheri *et al.*, 2005; Black *et al.*, 2004; Thomas & Penchansky, 1984; Penchansky & Thomas, 1981).

2.3 Access and Healthcare Planning

When healthcare services are distributed in geographic space and made available, an opportunity to obtain healthcare is created. Unless services are made 'available' there can be no consideration of access to healthcare. Resources or services are scarce, and their efficient delivery requires adequate access by people (Wang, 2006:77). This is why the last few years have seen a growing recognition of the fact that while access is an important concept in the area of service access planning, other related factors also account for accessing healthcare services. Factors such as realised need, accessibility and utilisation come together in evaluating and planning healthcare services (McLafferty, 2003:32).

Since the early 1960s, considerable efforts have been devoted to service delivery planning by researchers from a wide variety of fields such as spatial planning, operations research, management science, regional economics, economic geography, civil engineering (Ribeiro & Pais Antunes, 2002:553). When considering the provision of healthcare services, spatially equitable access opportunities and the minimisation of spatial access costs take primacy. The supply of services can be considered as some sort of a prerequisite for access (Joseph & Phillips, 1984:52).

One of the primary objectives when supplying healthcare services is to achieve what is called social and spatial equity. The concept of equity has been known to connote fairness and justice in the distribution of resources and liabilities in any society (Samuel & Adagbasa, 2014:270). According to Wang (2006:77) the spatial distribution of resources or services is not uniform and needs careful planning and allocation to match demands. Hence, the organisation of health services (number, sizes, types and locations) should always ensure that facilities are within reasonable reach to contribute to effective service delivery.

Access to healthcare services is in part a function of the distribution and location of service facilities (Ingram, 1971 & Moseley, 1979 *in* Joseph & Phillips, 1984:10). Thus, service access planning should be approached as a means of improving access to ensure equitable service delivery. This is because when making decisions about the provision of public health services a number of guiding principles apply; these being equity, effectiveness and efficiency (Amer, 2007:11). But then again, some degree of geographical variation is inevitable as services are not provided at every location. Therefore, some people will always be nearer to services than others

(Amer, 2007:167). The real question, according to Amer (2007:167) is what degree of spatial inequality is acceptable and when should it be considered unjust. One way of evaluating spatial (in)equality is to measure the accessibility and availability of services to indicate whether provision is sufficient and provided equitably.

2.4 Primary Healthcare Provision in South Africa

While some population in the developed world is generally covered by a system of universal health coverage, most middle- and low-income countries (often with higher levels of inequality), have a tax revenue that alone is not sufficient to provide healthcare services at a level that is acceptable to both the wealthy and poor (Econex Health Reform Note 15, 2011:9). Such developing countries experience public concerns about healthcare services that include longer waiting times, shortage of medication at facilities, poor attitudes and behaviour by healthcare staff.

As these realities are widely shared by many developing countries, there are certain countries which have initiated steps towards achieving universal health coverage or insurance. A few examples in the developing world which have introduced universal health coverage or insurance include countries such as Thailand, Brazil and Mexico (Econex Health Reform Note 13, 2011:7). Similarly, South Africa is also exploring national health insurance models that will enable individuals to obtain better quality treatment at healthcare facilities. This is because access to healthcare is an important issue and continues to be a priority in South Africa. This can also be recognised in most service delivery policies which emphasize the need to improve access for all people. It is even stated in the South African constitution that every citizen should be granted access to services (Green *et al.*, 2009:167). And thus, access to services in South Africa, has not only become a need but also a basic human right.

As much as efforts are being made to implement universal health coverage or insurance, public primary healthcare is still in the interim seen as the key element and major strategy for the provision of health services in developing countries (Peterson, 2001:7). In most sub-Saharan countries, post-independence governments adopted the primary healthcare approach and took on a dominant role in the provision of healthcare with the objective to provide universal access to health services at no or little cost to the user (Berman, 1998 *in* Amer, 2007:10). After a few years, significant progress to a certain level was obtained in some countries (Econex Health Reform Note 13, 2011:5).

In South Africa, the concept of primary healthcare is the preferred strategy to deliver healthcare services to communities. It immediately became more pertinent after the democratic elections, and after this free primary healthcare for all using the public healthcare service sector was implemented. This strategy has resulted in considerable improvement in terms of affordability and

accessibility of public healthcare services offered to poor households since 1994 (Econex Health Reform Note 1, 2010:1).

Primary healthcare is defined by Ramela (2009:1) as a framework of services within the district in which healthcare is promoted and delivered. It is the first level of contact with the healthcare system and involves the provision of an integrated healthcare package which includes preventative, promotive, curative, supportive and rehabilitation services (Thandrayen, 2008:2). This comprehensive package is expected to be universally accessible and guaranteed for every citizen in South Africa (Harrison, 2009:7). The services are offered by a variety of providers in the health sector. These providers differ in their accessibility, acceptability and affordability (Thandrayen, 2008:8).

In South Africa, large quality differences exist between the providers of healthcare services. Hence, providers are fragmented into public and private service sectors. Primary healthcare services are provided by the public sector at no cost to the patient while the private sector offers services at a fee. Just like police services and public roads, the public service sector healthcare is financed through general taxation and provided freely to the entire population as a public good (Econex Health Reform Note 15, 2011:1).

Provincially funded clinics that are tasked with providing curative services, local government funded clinics that provide preventative services and CHCs form the public service sector platform for the delivery of the primary healthcare package within the District Health System (DHS). The DHS was established as a basic building block for the delivery of healthcare in South Africa allowing healthcare provision to be built around the principles of primary healthcare. In addition, family practitioners or district surgeons which provide services under public contracts and government hospitals in areas where access to clinics and CHC is limited provide primary curative care (though they are meant to provide secondary and tertiary level care) also form part of the public service sector (Thandrayen, 2008:8). The private sector consists of general practitioners, private clinic chains, private hospitals and traditional healers. The cost of services provided by general practitioners, private clinic chains and private hospitals tends to be higher and more expensive but with generally higher patient satisfaction rates compared to the public service sector (Econex Health Reform Note 15, 2011:9).

Although there is a large perceived quality difference between the public and private health sectors currently, it is stated in the Econex Health Reform Note 15 (2011:8) that there is only a very small variation in terms of health outcomes between the two service sectors. While there is strong commitment to and major investment in public primary healthcare services, many factors undermine the quality and efficiency of these services. Factors such as organisational structure, limited resources and staff attitudes adversely affect the delivery of primary healthcare services (Ramela, 2009:25). Furthermore, challenges facing the health sector include staff shortages, high

workloads and an increased primary healthcare package of services without a concomitant increase in the budgetary allocation (City of Johannesburg Integrated Development Plan, 2011:198). The spread of diseases in deprived areas, a significant factor in the reduction of life expectancy, is also a key contributor to this situation (City of Johannesburg Integrated Development Plan, 2011:78). The introduction of free health for all at primary healthcare facilities has led to congestion and a reduction in consultation times (Thandrayen, 2008:9). Harrison (2009:2) further adds that although in South Africa the restructuring of the public health sector post-1994 achieved substantial improvements in terms of access, rationalisation of health management and more equitable health expenditure, fifteen years later these early gains have been eroded by a greatly increased burden of disease, poor health outcomes relative to total health expenditure, generally weak health systems management and low staff morale. The two major aspects relating to these issues is the accessibility of public primary healthcare and the quality of services, even in countries which have a long and cherished tradition of free healthcare (Econex Health Reform Note 13, 2011:6).

2.5 Conclusion

Like quality, access is an important concept in healthcare service planning. In this chapter, the notions of access and accessibility in relation to spatial planning in the healthcare context were discussed. This chapter was based on the results of a theoretical review of the concept of access and service access planning literature.

The concept of accessibility was operationalised within the context of this study. It was recognised that access to healthcare facilities is one of the important facets in the healthcare planning process. Healthcare planning is inevitably tied up with the notions of equity, effectiveness and efficiency. Given the spatial perspective of this study, performance of a healthcare service delivery system is then assessed in terms of the overall accessibility levels of the uninsured population to public healthcare services.

CHAPTER 3

3 GIS-BASED MEASURES OF SPATIAL ACCESSIBILITY

3.1 Introduction

The use of GIS in various fields is making it possible to plan and evaluate the impacts of a wide range of social facilities and locational planning strategies. One of the principle reasons is that GIS provides an excellent platform for analysing and representing virtually unlimited variety of spatially related conditions. Much work is being done from a selection of accessibility planning approaches that are continuously developed and incorporated in the GIS suite of decision support tools. The focus is on the need for improved measures of accessibility to services, and the need to find practical tools to support and improve current facility planning practice based on more realistic assumptions (Green *et al.*, 1997:4). In this way, service providers can also be able to translate potential spatial access opportunities into realised access opportunities.

To appreciate what contemporary GIS-based methods and techniques have to offer, the succeeding subsection gives a brief overview of the different kinds of accessibility measures found in the literature. The chapter then moves on to review accessibility measures focusing on their methodological aspects. The emphasis here is to review accessibility measures for their ability to evaluate access to healthcare services. The subsequent sections describe the methods that incorporate demand and supply characteristics into certain measures so that accessibility can be measured. Several case studies, found in the literature, that have applied accessibility measures are discussed.

3.2 Approaches to Measuring Spatial Accessibility

The evidence for regional disparities, as highlighted by Joseph and Phillips (1984), emphasizes the importance of measuring the various facets of performance in a healthcare service delivery system. Since the early 1990s, interest in GIS tools that are used to store, manage, process, analyse and present geographical data has been booming (Geertman *et al.*, 2003:157). Consistent with the above, there have been growing advances in GIS as an important tool for health care planning. This is particularly pertinent in the context of measuring access to healthcare services as a means of planning for improved service provision.

GIS-based accessibility analysis offers a useful approach that can be used to support location planning in the urban health sector (Amer, 2007:44). In the past decade, various studies in support of utilising this approach have been embarked upon by geographers and planners. Increasingly, sophisticated measures are being developed by computing the measures separately for different

trip purposes, different travel modes and times, different age, sex, race and occupational groups, and distinct activity types at each destination (Green *et al.*, 1997:4).

The traditional approach to measuring access has been the number of facilities to population ratio as a measure of availability (Higgs, 2004:122). One of the problems associated with the provider-to-population ratio as a measure of availability is that patients frequently travel outside their residential areas for healthcare; this is especially so for those residing in non-metropolitan areas (Makuc *et al.*, 1991:347). Also, these measures do not properly handle such peculiarities as the use of services in other communities, the failure to use the nearest facility, overlapping coverages and redundant services (Rosero-Bixby, 2004:1273).

Talen (2003:187) has described a number of measures applied when measuring accessibility such as container, coverage, gravity, travel time and distance. The most basic container measures compare the supply of services with the potential demand for services in a defined area (Higgs, 2004:122-3). An example of such a measure would look at the number of clinics per hundred thousand people in an area. Such measures are useful in indicating the probable accessibility of an existing or potential health facility while assuming that there is no cross boundary flow of people from adjoining areas. This may overestimate the actual supply of services to the population, or the other way around.

There has been development of a rich collection of studies focused on measures of access to services (for example Green *et al.*, 2009; Tanser *et al.*, 2006; Higgs, 2004; Lou & Wang, 2006; Morojele *et al.*, 2003; Lovett *et al.*, 2002 and Khan, 1992). Most of these studies have demonstrated the useful tools provided by GIS to measure geographical access to services. McLafferty (2003:28) states that such studies have also explored GIS tools to analyse geographical inequalities in service access as well as those patterned along social and economic lines. Physical access to health care affects a large array of health outcomes, yet meaningfully estimating physical access remains elusive in many developing countries where conventional geographical techniques are often not appropriate (Tanser *et al.*, 2006:691).

To overcome the abovementioned shortcomings, GIS and related network analysis tools have been used to allocate the flows from demand origins to one or more supply centres, and this has then been used to demarcate supply centre catchment areas, or estimate the flows attracted by each supply centre (Morojele *et al.*, 2003:6). This type of analysis is not container based but allocation to a facility does not guarantee utilisation of the services.

Previous studies on the role of spatial factors have examined the impacts of three broad sets of factors on overall accessibility: (a) the spatial configuration and characteristics of the health delivery system along with a broad range of quality measures associated with particular services; (b) the role of the transport system in getting individuals to these destinations, including the

respective importance of private and public transport in different socio-cultural contexts; and, (c) the characteristics of individuals utilising health services or, more commonly, the characteristics of the areas in which they reside based on relevant census data (Higgs, 2004:122).

Bagheri *et al.* (2005:1) used network analyst to generate the best route based on the shortest time from residential areas to primary healthcare facilities in the Otago region of New Zealand. Instead of simple geometric centroids of the meshblocks, the mean centre of population distribution within each meshblock polygon was used. The study found that to improve on the approach consideration should be given to non-spatial factors such as deprivation indexes, ethnicity, education, gender, age, income, housing and transportation modes and then combining spatial and non-spatial in one frame when evaluating accessibility of primary healthcare.

Information from patient registers was combined with details of general practitioner surgery locations, road network characteristics, bus routes and community transport services in a GIS to measure accessibility to surgeries by public and private transport in East Anglia by Lovett *et al.* (2002:97). The research was able to demonstrate the possible incorporation of patient registers and GIS in measuring accessibility, though it was recommended that the practical difficulties of using these data sources and techniques should not be underestimated.

More recently a study was conducted by McGrail (2012:1) to determine the spatial accessibility of primary health care utilising the two step floating catchment area (2SFCA) method. This study was able to demonstrate the necessary combination of both a distance-decay function and variable catchment size function in order for the 2SFCA to appropriately measure healthcare access across all geographical regions in Victoria, Australia (McGrail, 2012:1). Table 3.1 gives a summary of more measurement of accessibility examples from the healthcare sector.

Table 3.1: Examples of previous studies on measuring accessibility

| Authors | Area | Health focus | Methodology | Findings |
|-------------------------------|---------------------------|-----------------------------|---|---|
| Samuel & Adagbasa (2014) | Ibadan | Health resources | Composed index of critical accessibility (CICA) | Significant proportion of the population still finds it difficult to access basic health services as and when needed. |
| Al-Taiar <i>et al.</i> (2010) | Yemen | Vaccination | Measured straight-line distances, driving distances and time. | All three measures showed strong association with vaccination of children after adjusting for socio-economic status. |
| Nteta <i>et al.</i> (2010) | Tshwane Region of Gauteng | Primary healthcare services | Self-administered questionnaires | Facilities are accessible to most participants and |

| | | | | |
|-----------------------------|--|--|---|---|
| | Province | | | effectively used. |
| Tanser <i>et al.</i> (2006) | Hlabisa health sub-district in KwaZulu Natal | Primary healthcare | Cost analysis in GIS | Significant logistic decline in usage with increasing travel time |
| Lin <i>et al.</i> (2005) | Michigan | Pain management | Measured distance between patient and facility's zip-code | Similar differences observed between revealed and potential access in both rural and urban areas. |
| Lou & Wang (2003) | Chicago | Primary care | Two-step floating catchment area and gravity based | Two-step floating catchment area: simpler and easier to interpret, for use in improving the designation of health professional shortage areas. |
| Parker & Campbell (1998) | Scotland | General practitioner services, accident and emergency services | Calculated network distance between patient and facility's zip-code | General practitioner services: "the majority of patients choose medical practices near their home address; many patients do not elect to receive medical services from the practice which is geographical closest to their home address." |
| Mthembu (1997) | Manguzi health ward, in KwaZulu-Natal | Healthcare facilities | Scheduled interviews | Mobile clinics and traditional healers were significantly accessible but residential clinics, general practitioners and hospitals were found to be not as easily accessible. |

3.3 GIS and Actual Accessibility to Healthcare

When looking at the type of accessibility measures used in health care analysis, most publications present studies of potential accessibility (Amer, 2007:43). While measuring potential accessibility has been the traditional method, actual accessibility may now be a more meaningful approach. Although GIS studies that incorporate actual health utilisation are relatively rare (Gatrell & Senior, 1999:934), studies by Gatrell *et al.* (1998), Jones *et al.* (1998), Martin *et al.* (1998), Haynes *et al.* (1999), Hyndman *et al.* (2000) and Maheswaran *et al.* (2003) have examined the spatial relationship between the location of potential clients and detailed patterns of utilisation in developed countries (Higgs, 2004:129).

It is clear that most GIS applications in the healthcare field emanate from the developed countries while practical applications in developing countries such as sub-Saharan Africa are currently virtually non-existent (Amer, 2007:46). Application of such measures in developing countries is constrained by the lack of data inputs and this remains a considerable bottleneck. Healthcare planning requires spatial data on health resources, population, utilisation, treatments, and outcome. But such datasets are often unavailable or provided at different temporal and spatial scales (McLafferty, 2003:37).

This is particularly true for South Africa and Scott *et al.* (2002) draws attention to the limitations of existing data sources. In South Africa, the District Health Information System (DHIS) was put in place to cater for health information needs. This system is computerised and has a link to a GIS component but most of the data are related to the facilities which mean that the residential or work addresses of the people visiting the facilities are not recorded in this system. All data outputs are aggregated to a facility level, reducing its value for detailed accessibility analysis based on the origins of the patients.

To supplement the DHIS data, population based cancer and tuberculosis (TB) registers which do include addresses of patients are available and can be used as potential proxy datasets to examine PHC utilisation patterns. However, a study by Scott *et al.* (2002) in KwaZulu-Natal discovered that the registration data in the cancer registry had incomplete records. This reflected dispersed and uncoordinated data collection processes and geographical variations in registration efficiencies (Scott *et al.*, 2002:239). Unless there are improvements in the availability and quality of input data, the full potential of acceptable and robust spatial analysis methods in support of healthcare planning will remain untapped.

3.4 Conclusion

While specific measures of potential accessibility are easier to put into operation and interpret than actual accessibility for the purposes of monitoring individual aspects of health care delivery, it is important to note that availability and potential accessibility does not guarantee utilisation of services (Joseph & Phillips; 1984:93). And so, potential accessibility measures may fail to include the demand of individual preference. In other words, utilisation should also be seen as an indicator of accessibility as utilisation is a manifestation of potential accessibility.

The level of accessibility can sometimes be measured by looking at the use of services or quantity of visits to a facility such as patient visits or headcounts. On an international scale, many studies have used patient registers as demand input when measuring potential accessibility. However, in South Africa, owing to the absence of accurate databases such robust analysis is hardly applicable. There is a need to focus on improved measures of access to local public facilities and

the need to find practical tools to support and improve current facility planning practice (Green *et al.*, 1997:1).

Accessibility provides a useful methodological framework to support healthcare planning. It does so by providing a mechanism and useful components for assessing access to healthcare. This chapter looks at how measures of accessibility can be used or can be applicable to assessing accessibility for different groups of people for different objectives. The use of GIS in South Africa for assessing service provision and developing facility plans, leading to improvements in governance and equitable service delivery is well underway, but the lack of detailed databases remains a bottleneck for more robust analysis. This chapter also highlights the need for improved measures of access to health services that take into consideration potential and actual accessibility to support and improve current service access planning.

CHAPTER 4

4 DATA PREPARATION AND ANALYSIS

4.1 Introduction

Measuring the accessibility of healthcare services and exploring interventions to improve such access can be challenging. This challenge is compounded by the task of translating the relevant data into a format that is clear and persuasive to policymakers and funding agencies (Phillips *et al.*, 2000:971). This chapter discusses the general processing of the spatial data used in this study. This includes a detailed discussion around each set of data and the way in which it was assembled. It must be noted that in the light of data error, inconsistencies and incomplete data, considerable time and effort was devoted to data pre-processing. As the general processing of each dataset is detailed, problem areas of the data are also highlighted and discussed. The intended outcome of the data preparation was to create a pool of reliable datasets.

4.2 Data Collection and Preparation

A key factor in strategic or operational planning is the availability of appropriate data and information to be used in decision-making (Abbot, 1996:2). Besides in the planning field, data are also fundamental to any type of research. The successful completion of any research depends critically on timely, organised and accurate data. Data collection usually starts with a single case in a small area and then moves on to include various cases and to cover larger spatial units.

There are many different kinds of data about the natural and human environment that are continuously collected by individuals, research teams and organizations (St. Martin & Pavlovskaya, 2010:174). Spatial data for geographers, and most people interested in studying related GIS projects, remain an important form of information. For researchers embarking on GIS studies, generating spatial data such as population census is expensive and tedious. Such data cover national boundaries and contain hundreds and thousands of variables that individual researchers could not possibly generate. The effort placed into collecting datasets of comparable scale and size is considerable and takes up a large proportion of the research period. Obviously, this has led to an increase in the use of readily available secondary datasets.

This research made use of three main types of secondary data basic to accessibility analysis. This was comprised of (1) locations of relevant health service delivery points; (2) the distribution of the uninsured population in the study area; and, (3) a detailed road network. These three main types of data are just mentioned here, in the following subsections they are all described in detail and also in Addendum A.

The main point is that it was not within the scope of this study to collect raw data and it was purely dependant on secondary data. Although secondary data are mostly created by someone else, they inform a great deal of academic work and provide opportunities for particular forms of analysis (St. Martin & Pavlovskaya, 2010:176).

While the advantages and limitations of secondary data were carefully considered, these datasets were derived from a variety of sources as listed and explained below. The datasets collected as input to the analysis are as follows.

4.2.1 Spatial layer of the study area

A spatial layer of the City of Johannesburg was obtained to produce spatially smaller analysis units of hexagons. In tessellating the spatial layer into hexagons, the total area taken into account coincides with the city boundary. The tessellation was dimensioned in such a way that it subdivides the study area into smaller geographic units of equally sized hexagons of 20 hectares as shown in Figure 4.1. With this level of spatial disaggregation the spatial resolution remains sufficiently detailed.

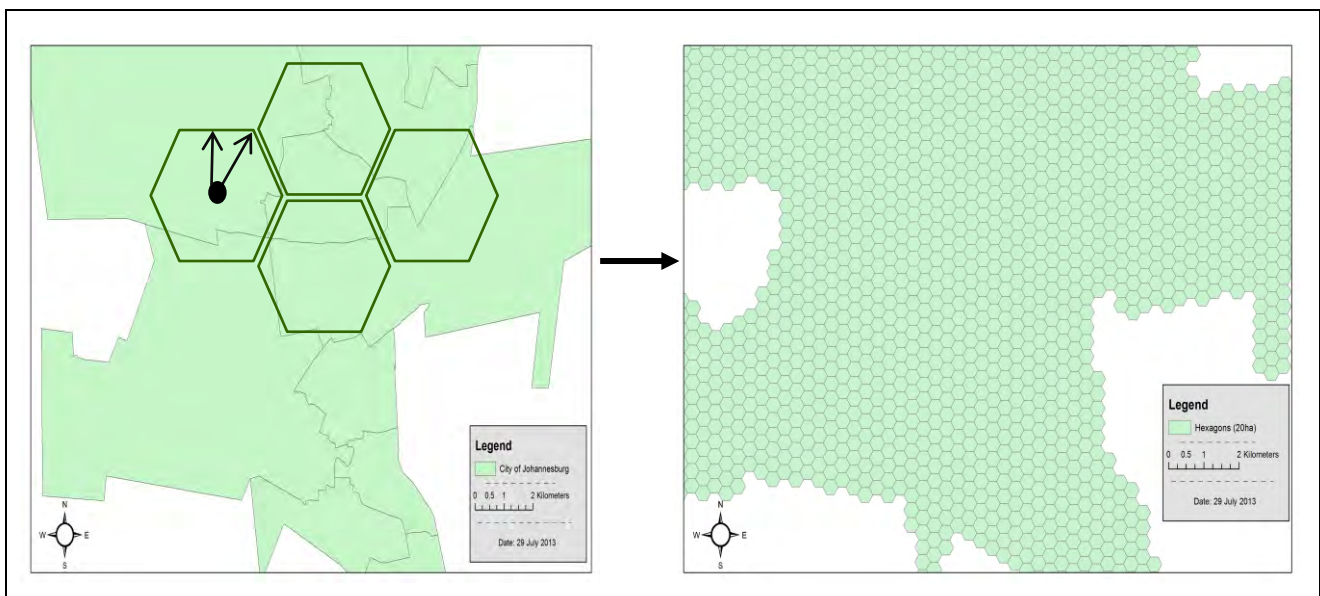


Figure 4.1: Tessellating the study area

The reason for using hexagons as analysis units is firstly that it allows the analysis output to be produced on a more detailed level than for instance working with sub-places and thus allows for the more accurate identification of problem areas (Green *et al.*, 2012). Secondly, the hexagons give a better distance estimate. Since the catchment area analysis model links the centroid of the analysis units to the road network and from there to the facilities being analysed, hexagons give a better distance estimate as the radius is the same for all points on the perimeter. This distance calculation was the access distance estimate applied to the entire uninsured population within a

particular polygon and in the case of irregular polygons the distance measure from the centroid will lead to a higher degree of error in the estimated travel distance being generalised to a specific polygon (Mokgalaka *et al.*, 2013:10). In addition, according to Green *et al.* (2012:6), a finer-grained analysis gives more accurate distance measures, especially in high-density areas.

To the contrary, as illustrated by Figure 4.2, a circle has no differences in the distance from the centroid to the sides of the polygon, the implication being less error in the distance measure being applied to the entire polygon. However, circles do not nest as they have gaps in between. Squares do nest, but the distances from centroid to sides have a high deviation. Hexagons are therefore a good compromise as they nest and mitigate the error in distance measure from the sides to the centroid (Mokgalaka *et al.*, 2014:6). The hexagons were then spatially classified in terms of the administration regions in which they are located. In this study, the administration regions are used for reporting purposes only and also as a form of consistency or common platform when discussing the findings.

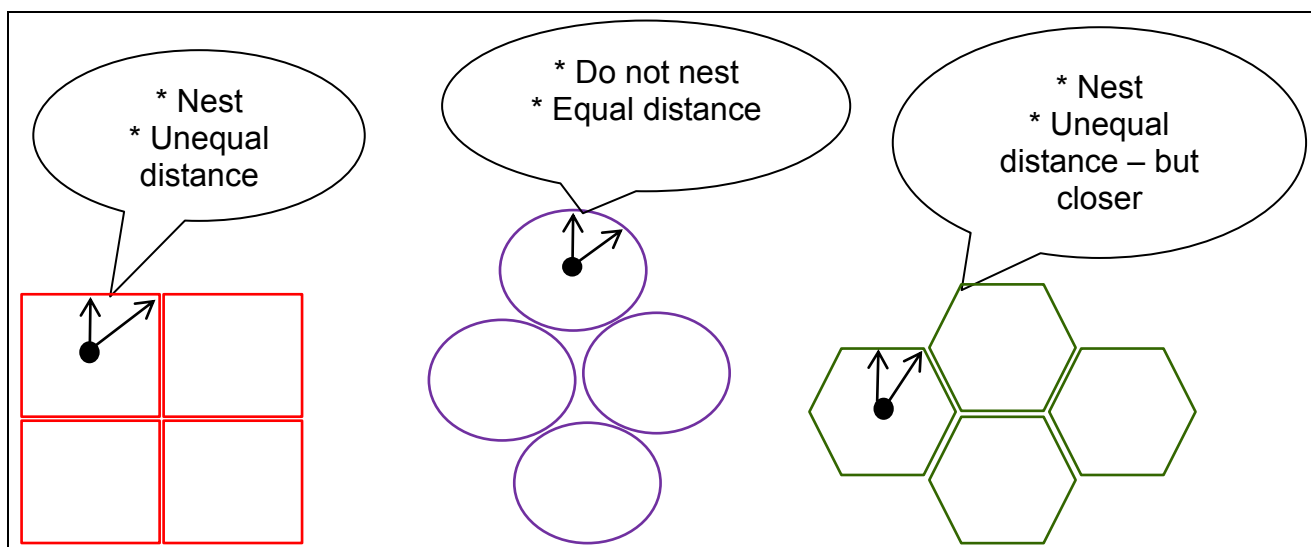


Figure 4.2: Approximation of distance for analysis unit

4.2.2 Transport network

A 2010 AfriGIS (Pty) Ltd version routable vector layer of the provincial and major roads, including the in-depth street centre lines of the study area was obtained from the CSIR. The road network was based on a subset of the transport network data used in an earlier accessibility study of the City of Johannesburg by the CSIR. This subset could be readily used since the attribute data was already cleaned and prepared when obtained. The road network was sufficiently complete and highly accurate as it covered the complete road and street network of the study area. A road network was used as it takes into consideration the natural and the built environment of the study area and can therefore accurately simulate the way in which people would travel to facilities contradictory to using straight-line distance as shown in Figure 4.3.

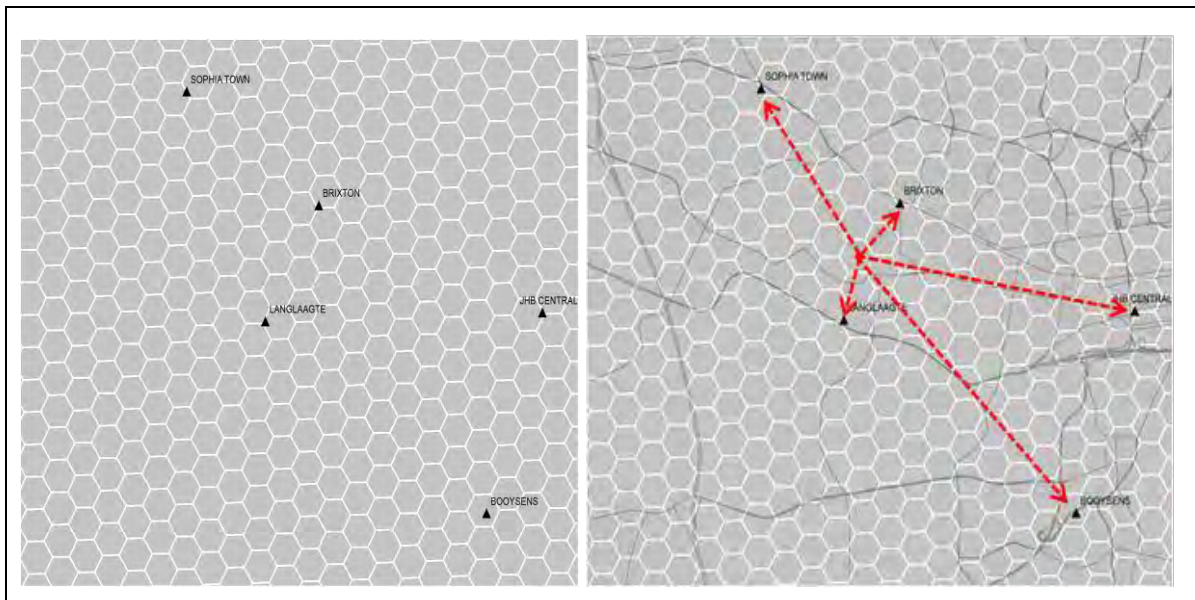


Figure 4.3: Measuring distance on a transport network from each hexagon to all facilities

The prepared transport network was used to create an origin-destination (OD) matrix or distance table. A distance table always refers to a specific map of origins and a specific map of destinations. An example of this OD matrix is illustrated in Table 4.1. This is a look-up table of all the connections between the hexagons, arranged from the shortest to the longest distance. For this study the unit used to measure access was distance in kilometres. Distance was used rather than travel time because time would make interpreting the results difficult due to the multitude of transport modes that could potentially be used by the uninsured population. In addition, Martin *et al.* (2002:8) state that transportation adds complexity to the measurement of accessibility as an area typically contains a mix of people who rely on different transportation modes.

Table 4.1: Origin-destination (OD) table or matrix

| Hexagon ID | Sophia Town | Brixton | Langlaagte | BooySENS | Johannesburg |
|------------|-------------|---------|------------|----------|--------------|
| 6011 | 2km | 4km | 3km | 25km | 5km |
| 5862 | 1km | 5km | 6km | 2km | 1km |
| 4563 | 2km | 3km | 1km | 7km | 2km |
| 4562 | 5km | 8km | 9km | 2km | 3km |
| 4552 | 2km | 1km | 3km | 5km | 6km |
| 369 | 1km | 5km | 1km | 7km | 8km |

4.2.3 PHC facility data

The 2011 PHC facility dataset was obtained from the Gauteng Provincial Department of Health (GPDH). The facilities selected for the analysis were mainly those that offered primary healthcare services. This included facilities that acted as a first contact point with the healthcare delivery system. These were facilities offering level one services of the primary healthcare package and thus excluded those facilities offering trauma and casualty services. Furthermore, hospitals that offer primary health care were also excluded because ideally they are mainly meant to provide secondary and tertiary level care. In addition, Thandrayen (2008:8) points out that hospitals provide PHC services where access to clinics and CHC is limited, e.g. rural or remote areas. This is not the case in the City of Johannesburg given the spatial distribution of clinics and CHCs. Another set of facilities which was excluded from the analysis were mobile clinic facilities because they were not stationary and their headcount data were recorded and assigned to the nearest fixed facility from the mobile route within the City. The facilities were further selected on the basis of the following criteria:

- I. Administered by the public sector.
- II. Had a fixed geographical location.
- III. Had attribute data about professional nurse clinical work days, facility operating days and hours.
- IV. Had the total headcounts for the year 2011. A database of the headcounts of the actual visits, recorded per facility.

The total number of state-owned operational facilities used for this study was 124 facilities (10 CHCs, 113 Clinics and one Satellite Clinic)

For the purpose of this study each facility was separately specified a capacity, i.e. capacity was expressed as the potential to accommodate visits to a professional nurse in a facility. Determining capacity for each facility is crucial for this study as information on, for example, staff capacity impacts on how the facility serves the uninsured population demand. In 2008, the CSIR undertook an Accessibility Mapping and Optimisation of Community Social Services study in the eThekweni Metropolitan Area. Through a discussion with eThekweni health personnel, a professional nurse rate per day – the average patient number a professional nurse can attend to in a shift – was established. The number of patients a nurse can attend to in a shift was established to be an average of 20 visits per nurse shift including antenatal visits that take longer. This equates to 4 710 annual visits per professional nurse for a 240-day work year (Green *et al.*, 2012:10). Based on this, the CSIR then developed an equation to calculate the total supply or capacity for each facility as follows.

$$n \times s \times ps \times d = \text{facility capacity}$$

where

n = number of nurses at a facility per shift

s = hours of operation of a facility

ps = number of patients a nurse can attend to in one shift

d = number of days per annum that the facility operates.

[ps = p – (ANCV*3.125) + ANCV:

p = normal patient visits per shift for which one visit takes 16 minutes to attend to and a shift lasts 8 hours: $p=(60/16)*8 \therefore p = 30$. **ANCV** = anti-natal care visits which take 3.125 times longer (50 min) than a normal visit. ANCV is the actual number of anti-natal visits recorded for one year for each facility]. (Green *et al.*, 2012:10)

Equation 4.1: Facility capacity calculation (Adopted from Green *et al.*, 2012:10)

This equation then formed the basis for determining the capacity for each facility in this study based on the supply of professional nurses. The reason behind using professional nurses emanates from a discussion with the GPDH officials regarding a referral path that depends on the availability of a doctor at the facility. Most facilities in this study area had session doctors, which means the doctor visited a specific facility according to a schedule. In these cases a patient will arrive at a facility, where an enrolled student nurse or assistant nurse who has completed the first basic level of nursing qualifications, or a nurse who has completed the first level qualification to be classified as a nurse checks the vital signs of the patient and assists with basic activities such as weighing. From here the patient is referred to a professional nurse with the highest level of nursing qualifications for diagnosis and a license to dispense medication. Then, if the case is too severe for the professional nurse to treat, the patient will make an appointment to see the doctor during one of the sessions when he or she is scheduled to visit the facility. Given this, the professional nurses are considered suitable for use as the representative of healthcare supply in this study area. The exact number of professional nurses for each facility or the total for the entire study area cannot be stated in this dissertation due to a non-disclosure agreement with the GPDH.

According to Green *et al.* (2012:10-11), it is acknowledged that the National Department of Health had planned new initiatives to increase the number of visits to a clinic for all services which include

services rendered by professional nurses as applied above and those to support staff in a well-functioning clinic with an effective skills spread to 33 visits per shift in a 24-hour clinic and 40 visits per shift or day at 8-hour clinics. The latter was applied in this study. The visits excluded any other services at a facility a person may use on the same day, for example X-rays, doctor consultations, and obtaining medicines from the pharmacy (Green *et al.*, 2012:10). The capacity calculation in Equation 4.1 was then adopted from Green *et al.* (2012:10) and adapted to the following Equation 4.2.

| | |
|---|-----|
| pw / d = n | [1] |
| and | |
| n x s x ps x d = capacity | [2] |
| where: | |
| pw = professional nurse working days | |
| n = number of professional nurses at a facility per shift | |
| s = hours of operation of a facility | |
| ps = number of patients a nurse can attend to in one shift | |
| d = number of days per annum that the facility operates | |

Equation 4.2: Facility capacity calculation applied in this study

4.2.4 Access standard

Access standards are of cardinal importance in an accessibility analysis as they can either determine or indicate, spatially, the level of access of a facility. In addition, if no distance is set or set too high then all the uninsured population will be allocated to all facilities. The 5km National Department of Health Standard (2011 & 2000) for primary health care was applied in this study. The 5km travel distance standard was confidently applied in this study because it had been specifically tailored for the study area based on the socio-economic profiles drawn up by the CSIR together with the GPDH for an accessibility study in 2012 (Green *et al.*, 2012). The socio-economic aspect was taken into consideration as this has an influence on the kind of transport mode most likely to be available and used, which in turn influences the ease of accessing a facility within a given distance (Mokgalaka *et al.*, 2011:4). This 5km travel distance standard equates to a normal walking time of a maximum of one hour.

4.2.5 Actual demand data

In addition to the headcounts collected with the PHC facility dataset, a second set of the actual demand was obtained. Since there was no residential address database of all the patients who visit public primary healthcare facilities due the majority of patients retaining their medical cards, a 2011 Electronic Tuberculosis Register (ETR.Net data) with 23 294 records was considered as a good proxy to serve as actual demand data in this study. This was considered a good representative sample of actual visits because the patient register stores data from the first contact visit that people make before the TB diagnosis. Literature (Al-Taiar *et al.*, 2010 and Scott *et al.*, 2002) has also highlighted the practicality of using population based cancer and TB registers as good patient register proxy datasets as they comprise the patient's residential addresses. A soft-copy database of patient records was obtained from the GPDH.

In terms of data preparation, a very considerable and time consuming part involved the cleaning and geocoding of the patient register database. Geocoding is the conversion of addresses (like 1600 Amphitheatre Parkway, Mountain View, CA) into geographic coordinates (like latitude 37.423021 and longitude -122.083739) which you can use to position a map (Lloyd, 2010:13). The patient records were captured and coded in Microsoft Office Access. The records were each assigned a unique identifier code. In a GIS environment, the addresses of the records were geocoded using a python script. The script sends a request to the Google Geocoding API (Application Development Platform) as follows. For each address it began with a Google geocoding routine and then returned a coordinate set including latitude, longitude and the actual address Google geocoded it to. The return address served to validate the sets of coordinates. This process is called reverse geocoding. This routine was repeated for all the records. It was, however, observed in the initial stages of the data pre-processing that 24.1% of the records register database had missing and incomplete residential addresses. (This was also discovered in the Scott *et al.* (2002:239) study that uses a cancer register.) Those records that had incomplete residential addresses were geocoded to street or suburb level depending on the level of information available. This is done through a process called address interpolation or address matching where the locations can be predicted given the level of information provided. Those records that did not have an address, 3.09% of the entire dataset, were excluded from the analysis. Another set of records that was excluded from the analysis concerned those records that reported to a facility in a prison, 1.34% of the entire dataset. These were also excluded because the services are offered periodically and exclusively for people in prison and therefore the patients were obliged to use only those facilities. From the original dataset, 95.57% of the records with each having a unique identifier code, the facility visited, residential address and geographic coordinates of the patient were then used as input into the analysis.

4.2.6 Uninsured population

The target population of the study was considered to be the uninsured population. The 2011 National Census served as the basis for determining the uninsured population. Three methods of calculating the uninsured population were realised. These methods were based on a combination of three variables from the population data: (a) the annual household income category; (b) age; and, (c) average facility visits. In 2011, StatsSA undertook a General Household Survey to establish the proportions of uninsured and insured people per annual household income group. Similarly, the City of Cape Town also established what it calls the health dependent population ratio derived from the total population data taking into consideration socio-economic profiles of the population (Green *et al.*, 2014). Through applied research and various engagements with government officials over the past years, the CSIR also developed two methods of calculating the uninsured population. The first method, referred to as scenario 2 for reporting purposes in this study, was developed by the CSIR in 2007 for measuring access to a range of social facilities in eThekweni Metropolitan Municipality. This method was later adapted by the CSIR to develop another method, referred to as scenario 3, for a study done in the City of Johannesburg and eThekweni Metropolitan Municipality in 2012. Both these scenarios were based on input from the Department of Health in each of the metropolitan areas (Green *et al.*, 2012; Green & Mans, 2008). These methods are labelled scenarios for ease of reference in this study and the following discussion specifies how they were determined for use in this study.

To calculate the uninsured population, the data required specific age and income breakdown. The first task was to decrease the eleven 2001 StatsSA average annual household income groups to five for the purpose of this study in order to enhance the stability of the data. Census 2011 found that over the past ten years, the average annual household income for all households in South Africa more than doubled. The Consumer Price Index (CPI) also indicates that income should have increased during this period in line with inflation (StatsSA, 2011:41). For this reason, following income group studies by Van Wyk and Van Aardt (2008), the StatsSA average annual household income groups were adjusted with the change in CPI between 2001 and 2011 as illustrated in Table 4.2.

Table 4.2: 2001 & 2011 Annual Income Household Groups

| Income Groups | 2001 StatsSA Annual Household Income Groups | 2011 Adjusted Annual Household Income Groups |
|----------------------|--|---|
| Low | 0 to R9 600 | 0 to R19 200 |
| Low-Middle | R9 601 to R38 400 | R19 201 to R76 800 |
| Middle | R38 401 to R153 600 | R76 801 to R307 200 |
| Middle-High | R153 601 to R614 400 | R307 201 to R1 228 800 |
| High | R614 400+ | R1 228 801+ |

The 2011 National Census was acquired from StatsSA through Community Profiles. This is a package of different CDs containing 12 summarised databases on certain topics embalmed in a SuperCross application. The interactive SuperCross application was used to create cross-tabulations of data on different geographical levels and to export them to a usable format for manipulation. See Figure 4.4 for an example of data cross-tabulation. Using SuperCross, population was firstly extracted based on household size and the five 2011 income groups on a ward level. The data was then used to calculate the number of people in each of the income groups using the household size per wards. In SuperCross, population was again extracted based on two age groupings of older than 5 years (>5) and 5 years and younger (=<5) on ward level. This data was then used together with the calculated results from the first data extraction to calculate, in each income group, the number of people in the >5 and =<5 years age groups per ward.

Census 2011; Interactive data in SuperCROSS - [Household-Income-Size_21032013.scs]

File Edit Cross Calculations Window Help

Statistics South Africa
Dwellings
Table 1
Geography by Annual household income and Household size
for Household weighted

| | No income - R 9601 - R 19 600 | | R 19 601 - R 38 200 - R 38 201 - R 76 400 | | | | | | | | | | R 76 401 - R | | | |
|-------------------|-------------------------------|-----|---|-------|-----|-----|-----|-----|-----|-----|----|-----|--------------|-----|-----|-------|
| | 9 | 10+ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | 1 | 2 | 3 | 4 |
| 79800001: Ward 1 | 39 | 58 | 612 | 690 | 733 | 789 | 655 | 451 | 246 | 146 | 87 | 87 | 74 | 137 | 147 | 178 |
| 79800002: Ward 2 | 29 | 28 | 614 | 702 | 789 | 883 | 638 | 452 | 230 | 134 | 65 | 67 | 89 | 185 | 148 | 185 |
| 79800003: Ward 3 | 28 | 28 | 431 | 517 | 540 | 583 | 454 | 315 | 210 | 109 | 68 | 97 | 49 | 97 | 79 | 112 |
| 79800004: Ward 4 | 51 | 38 | 656 | 618 | 700 | 750 | 557 | 387 | 191 | 123 | 70 | 92 | 99 | 142 | 147 | 194 |
| 79800005: Ward 5 | 49 | 42 | 832 | 828 | 905 | 880 | 606 | 454 | 219 | 147 | 58 | 103 | 115 | 150 | 138 | 163 |
| 79800006: Ward 6 | 21 | 26 | 857 | 832 | 712 | 717 | 491 | 285 | 192 | 82 | 55 | 68 | 77 | 104 | 101 | 102 |
| 79800007: Ward 7 | 26 | 24 | 496 | 648 | 543 | 537 | 393 | 240 | 150 | 89 | 57 | 67 | 135 | 313 | 386 | 549 |
| 79800008: Ward 8 | 18 | 21 | 1 191 | 1 230 | 847 | 615 | 352 | 219 | 119 | 68 | 18 | 33 | 90 | 171 | 256 | 278 |
| 79800009: Ward 9 | 4 | 8 | 243 | 521 | 371 | 328 | 199 | 107 | 51 | 18 | 11 | 14 | 108 | 365 | 486 | 570 |
| 79800010: Ward 10 | 11 | 13 | 549 | 746 | 521 | 386 | 268 | 116 | 90 | 41 | 18 | 30 | 113 | 303 | 378 | 387 |
| 79800011: Ward 11 | 24 | 43 | 892 | 740 | 550 | 495 | 322 | 212 | 106 | 78 | 49 | 82 | 235 | 314 | 324 | 353 |
| 79800012: Ward 12 | 21 | 20 | 752 | 595 | 574 | 384 | 248 | 163 | 99 | 56 | 35 | 43 | 253 | 323 | 336 | 389 |
| 79800013: Ward 13 | 14 | 10 | 521 | 549 | 501 | 503 | 338 | 165 | 81 | 43 | 26 | 25 | 634 | 778 | 930 | 1 101 |
| 79800014: Ward 14 | 15 | 9 | 275 | 355 | 373 | 345 | 207 | 149 | 87 | 45 | 20 | 18 | 315 | 494 | 616 | 697 |
| 79800015: Ward 15 | 47 | 67 | 446 | 406 | 384 | 361 | 257 | 180 | 123 | 92 | 80 | 134 | 130 | 117 | 142 | 118 |
| 79800016: Ward 16 | 13 | 26 | 904 | 590 | 447 | 360 | 265 | 188 | 122 | 87 | 43 | 77 | 324 | 255 | 214 | 218 |
| 79800017: Ward 17 | 20 | 33 | 283 | 427 | 446 | 443 | 370 | 226 | 124 | 73 | 46 | 67 | 60 | 178 | 298 | 390 |
| 79800018: Ward 18 | 28 | 52 | 129 | 374 | 399 | 429 | 374 | 230 | 154 | 116 | 68 | 100 | 84 | 225 | 361 | 539 |
| 79800019: Ward 19 | 26 | 64 | 645 | 580 | 414 | 369 | 220 | 140 | 96 | 54 | 43 | 67 | 210 | 228 | 261 | 231 |
| 79800020: Ward 20 | 23 | 34 | 672 | 553 | 503 | 466 | 367 | 227 | 141 | 118 | 76 | 137 | 199 | 223 | 199 | 221 |
| 79800021: Ward 21 | 27 | 25 | 885 | 616 | 561 | 453 | 303 | 196 | 141 | 94 | 45 | 86 | 309 | 266 | 282 | 255 |
| 79800022: Ward 22 | 22 | 53 | 433 | 466 | 424 | 369 | 249 | 153 | 97 | 75 | 48 | 78 | 182 | 252 | 317 | 343 |
| 79800023: Ward 23 | 3 | 3 | 784 | 309 | 133 | 90 | 24 | 13 | 4 | 3 | 1 | - | 638 | 884 | 501 | 452 |
| 79800024: Ward 24 | 22 | 17 | 1 062 | 713 | 498 | 443 | 283 | 188 | 105 | 50 | 29 | 46 | 259 | 153 | 135 | 124 |
| 79800025: Ward 25 | 27 | 38 | 989 | 738 | 508 | 458 | 340 | 228 | 110 | 73 | 56 | 103 | 300 | 286 | 289 | 330 |
| 79800026: Ward 26 | 27 | 48 | 501 | 459 | 326 | 318 | 192 | 163 | 87 | 75 | 49 | 112 | 127 | 144 | 137 | 155 |
| 79800027: Ward 27 | 19 | 39 | 467 | 413 | 356 | 298 | 237 | 157 | 111 | 66 | 49 | 79 | 152 | 166 | 178 | 185 |
| 79800028: Ward 28 | 31 | 76 | 575 | 482 | 407 | 321 | 240 | 138 | 89 | 76 | 39 | 101 | 130 | 195 | 171 | 202 |
| 79800029: Ward 29 | 27 | 44 | 394 | 385 | 352 | 315 | 248 | 135 | 105 | 67 | 45 | 80 | 120 | 202 | 205 | 210 |
| 79800030: Ward 30 | 32 | 45 | 1 546 | 1 111 | 730 | 421 | 283 | 153 | 106 | 73 | 38 | 74 | 246 | 316 | 199 | 155 |
| 79800031: Ward 31 | 28 | 46 | 1 157 | 834 | 547 | 379 | 205 | 114 | 79 | 49 | 34 | 52 | 176 | 198 | 143 | 152 |
| 79800032: Ward 32 | 9 | 5 | 1 248 | 627 | 460 | 312 | 162 | 92 | 47 | 23 | 16 | 16 | 1 073 | 970 | 627 | 493 |
| 79800033: Ward 33 | 32 | 45 | 483 | 431 | 390 | 389 | 249 | 162 | 112 | 61 | 56 | 93 | 182 | 224 | 238 | 249 |
| 79800034: Ward 34 | 16 | 35 | 1 260 | 781 | 523 | 427 | 236 | 151 | 101 | 77 | 45 | 76 | 287 | 267 | 231 | 227 |
| 79800035: Ward 35 | 13 | 41 | 464 | 425 | 385 | 344 | 256 | 149 | 103 | 87 | 53 | 81 | 111 | 163 | 123 | 187 |
| 79800036: Ward 36 | 19 | 20 | 367 | 360 | 357 | 329 | 230 | 145 | 93 | 93 | 45 | 79 | 90 | 156 | 172 | 188 |
| 79800037: Ward 37 | 19 | 36 | 602 | 557 | 385 | 385 | 249 | 163 | 115 | 71 | 49 | 123 | 129 | 131 | 153 | 136 |

Figure 4.4: Sample cross-tabulation in SuperCross

The second set of data serving as input in calculating the uninsured population of the study area was the 2011 StatsSA General Household Survey (GHS) data on medical aid coverage by total annual household income. As the GHS data was only available on the lowest spatial level of metropolitan area and non-metropolitan area distinction, data was then acquired on a provincial level. This is because it was difficult to extract only the City of Johannesburg data from the Gauteng Provincial data since this province has three metropolitan areas, namely City of Johannesburg, City of Tshwane and Ekurhuleni Metropolitan Municipality. Unlike the City of Johannesburg, City of Cape Town GHS data on medical aid coverage can be extracted easily from Western Cape Provincial data as it is the only metropolitan area in this province. It was determined, from the GHS data, that in 2011 75% of the population in the Gauteng Province were medically uninsured and 25% were medically insured. These ratios were then applied to the 2011

Census population of the City of Johannesburg, thus: $4\,434\,828 * 0.75 = 3\,328\,987$ uninsured and $4\,434\,828 * 0.25 = 1\,105\,841$ insured population.

Based on the calculation of the uninsured population and confirmed through discussions with the relevant officials from the GPDH and their experience with regard to users of government health services, the uninsured population figure was then used to calculate the uninsured population for each scenario as follows:

- i. **Scenario 1:** the status of uninsured was proportionally allocated to the population in each income category using the total uninsured population of the study area as the control variable. The ratios as derived from the GHS data were as follows:
 - a. R0 – R19 600 = 84%
 - b. R19 600 – R76 400 = 92%
 - c. >R76 400 = 47%
- ii. **Scenario 2:** all persons in the low-income group and 50% of persons in the middle-income group were assigned the status of uninsured (Green *et al.*, 2008).
- iii. **Scenario 3:** persons from the highest income category were first assigned the status of “insured”; the insured population estimate as determined above to be 1 105 841 people or 25% of the total population, and then people from the next highest income category and so on until the total insured population number has been assigned. Once the total number of insured population was reached, the remainder of the population was then considered to be uninsured (Green *et al.*, 2012).

The uninsured population for each scenario was then translated into the potential annual visits likely to be generated. In accordance to the information supplied by the GPDH and the eThekweni Department of Health for the Geographic Accessibility Study of Social Facility and Government Service Points for the Metropolitan Cities of Johannesburg and eThekweni by the CSIR in 2012, the total number of health visits were calculated on the agreed assumption that for every child who is 5 years and younger, 5 visits would be generated in eThekweni and 4 visits in Gauteng per year. For all persons older than 5 years, 3.5 visits in eThekweni and 3 in Gauteng per year would be generated (Green *et al.*, 2012:9). The visits rate for eThekweni was also applied in the 2008 study by the CSIR on Accessibility Mapping and Optimisation of Community Social Services in the eThekweni Metropolitan Area (Green *et al.*, 2008:4-1). In this study, the count of 2 annual visits for those >5 years and 4 annual visits for those =<5 years for City of Johannesburg based on findings which emanated from the countrywide 2011 PHC Utilisation study by the Health Systems Trust (2011, HST) was applied. Meaning that the >5 years total uninsured population was multiplied by 2 visits and =<5 by 4 visits for each ward. This resulted in the following total visits for each scenario:

- i. Scenario 1 = 7 124 518 visits per annum.
- ii. Scenario 2 = 7 149 055 visits per annum.
- iii. Scenario 3 = 7 416 886 visits per annum.

An accurate spatial distribution of the visits for each scenario onto the analysis units had to be undertaken. The 2008 Eskom’s Spot Building Count (SBC) dataset was obtained to serve as the statistical surface to transfer the visits data onto the analysis unit. The SBC point dataset was used for the distribution because:

- i. It is a static spatial unit.
- ii. It is not confined by boundaries and thus can be aligned to any demarcation.
- iii. It is a good proxy of population distribution.
- iv. Each SBC point is a potential household and thus not found in areas such as rivers and roads, as shown in Figure 4.5.
- v. Points can be used to transfer the data to a standardised analysis unit of the user’s choice.

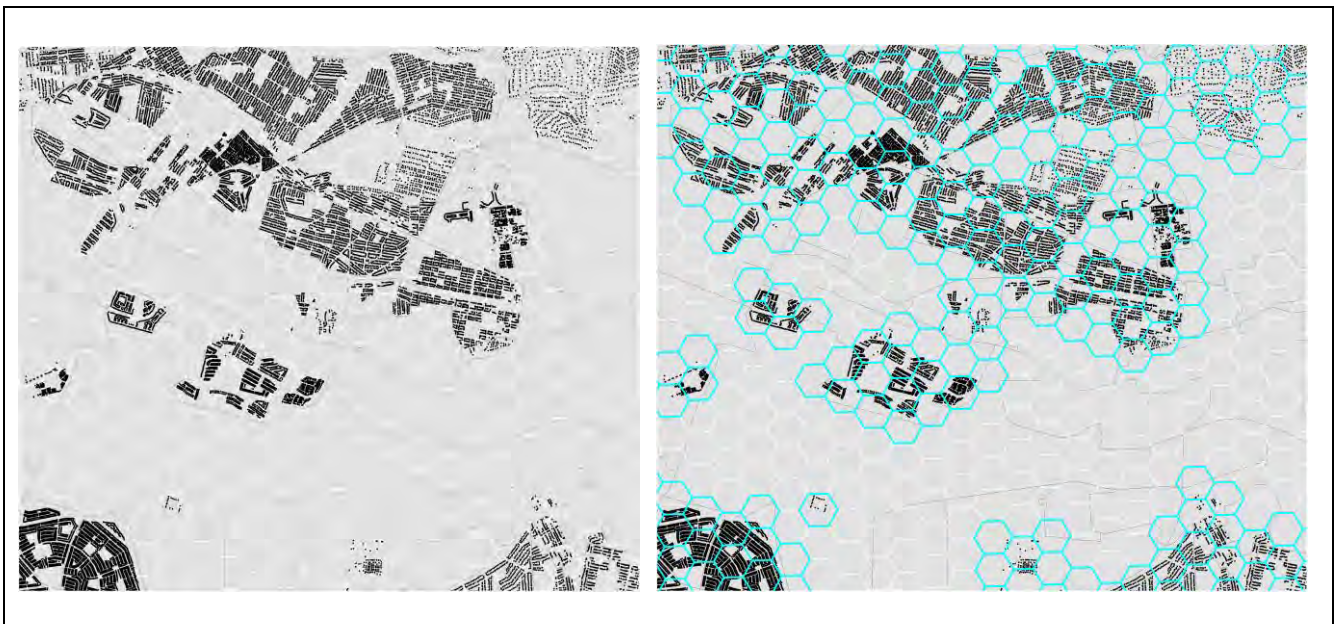


Figure 4.5: Use of SBC points as a proxy of population distribution

Since the SBC point dataset is only a building count and no other information is available regarding the size or type of structure it represents, Mans (2012:41) classified the dataset by assigning a weight to each point representing a building. In other words, the weight of the point would represent the probable household size of the building (Mans, 2012:42). This assigned weight then, in the context of this study, indicates the relative contribution of that point to the total visits for each scenario. The process of classifying the dataset was based on the principles of dasymetric mapping. Dasymetric mapping is defined by Eicher & Brewer (2001) as “a process of transforming data from the arbitrary zones of the aggregate dataset to recover (or try to recover) and depict the

underlying statistical surface. This transformation process incorporates the use of an ancillary dataset that is separate from, but related to, the variation in the statistical surface". A five-step hierarchical approach in classifying the dataset was followed by Mans (2012:42) and describes the steps as follows:

"Step 1 – Assign weights (potential household size) to the SBC-points. The average household size per census small area layer (SAL) was calculated (population divided by households) and this figure was then assigned the SBC-points falling inside each SAL. The assumption underlying this process is that each SBC is a potential household, but we know that this is not always the case. Hence, a hierarchical exclusion process is followed to get a more accurate representation (Steps 2 to 5)." (See Mans (2012:42) for Steps 2 to 5).

Once the household weights were assigned to each point, the following analysis steps to reassign the visits onto the analysis units were undertaken to achieve an accurate distribution. (The analysis steps are also illustrated by the diagram in Addendum B)

- i. Each ward came with a unique identity (I.D.) number from 2011 Census SuperCross in tabulated form.
- ii. In ArcMap the table was joined to the ward spatial layer based on the unique I.D.
- iii. Then the ward and analysis units were spatially joined to the SBC so that the ward and hexagon I.Ds are transferred to the point they have a spatial relationship with, i.e. each point had the ward and hexagon I.D.
- iv. Extracted the SBC table.
- v. In Microsoft Office Access summed values by ward I.D.
- vi. Determined the multiplication factor per point and then multiplied the SBC household weight by the total visits. The assumption here was that the SBC points with higher household weight took on more visits.
- vii. Summed SBC point by hexagon I.D.
- viii. Joined table with visits to the hexagon spatial layer in ArcMap based on the unique I.D. to commence with analysis.

The table with the visits was joined to the analysis unit in such a way that the field for each scenario was kept separate so that the analysis was rerun for each scenario.

4.3 Framework for Data Analysis

The GIS analysis tools used in this study consisted of two software applications: Flowmap and ARCGIS. Flowmap was used to undertake accessibility analysis while ARCGIS was used to prepare the data and outputs. According to Geertman *et al.* (2003:156), Flowmap is a stand-alone software package dedicated to the analysis of spatial interaction. An example of frequently and regularly occurring interaction is commuting, and Flowmap has the capability to analyse and model

the actual interaction data and also predict potential interaction flows (Geertman *et al.*, 2003:156). This capability makes Flowmap a very suitable tool to measure access to public primary healthcare. More reasons for choosing Flowmap to measure accessibility included:

- I. Origin and destination locations did not necessarily have to be part of the transport network when performing the analysis. This provided considerable flexibility in data management especially since the accessibility analysis was rerun for each of the three scenarios.
- II. When undertaking the catchment area analysis, it was possible to account not only for the distance parameter but also for the capacity of the facility.
- III. Large data sets, like the transport network used in the study, were handled with relative ease.
- IV. Analysis outputs were easily converted to ARCGIS file formats to produce results.

The Flowmap functionality used in this study to measure accessibility was the catchment area analysis model. Catchment area analysis determines the current situation of access with regards to capacity and location from all the origin locations or areas to the nearest destination. Catchment area analysis was undertaken using a GIS-based form of catchment allocation modelling in Flowmap. This allocates the visits from each origin to the closest destination using a transport network as shown in Figure 4.6.

In a catchment area analysis, environment capacity constraints and spatial competition are considered in addition to the distance parameter. Each origin represents a value which indicates its total visits and each destination location has a value which indicates the maximum amount of visits it can accommodate. These visits and capacity parameters are annual. The visits from the origin locations are allocated to the nearest destination location, unless the capacity of the closest destination has been reached. In such a case, the visit is then allocated to the next closest destination, and so on, and stopping the assignment either when capacity has been reached, or when the access distance range is exceeded. Unlike proximity counts, every visit in the catchment area analysis is allocated only once given that the distance from the origin is not more than the set maximum standard of 5km travel distance. This basically means that the catchment area analysis was only performed for one set of origin and destination location. This subsequently demarcates catchment areas around each facility and shows whether provision is sufficient and equitable. The catchment area analysis was carried out separately for each of the three scenarios.

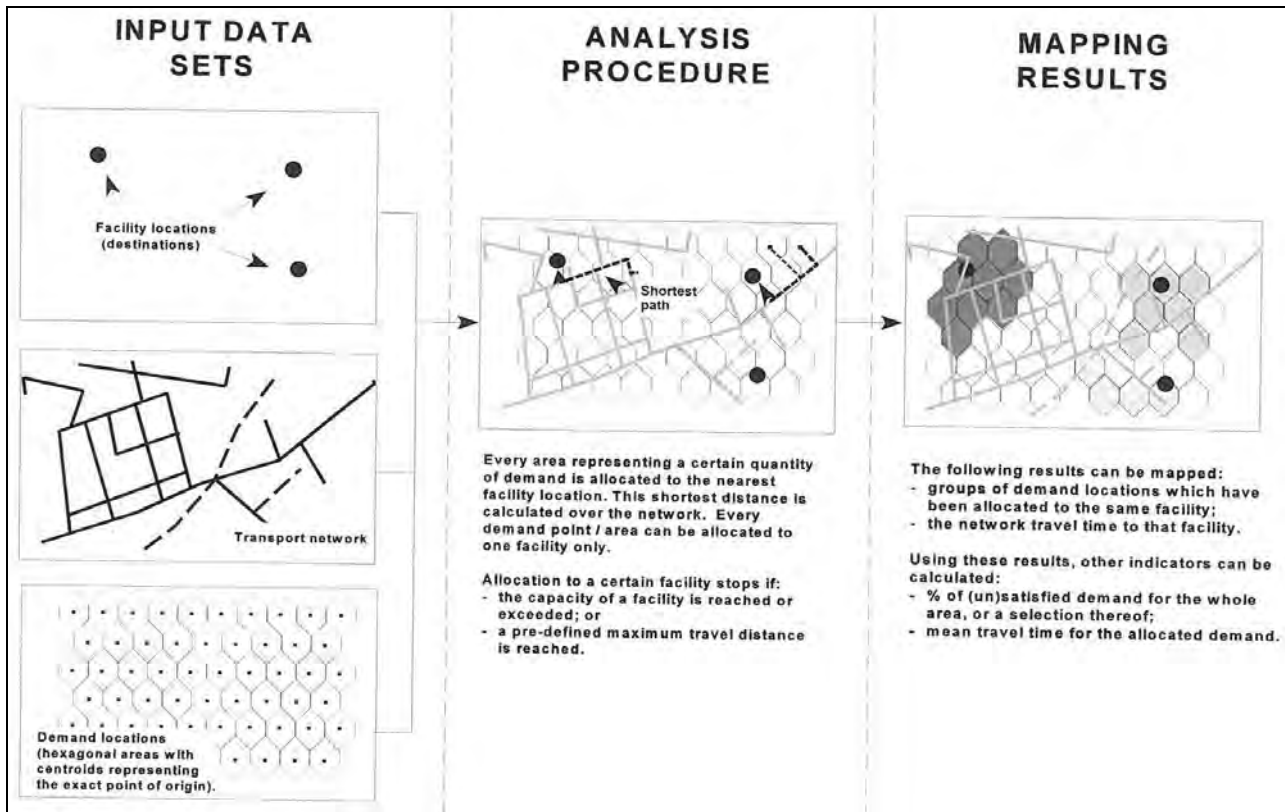


Figure 4.6: Catchment area analysis (Green *et al.*, 1996:6)

The catchment area analysis results from each of the three demand scenarios were then compared with the actual usage rates in the form of headcounts per facility recorded by the City. The Pearson function syntax in Microsoft Excel was used to analyse the extent of a linear relationship between two data sets; the actual visits in terms of headcounts as the set of independent variables and the allocated visits from the catchment area analysis as the set of dependent variables. The formula syntax and usage of the Pearson function returns the Pearson product moment correlation coefficient, r , a dimensionless index that ranges from -1.0 to 1.0 inclusive and reflects the extent of a linear relationship between two data sets (King *et al.*, 2011:106).

PEARSON(array1, array2)

The PEARSON function syntax has the following arguments:

Array1: A set of independent values.

Array2: A set of dependent values

Equation 4.3: Pearson function syntax

This revealed whether the allocated visits correlated with the number of visits actually generated in

the 2011 calendar year. The geocoded addresses from the patient register and the facility they actually visited were also analysed to indicate whether patients used the closest facility to their residence. The results and findings of the analyses are shown and discussed in the following chapter.

CHAPTER 5

5 RESULTS AND FINDINGS

5.2 Introduction

Although the framework for data analysis was discussed in detail in Chapter Four, Table 5.1 below summarises the criteria and processes undertaken in terms of the analyses.

Table 5.1: Criteria and processes for PHC analyses

| | |
|--|---|
| Description | The facilities selected for the analyses are mainly those that offer public primary health care services and act as a first point of contact with the health service delivery system. Attached to the facility data are attribute data indicating the capacity of the facility. |
| Facilities analysed | 116 primary health care facilities with fixed locations (Clinics and Community Health Centers) |
| Demand | A. Scenario 1 = 7 124 518 visits per annum B. Scenario 2 = 7 149 055 visits per annum C. Scenario 3 = 7 416 886 visits per annum |
| Supply | Each facility was separately specified a capacity, i.e. translated into the potential to accommodate visits (visits to a professional nurse in a facility). |
| Travel mode and access distance | Transport via existing road network, with a travel distance standard: Facilities must be accessed within 5km (National Health Standard) |
| Analyses undertaken | I. Measure access to primary healthcare facilities using the uninsured population visits. II. Compare results from the uninsured population analysis with the actual demand. |

5.3 Results and findings

This results and findings section will discuss:

- a. The general accessibility of the uninsured population to PHC facilities without taking their capacity into consideration, i.e. how far a person has to travel to reach a facility regardless of whether the facility can accommodate the visit.
- b. Capacity and travel distance constrained analysis for the entire uninsured population; i.e. how many visits can be accommodated by a facility with capacity within 5km from its location.
- c. A comparative discussion of the results from calculating and analysing the three uninsured population scenarios, and relating them to the actual demand.

Figure 5.1 is a travel distance map for all the uninsured population to the closest PHC facility when no measure of the facility size or service capacity is taken into consideration. The travel distance map displays the distance from the uninsured population's place of residence to the nearest facility by means of travel distance classes.

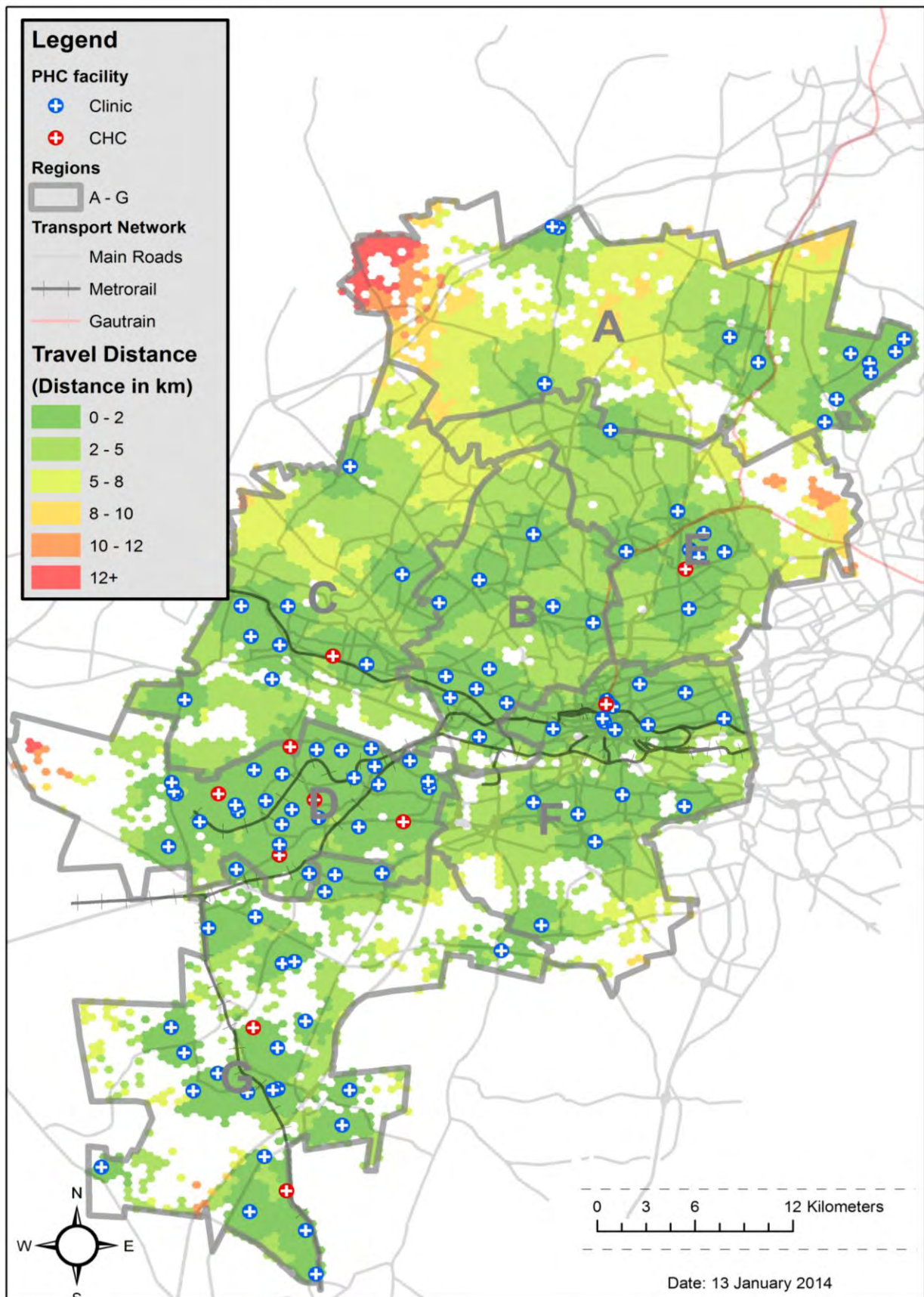


Figure 5.1: Travel distance to closest primary healthcare facility

This travel distance is shown in kilometres and displayed in a range of colour bands of varying kilometre increments. The dark green colours in the first lowest distance bands of 0-2km and 2-5km on the map represent locations that are closest to a facility, while lime green and yellow to red areas represent locations that are the furthest from facilities. The areas shaded with a white colour are in most cases areas where there is no population. From this, one can conclude whether the population is relatively far from the nearest PHC facility, or relatively close.

It is clear that access to public PHC facilities in the City of Johannesburg is very good. Figure 5.1 shows a good distribution of facilities within the study area. The average travel distance to a public PHC facility across the area is 3.6km, well within reach of a facility. In terms of figures, 53% of the City's population is within 2km and 93% within 5km of a facility. This is particularly good given that the national travel distance standard for primary health care is 5km (National Department of Health Standard, 2011 & 2000), and this therefore proves the practicality of the travel standard especially for this study area.

Looking at Figure 5.1 again, public PHC facilities appear to be well located. The study area has more facilities located in the more dense areas of Region G while the low dense and / or sparse areas of Region A and B have fewer facilities. This shows that the facilities are distributed well and in line with the population growth patterns of the study area as a whole. For example, there is a concentration of PHC facilities in the high dense areas of Soweto which has been ranked the largest town in South Africa in terms of population growth by Census 2011 (StatsSA, 2011:41).

Figure 5.2 illustrates the catchment areas of the facilities irrespective of distance and capacity while Figure 5.3 is the inverse. It is clear that when no measure of capacity and travel distance is set, all the demand in the City will be accounted for at all facilities. So in this case, even if a facility is located 65km away from the potential demand for example, people will still be allocated. This, however, does not indicate whether the provision of services is both sufficient and equitably provided, especially from a desktop-based study. Nevertheless, this can be used to define the potential catchment population per year for each facility.

On the other hand, Figure 5.3 indicates the catchment areas of the facilities taking into account distance and capacity measures. Of interest in the figure is, firstly, the appearance of facilities that seem well capacitated in the northern suburbs of the study area and, secondly, there are indications of capacity shortfalls in areas with higher population densities (central, west and south areas) where the capacity of these facilities runs out within 2km from them. This is more prominent in the areas of Region D where catchment areas run up to 2km travel distance. These areas include Meadowlands, Protea Glen and Naledi in the Soweto area, Orange Farm and the Johannesburg Central Business District (CBD).

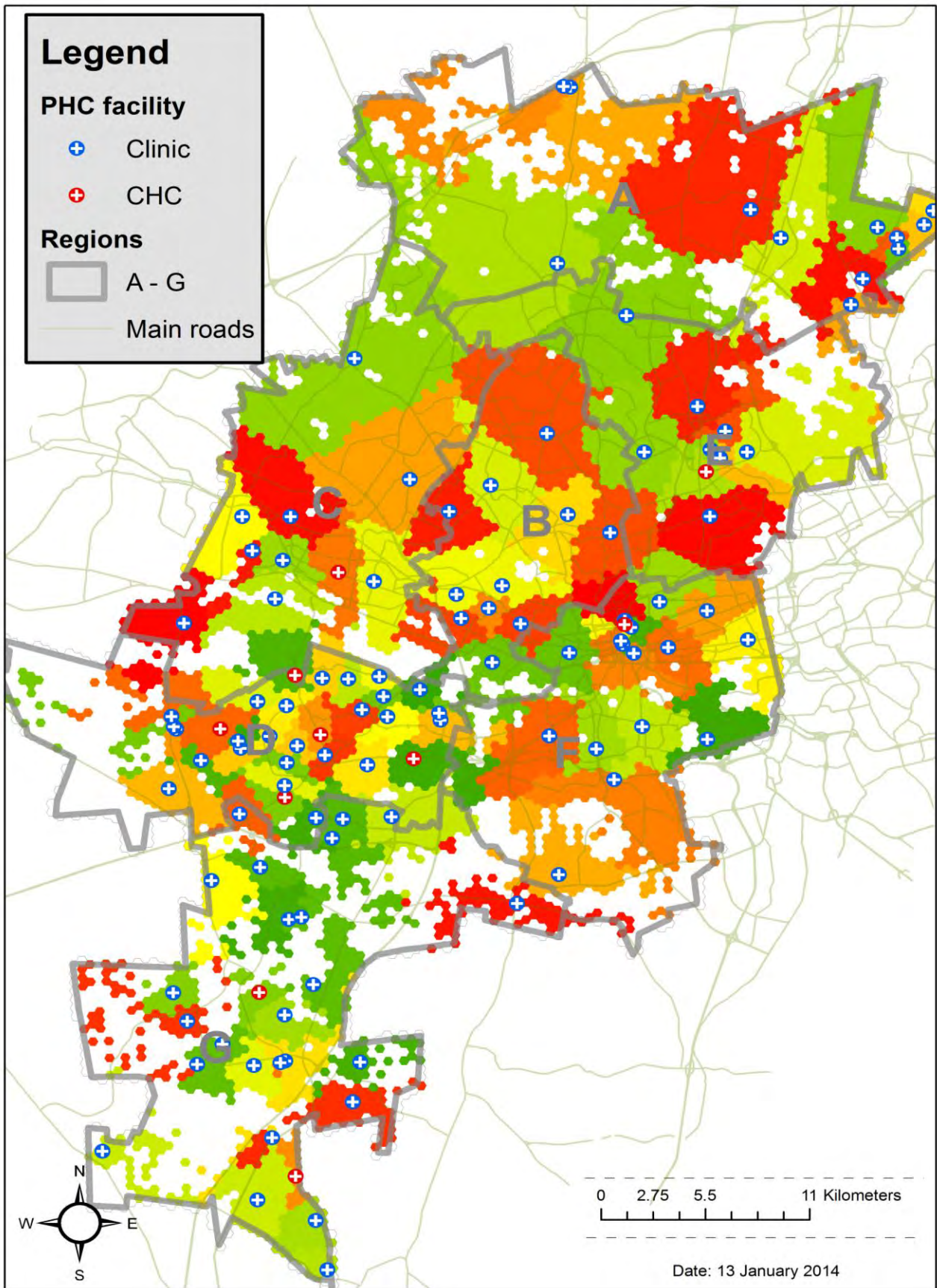


Figure 5.2: Facility catchments areas irrespective of distance

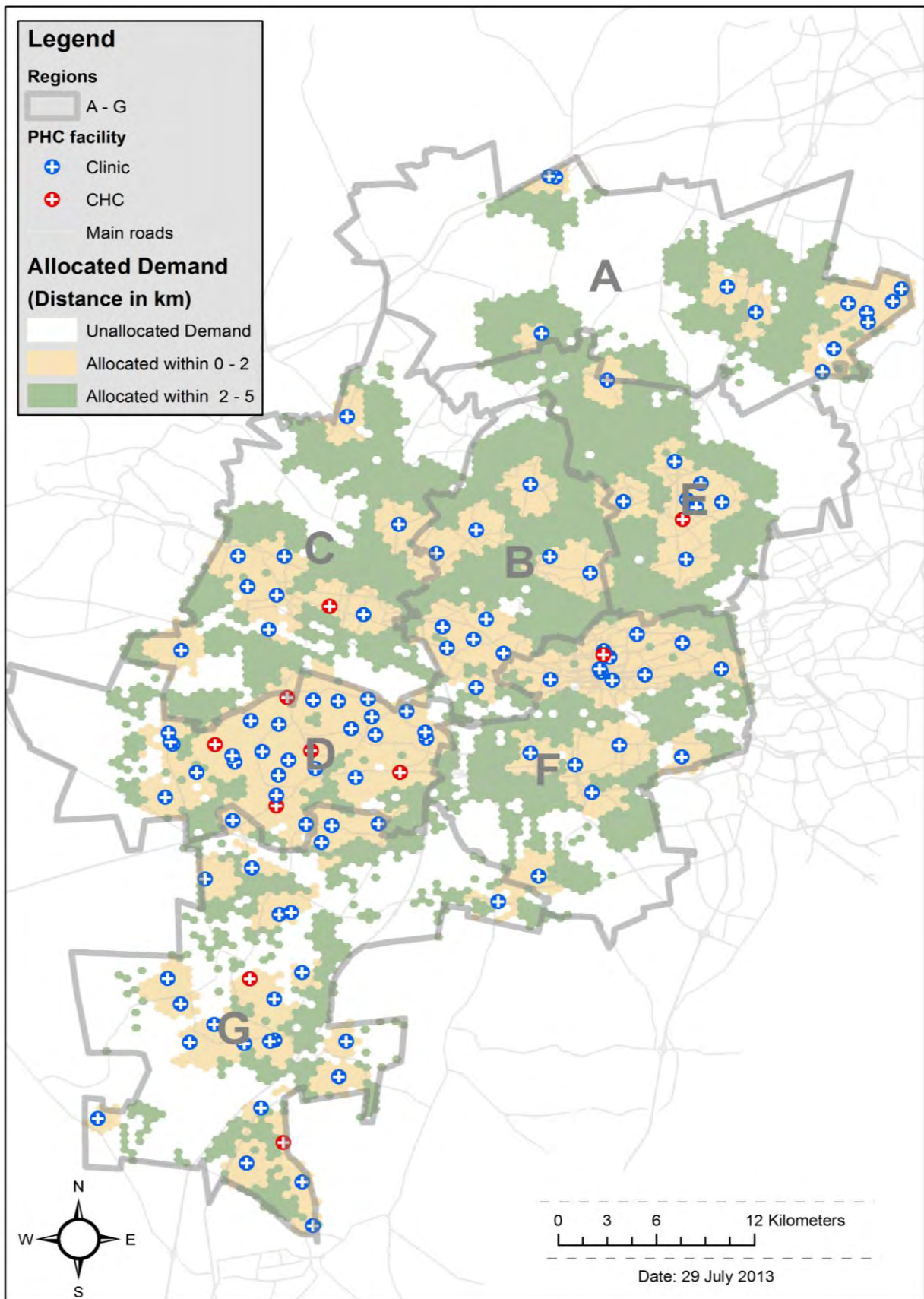


Figure 5.3: Allocated demand in distance band (capacity & access distance constrained)

The capacity shortfalls could be due to one of the following reasons; (1) mainly as a result of the closest facilities being technically fully allocated to people living closer to the facility and thus being in reality overburdened; or, (2) in high density areas, the facility being too small to cope with the local demand; or, (3) there are few facilities for the total demand in the area. Although public PHC facilities are very well distributed throughout the City of Johannesburg, with an average travel distance of 3.6km to access a facility, capacity issues may lead to high demand pressures on certain services at facilities.

The total number of headcounts that were recorded for the 116 facilities covered in this study was found to be 7 684 912 visits while the total for each of the scenarios was:

- i. Scenario 1 = 7 124 518 visits per annum.
- ii. Scenario 2 = 7 149 055 visits per annum.
- iii. Scenario 3 = 7 416 886 visits per annum.

The total calculated visits of the uninsured population for the three scenarios seem to add up closely to the total headcounts, in particular scenario 3.

Figure 5.4 indicates the catchment areas of the three scenarios when considering facility capacity and a 5km travel distance. This figure indicates that there is no significant difference in the spatial extent of the catchment areas of the facilities across the three scenarios but that there is a significant increase in the number of allocated demand visits per scenario: scenario 1 (6 711 292) < scenario 2 (6 828 738) < scenario 3 (7 120 648). At the top of each scenario in Figure 5.4 the total numbers of allocated demand visits from the catchment area analysis are specified. The total allocated and unallocated demand visits per region for each scenario are summarised in Table 5.2.

Looking very closely at Region C on Figure 5.4 some facilities appear as though they do not have a catchment due to their immediate surrounding areas being shaded in white. This is however not the case. The areas shaded in white indicate analysis units that do not have population or have unallocated demand areas. And in this case are the former. This is because the areas allocated to the facility catchment are not within the immediate surroundings of the facilities as a result of dasymetric mapping where areas with no population were excluded.

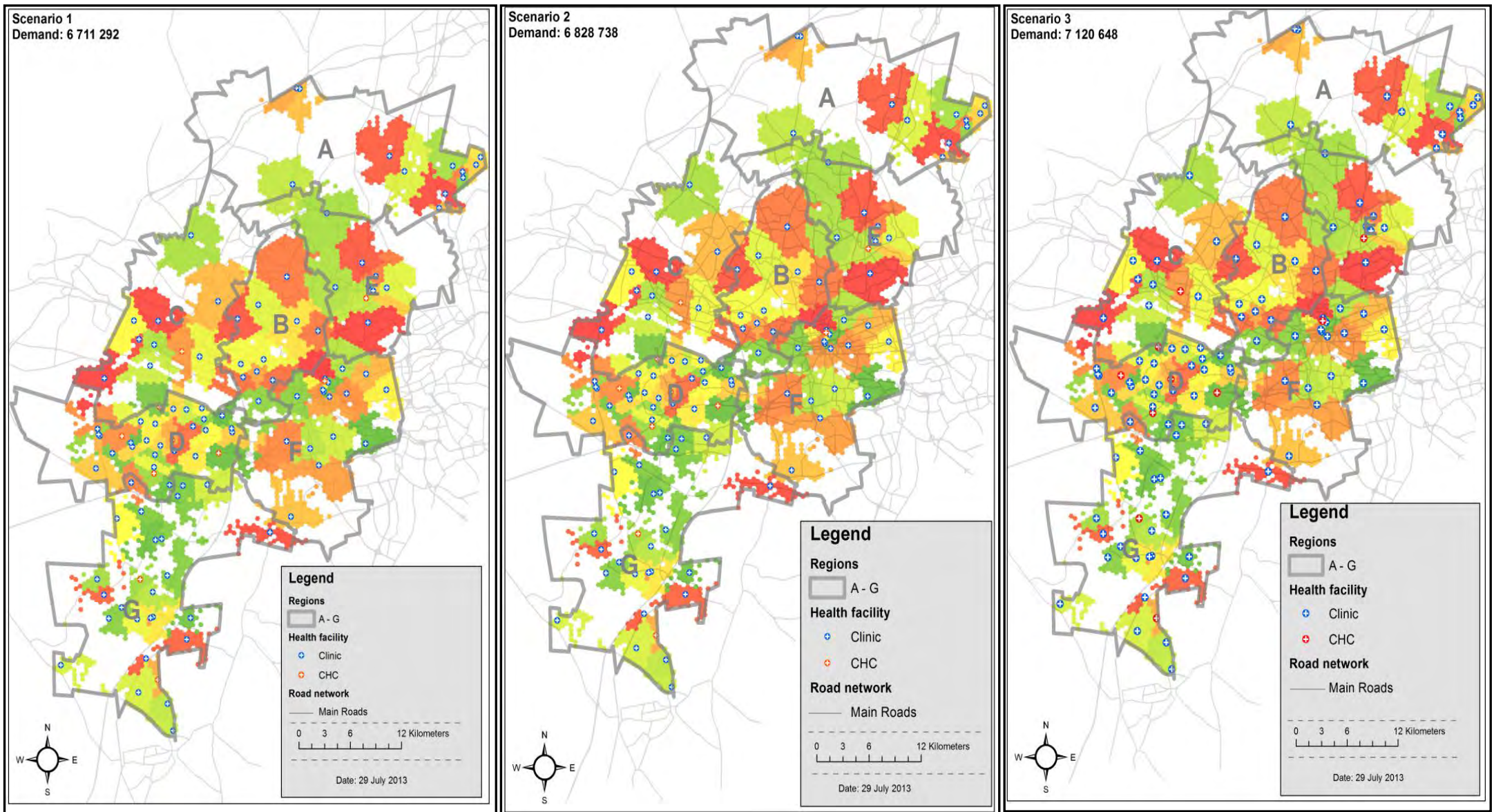


Figure 5.4: Total allocated demand visits per scenario (capacity & access distance constrained)

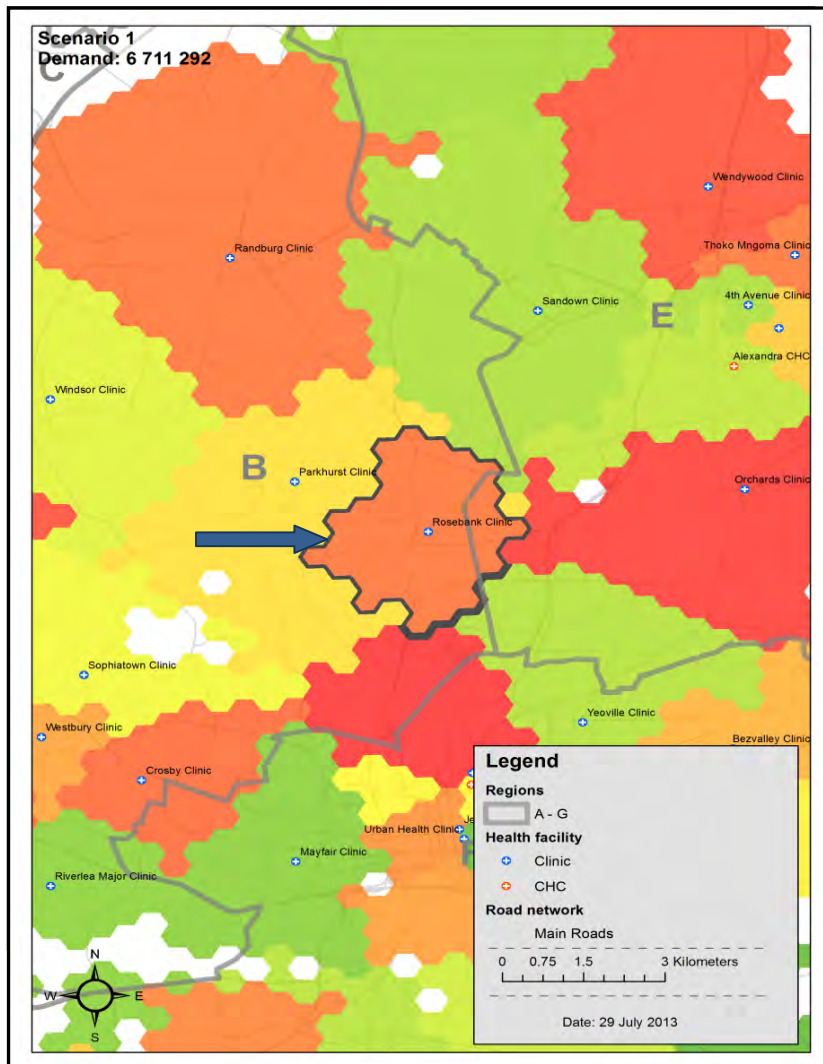
Table 5.2: Summary of allocated demand visits per region

| Regions | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|--------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|
| | Allocated Demand | Unallocated Demand | Allocated Demand | Unallocated Demand | Allocated Demand | Unallocated Demand |
| A | 953 487 | 124 229 | 996 407 | 92 491 | 1 088 356 | 91 348 |
| B | 431 220 | 8 296 | 344 288 | 4 788 | 319 161 | 3 838 |
| C | 801 976 | 147 750 | 771 172 | 123 825 | 783 198 | 113 167 |
| D | 1 807 418 | 3 858 | 1 966 493 | 4 056 | 2 070 716 | 3 721 |
| E | 612 775 | 89 672 | 553 244 | 59 230 | 585 891 | 50 032 |
| F | 883 787 | 15 148 | 866 040 | 10 159 | 857 212 | 7 400 |
| G | 1 220 630 | 24 275 | 1 331 094 | 25 772 | 1 416 114 | 26 738 |
| Total | 6 711 292 | 413 227 | 6 828 738 | 320 320 | 7 120 648 | 296 243 |

The only noticeable spatial difference between the three scenario figures is the catchment area of Rosebank Clinic as indicated by the arrows in Figure 5.5. Rosebank Clinic appears to be spatially accommodating fewer demand areas in scenario 1 compared to scenario 2 and 3 where it appears to be accommodating a considerable amount of demand areas for both scenarios. This is because Rosebank Clinic is located in a high income area. Given that in scenarios 2 and 3 a large number of the high income population were assigned the status of medically insured and thus eliminated from the analysis, the facility then accommodates more visits emanating from the surrounding areas. As a result, this creates a spatially wider catchment for Rosebank Clinic in scenarios 2 and 3 than in scenario 1. The demand visits in scenario 1, which has more high income population as proportionally allocated, quickly fills up the Rosebank Clinic to its maximum capacity before it could even accommodate visits from other surrounding areas, hence it appears to be covering a spatially small area in this scenario. This then indicates that the calculated scenarios are somewhat different and thus further analysis in this study needs to show where the vast majority of the growth in demand visits from the uninsured population will come from.

Overall, the catchments of the facilities for the three scenarios appear to follow the same pattern when spatially represented. Facilities that are in close proximity to one another have smaller catchments (Region D and G) and therefore appear geographically to be accommodating few demand areas. However, these small catchments have the highest number of demand visits. This is illustrated by Table 5.2, where it can be seen that the total allocated demand visits across the three scenarios in Region D and G are over a million. This is because most of these facilities are in high density areas where PHC service demand is very prominent.

A



B

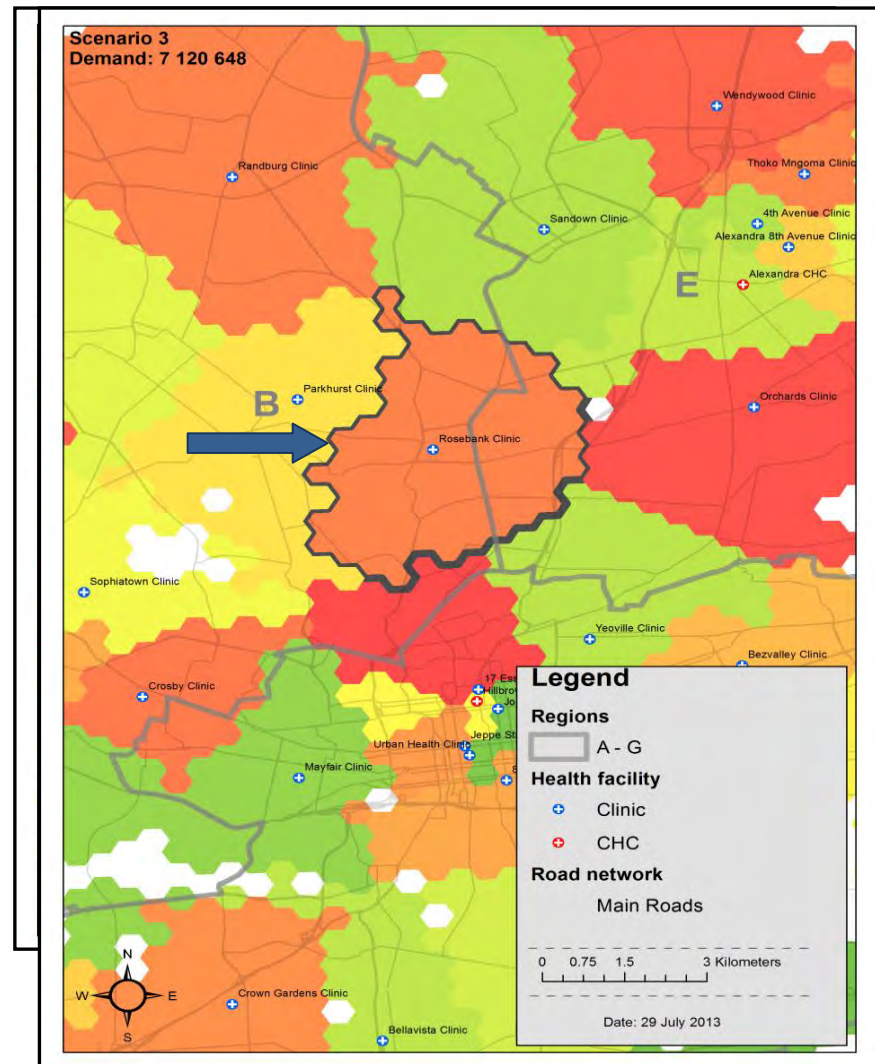


Figure 5.5: The spatial extent of Rosebank Clinic catchment area in Scenario 1 against Scenario 3

On the other hand, facilities located further apart have larger catchments and geographically appear to be accommodating a large number of demand areas. The results in Figure 5.6 indicate the spatial extent against the total allocated demand visits in low and high income areas. The point here is that the size or extent of the catchment is spatial and thus does not equate to demand. In low income areas (A), where facilities are in close proximity to one another, the catchment areas appear spatially smaller as compared to the wider catchment areas in B.

The facilities in A accommodate 70% of the entire City's healthcare demand visits due to the density of the uninsured population. In addition, if one looks at the total allocated demand visits for the two facilities in B, they are both almost half the total of the allocated demand visits of the two facilities in A. This explains why facilities in areas in B, low dense areas, only accommodate or serve 10% of the demand. The remaining 20% is allocated to facilities in the intermediate and sparsely dense areas.

The correlation coefficient results indicate that the modelled demand visits for all three scenarios have a moderate positive correlation with the facility headcounts. In comparison to one another, scenarios 2 and 3 have a slightly higher moderate positive correlation of 0.35 while scenario 1 has moderate positive correlation of 0.34. When looking at the proportion of allocated demand per facility equal to or greater than the facility headcounts, results are as follows: 53%, 54% and 55% for scenarios 1, 2 and 2 respectively. In total, the headcounts recorded by the City exceed the total from each of the three scenarios with the total allocated demand visits from scenario 3 adding up closely to the total headcounts for the entire city.

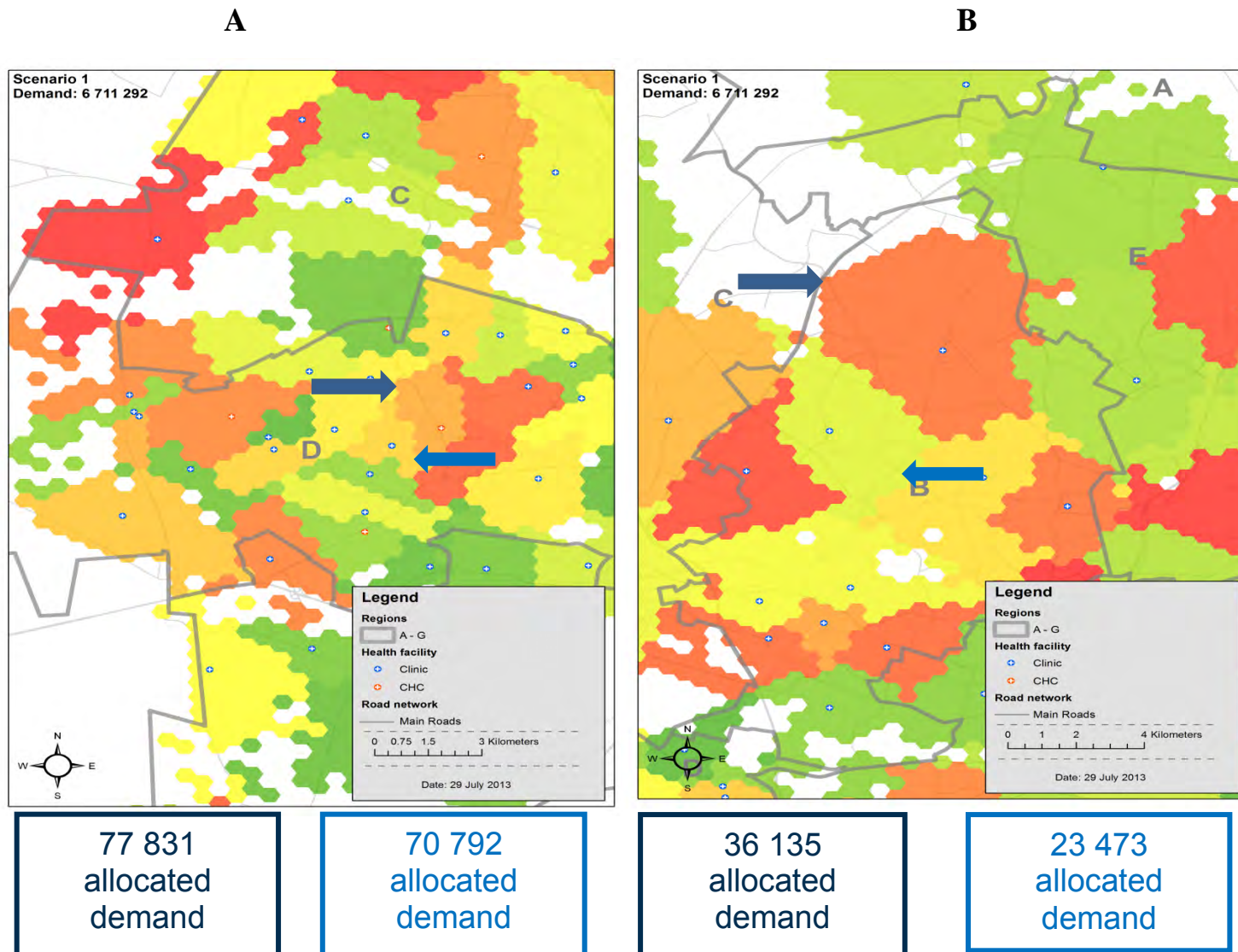


Figure 5.6: The spatial extent of facility catchments against allocated demand visits in (A) low and (B) high income areas

Before analysing the patient register data further at a facility level, it was considered necessary to identify and eliminate outliers in the last step of the analysis. Table 5.3 shows a summary of the distance statistics that emanated when identifying the outliers. Although in the actual analysis the outlier quartiles are per facility, the statistics here are provided per region. It is shown that Region G had patients who travelled the furthest, 50km, to their closest PHC facility. The outliers are also displayed in Addendum C where the actual distance travelled and facility visited by patients are shown using flow lines indicating the cross-border effect in the actual choice behaviour scenario as compared to the rational behaviour scenario.

Table 5.3: Summary of the distance statistics from identifying the outliers

| Region | Number of patients | Outlier quartile (km) | Max distance travelled (km) | Mean (km) |
|--------|--------------------|-----------------------|-----------------------------|-----------|
| A | 2138 | 12 | 31 | 4 |
| B | 674 | 7 | 32 | 3 |
| C | 2200 | 5 | 2 | 3 |
| D | 7024 | 2 | 35 | 1 |
| E | 2204 | 3 | 27 | 2 |
| F | 3995 | 7 | 26 | 2 |
| G | 3801 | 8 | 50 | 2 |

After analysing the geocoded residential addresses from the patient register it was found that 44.26% patients did not use their closest facility. This means that almost 45% of the patients did not reside in the catchment areas of the facilities they visited. Findings show that only 1% of the patients reside outside the City's boundary. There is a noticeable trend of patients from the southern suburbs using facilities located in the Johannesburg CBD. Various reasons can be attached to these results but it is not possible to identify such reasoning from the dataset used in this study. These reasons may include perceptions of better services, availability of treatment, knowledge of capacity due to long queues at closer facilities, stigmatisation, need for specialised procedures, mobility and transport network and workplace located next to a facility. However, it is not within the scope of this study to confirm these possible reasons.

5.4 Conclusion

This chapter discussed the findings from the analysis undertaken to test three different approaches to calculating public PHC demand. The three different demand scenarios tested show no significant difference in the spatial extent of catchment areas of facilities. However, the total allocated demand per scenario increased significantly from scenario 1 through to scenario 3. When compared to the total headcounts recorded for the City, the headcounts exceed the totals of

each of the three demand scenarios. However, the allocated demand of scenario 3 seems to be more in line with facility headcounts as was confirmed by a positive correlation. Therefore, from the three scenarios tested the equation used in calculating the uninsured population for scenario 3 is most suitable for implementation in a GIS-based accessibility analysis.

The results from the patient register indicates that while 1% of the patients who use the facilities within the City reside outside the city boundary, almost 45% of the patients residing in the City did not use their closest facility as per the model prediction. Most of the facilities visited by the patients were those located in the Johannesburg CBD. It can thus be concluded that the model under-predicts the use of facilities that are further away from the uninsured population's place of residence.

CHAPTER 6

6 DISCUSSION

6.1 Introduction

Political changes in South Africa during the past few decades have increased people's movement and this has given rise to a number of developments relating to serving people's healthcare needs. The problem of access lies not only in the locations or number of facilities provided but also with other socio-economic factors (Lin *et al.*, 2005:1889). This makes the spatial arrangement of healthcare provision in rapidly changing urban settings an issue that requires ongoing attention from health planners (Amer 2007:25). People within different socio-economic groups often suffer from poor access to certain activities or opportunities because of their lack of economic or transportation means for example. Access can thus become a social justice issue, which calls for careful planning and effective public policies by government agencies (Wang, 2006: 77)

GIS is not the complete solution to understanding the distribution of disease and the problems of public health but a tool to better illuminate how humans interact with their environment to create or deter health (Ricketts; 2003:1). Nevertheless, the use of GIS in assessing service provision and developing facility plans leading to improvements in governance and equitable service delivery is well underway.

6.2 Determining the Uninsured Population

Whilst it is seen as important to improve people's wellbeing, it is also important to mention that providing quality healthcare services may be complex. This is because of the diversity of people's healthcare needs across space and time. This variation, according to Joseph and Phillips (1984:9), originates from the view that people are not spread evenly across the earth's surface and that resources are not equally accessible by and available to all individuals. McLafferty (2003:26) also adds that the population differs along many dimensions including those of age, gender, culture and economic status and that this affects their need for services, and their ability to travel to obtain the types of services that they are willing and able to utilise. It follows that there is a complex relationship between the spatial separation and distribution of population and services, how they are connected geographically, and the multidimensional category of the demand for healthcare arising from various biological, socio-economic and cultural elements (Valongueiro & Campineiro, 2002:3). These factors account for the variation in need and use of healthcare services.

Urban areas exhibit these variations in the spatial distribution of healthcare needs. Such variations occur as a result of permutations in population densities, socio-economic, demographic and living conditions which all impact on the health status of the people (Amer, 2007:25). According to Khan and Bhardwaj (1994:71), spatial planning strives to enhance potential spatial access opportunities for a target population, and make these opportunities as fair or equitable as possible on the basis of selected criteria.

Calculating the uninsured population using variables such as income profiles to serve as demand for public primary healthcare is a methodology that can help both the provider as well as health planners understand the composition of their populations and provide a view of the trajectory or composition of their current and future population. A study by Bagheri *et al.* (2005) also found that to improve on the approach, consideration should be given to non-spatial factors such as deprivation indexes, ethnicity, education, gender, age, income, housing and transportation mode and then spatial and non-spatial factors should be combined in one frame when evaluating the accessibility of primary healthcare. This would help in understanding how health authorities need to plan for change and modify their operations.

The study selected three methodological approaches to calculate the uninsured population. This involved a set of baseline data pulled from a number of different sources that are considered reference or standard datasets for such calculation. This was one of the challenges for this study because the calculations also involved some assumptions. To make those assumptions as accurate as possible, the study examined the projections and forecasting models produced by organizations such as the CSIR and StatsSA. The three selected uninsured population calculations are to a certain extent different. Firstly, in terms of the very important driver of healthcare access which is affordability. For this reason, the contribution for medical aid schemes and private health care use was considered across the three calculations but at varying levels of the household income groups. According to Aday and Andersen (1974:209), some research equates access with characteristics of the population such as family income and insurance coverage. Secondly, the age and average visits mix; a household with more children generates more annual visits compared to a household with less children. That is to be expected given that in this study children were considered to generate more annual visits to a PHC facility than adults. Thirdly, still from a household structure point of view, there are more people in the low-income household than in the high-income household. This is further complicated by the growth in the number of households due to smaller size households such as the multi-dwelling nature of many stands (Van Rooyen *et al.*, 2009:66). This is especially true for the low income areas. Low-income households also do not have the same number of children compared to people living in middle- and high-income households. In general, there are some important demographic differences between these three calculations — the third calculation having more uninsured population due to considering all the

high-income population insured and the low and middle uninsured where household sizes are the highest.

While there are possible transitions of individuals from uninsured to insured status, the analytics show that the vast majority of the public PHC service demand growth will still come from the uninsured population; especially in low income areas.

6.3 Measuring Access

As metropolitan areas continue to develop and expand over time, there is a requirement that the spatial structure of healthcare provision should be more in line with residential density patterns. This is because to achieve this end, the distribution of healthcare resources must be commensurate with the needs of the population; such a distribution may be considered equitable (Khan & Bhardwaj, 1994:71). Hence, evaluating the performance of a healthcare delivery system by measuring access to services is important.

Measuring access can be seen as a relational evaluation of services relative to potential users' demand measured within a specified distance range and using a detailed transport network, and is therefore not a simple service-to-population ratio. A key advantage of measuring accessibility is that the measurements take into account service sufficiency with respect to the facility's capacity and location. In this study, measuring accessibility indicated that public PHC facilities in the study area are well located as they follow the growth pattern of the residential areas of the metropolitan area. In effect, it appears that a new health facility gets planned as the urban areas expand into peripheral areas. Travel distance to facilities is fairly good as, on average, residents can reach a facility within 3.6km. Thus, problems are likely to be more related to issues of service capacity facilities than to travel distances.

While the performance of primary healthcare service systems has been assessed in terms of facility numbers, little attention has been given to the usage of these facilities (e.g. McGrail, 2012; Al-Taiar *et al.*, 2010, Apparicio & Séguin, 2006, Bagheri *et al.*, 2005 & Lin *et al.*, 2005). On the positive side, this is useful for determining potential access to a service. A key advantage of using potential accessibility analysis is that of measuring facility sufficiency or quantity with respect to its location and service capacity within the administrative unit in which it is located. This makes it possible to identify spatial service backlogs with respect to residential patterns to improve the current service provision access at overburdened focal points where this was previously not realised.

Literature highlighted that while GIS-based measures of assessing accessibility are easier to put into operation and interpret than those of utilisation, it is important to realise that availability and accessibility does not guarantee the utilisation of services (Joseph & Phillips, 1984:52). And so, some accessibility measures may fail to include the demand of individual preference. In this way

highlighting that there is a need to take into account actual usage when measuring accessibility, and simply not only relying on the presence of a facility. However, this is a complex objective since there is no direct correspondence between need and use. McLafferty (2003:27), for example, has pointed out that although utilisation may sometimes reflect need, it may also reflect contextual and service related factors such as service affordability.

Research on the actual utilisation of the available healthcare services has not been looked into extensively due to the absence of healthcare service utilisation databases such as digital patient registers. Chapter 3 identified a gap in existing research in that there was ample evidence of the need for the type of analysis that incorporates utilisation rates. Therefore, an important contribution of this research work is the study and analysis of the calculated uninsured population as the target population and how this relates to the actual usage of facilities.

In developed countries the presence of patient registers, digital road maps, well-established public transport, information on the residence and employment data of the population, and on the resources available at each facility are combined to create indicators of the accessibility of healthcare services (Al-Taiar *et al.*, 2010:5). Following a study by Lovett *et al.* (2002), various information from a patient register was used to measure accessibility to surgeries by public and private transport in East Anglia. However, Al-Taiar *et al.* (2010:5) point out that such data inputs hardly exist in many developing countries even in hard copy form. The application of GIS-based accessibility analysis with the incorporation of the abovementioned inputs in countries like South Africa remains constrained by the lack of these datasets.

A study by Scott *et al.* (2002:240) focused on creating a health information system for cancer patients in KwaZulu-Natal and drew attention to the limitations of conducting such analysis in a South African context. Overall, the limitations which are also identified by McLafferty (2003:37) include: (1) privacy and confidentiality restrictions limiting access to data about health status and health outcomes, especially for individuals or for small areas; (2) data on healthcare utilisation and treatments are often proprietary, controlled by health insurers and provider organisations; and, (3) for public data, there are problems with compatibility and the sharing of information among agencies.

Although the District Health Information System (DHIS), with its ability to link to a GIS component, is available to cater for health information needs in South Africa, most of the data are facility-based with no reference to the origins of patients. This deficiency in datasets results in some accessibility analyses undertaken being based on a number of assumptions in measurement, thereby obscuring differences between individuals or groups (Green *et al.*, 2007:5). Such assumptions include presuming similar needs among patients by, for example, measuring accessibility based on the assumption of rational choice.

The presumed behaviour underlying rational choice is that people will minimise travel distances to access healthcare services, i.e. people will always go to their closest facility when seeking the service it provides as applied in the GIS-based catchment area analysis of this study. This might therefore give a distorted picture of the situation because people sometimes travel beyond their closest facility to seek the services they need, and their choice of service or facility may not always be motivated by proximity alone. In such cases, the measures may fail to provide adequate insight into accessibility issues (Green *et al.*, 2007:5). Intuitively, there could be a significant gap between potential and actual accessibility (Lin *et al.*, 2005:1882). Documented empirical studies that have focused on the actual utilisation are usually much more limited (Lin *et al.*, 2005:1882). The actual level of discrepancy between allocation and utilisation has not been studied extensively; therefore, it is difficult to accept or discredit a GIS-based accessibility analysis approach.

An important facet of this study has to do with actual access to facilities based on actual usage and the origins of users of each facility. This, in a way, responds to the need to measure access by the level of use and not simply by the presence of a facility. To supplement the headcounts, the actual distances travelled by the patients were analysed to serve as input in analysing the origins of the patients that use the facilities. This would give support to the attainment of more equitable access standards to a range of services in a metropolitan context and to test and evaluate optimal facility location, in conjunction with movement patterns. However, the only usable data for this analysis was the TB patient register. It therefore became apparent in the initial stages of cleaning the patient register data that the quality was poor due to incomplete residential addresses for most records. In addition, TB is a stigmatized disease and a patient might not follow rational behaviour in this case. A patient may rather go to a facility that is further away from home to avoid stigmatism, partly because of the connection with HIV/AIDS.

Although the patient register was used in this study, the data was incomplete and of a poor quality for detailed analysis. Lovett *et al.* (2002) in their study using patient registers to measure access state that there are practical difficulties in using data from patient registers and their applicability should not be underestimated. Nevertheless, the patient register data were able to show that a certain proportion of the population do not use the closest facility to home possibly because of accessing facilities from place of employment or because of the way the transport routes traverse the study area. Where there is available employment data for the population, a demand proportion from the workplace could be generated as input into the analysis.

6.4 Conclusion

Efforts are well under way for the broader adoption of GIS in South Africa by many institutions. The use of GIS has increased in the past few years. However, industries that can benefit to a great extent have not made full use of the GIS capabilities because it is still viewed primarily as a mapping tool. In addition, government, at all levels, and many other institutions collect and manage

information that has important spatial components but fail to maintain this information in a spatially enabled manner. What needs to be rolled out is a demonstrating tool of the application of GIS in these organisations to instil a better understanding of GIS, how it can be utilised and the benefits of capturing data accurately and continuously maintaining it.

Undertaking accessibility analysis for the strategic evaluation of primary health care services using GIS that incorporate utilisation rates has only been used to a very limited extent in South Africa. This approach can be used to greatly assist in the formulation of district plans and in ensuring that sector facility plans are put in place based on actual demand and usage when it comes to the provision of a range of services.

To provide a good representation that is closer to reality, detailed utilisation data and comprehensive databases about the population's demographics are required. It is no use knowing that one is living in an area with healthcare facilities if the resources are inaccessible. It is also important that in providing a service in an area that one has the data or resources to evaluate and monitor the performance and viability of the service.

CHAPTER 7

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The previous chapters comprehensively discussed how the different components of this study were integrated to effectively address the research problem. This chapter draws conclusions about the study based on the main aim of the research which is to evaluate whether GIS-based accessibility modelling is an appropriate method for determining public primary healthcare demand. The objectives of this study are presented in chapter 1 and reiterated below:

- I. Determine the actual demand for primary healthcare.
- II. Calculate the uninsured population.
- III. Measure access to primary healthcare facilities using the uninsured population.
- IV. Compare results from the uninsured population analysis with the actual demand.

Although Objective 1 forms the basis of this study, it must be emphasised that a valuable aspect of this research relates to Objective 2. For health plans to effectively address demand for services, a deep understanding of the specific target population to help focus services planning is required. Establishing the demand for public healthcare is crucial in the healthcare planning context due to population growth and continued change in healthcare needs. The purpose of determining the demand is to enable one to specifically target the appropriate population most likely to use the services.

7.2 Determining Public Primary Healthcare Demand

A step-wise process was followed in evaluating GIS-based accessibility modelling as an appropriate method for determining public primary healthcare demand. An overview of the steps and overall findings are as follows:

Step 1: Secondary data from a variety of sources was collected and prepared with care and diligence. This mainly involved large sets of spatial data and other relevant information. Each dataset served as input into the analysis.

Step 2: The target population demand for public PHC services was considered to be the uninsured population. Three different scenarios to calculate the uninsured population were generated and tested using a GIS-based catchment area analysis model. The results from the catchment area analysis were compared with actual public PHC demand in the form of headcounts and further analysis of the origins of the patients was undertaken using a patient register.

The following summarises the findings:

- i. The total headcounts recorded by the City exceeded the total visits calculated for each of the three demand scenarios.
- ii. The different demand scenarios tested showed no significant difference in the spatial extent of the catchment areas of the facilities.
- iii. However, the total allocated demand per scenario increased significantly from scenario 1 through to scenario 3.
- iv. The allocated demand visits per facility for scenario 3 had a moderate positive correlation of 0.35 with the headcounts for each facility.
- v. The total allocated demand visits in scenario 3 was strongly in line with the total number of headcounts of the City.
- vi. Only 1% of the patients from the register were found to reside outside the City's boundary.
- vii. Almost 50% of the patients from the register did not reside in the catchment areas of the facility they visited.
- viii. There was a significant use of facilities located in the CBD by patients from other regions in the study area.

In conclusion, the uninsured population calculation method used for scenario 3 was considered to be the most suitable for implementation in a GIS-based accessibility analysis. It was also concluded that the model under predicts the use of facilities that are further away from the uninsured population's places of residence.

7.3 Problems Encountered

Although GIS-based accessibility analysis enables the incorporation of various data inputs to be used in measuring geographical access to healthcare services, the study clearly demonstrates the need and importance of accurate and appropriate data. A major challenge experienced when undertaking this study was utilising data with different levels of accuracy from a variety of sources. This was mainly caused by incompatible and incomplete, if not unavailable, datasets. For example, epidemiological data was considered to serve as input in the determination of the demand scenario but the level at which the profile data was available was not spatially compatible for the scale of this study.

Lack of information on the capacity of each facility to accommodate patient visits also led to generalised capacity estimations. This was based on a facility capacity calculation adopted from the literature and adapted particularly for this study. Apart from the fact that the chosen datasets provided most of the necessary information needed to undertake the study, a number of the input datasets needed to be provided at a disaggregated level. The use of actual patient data, not a proxy, will be an added advantage but, if not possible, the development of a comprehensive patient database with geographical attributes will also enhance the analysis.

7.4 Success of Study

To reflect on the success of the research, the study was able to validate the appropriate method for determining public primary health care demand using GIS tools – calculating the uninsured population.

The recommendations listed below as produced by this research encapsulate what needs to be done to enhance the GIS-Based accessibility approach in calculating the uninsured population. In effect, a gap in the field has been realised as well as a base for in-depth research. This has been a successful piece of research with many points of learning especially for practice into theory, resulting in a significant contribution to knowledge. Furthermore, research publications produced as a result of this research have contributed to the field of GIS-Based accessibility analysis in the health domain. It has created the opportunity to publish and discuss with one's peers at international platforms and has also allowed other researchers to have access to research deemed by conference committees as making a contribution to the GIS community. These publications are listed below:

- (1) Mokgalaka, H, Mans, G, Smit, J and McKelly, D. 2013. "GIS-Based Accessibility Analysis- A Mixed Method Approach to Determine Public Primary Health Care Demand in South Africa", *Proceedings Global Geospatial Conference (Combined AfricaGIS and GSDI 14 Conference)*, Addis Ababa, Ethiopia, November 2013. [Accessed 13 January 2013].
<http://www.gsd.org/gsdiconf/gsd14/papers/160.pdf>
- (2) Mokgalaka, H., Mans, G., Smit, J. and D. McKelly. 2014. "Validating the Accuracy of GIS-Based Accessibility Analysis in Determining Public Primary Health Care Demand in Metropolitan Areas". *Proceedings of the Second AfricaGEO Conference*, Editors: J. Whittal and S. Motala. Publisher: CONSAS Conference, 2014. ISBN 978-0-620-60666-0 [Accessed 29 October 2013] http://www.africageoproceedings.org.za/?page_id=403
- (3) Mokgalaka, H. 2014. "Measuring Access to Primary Health Care: Use of a GIS-Based Accessibility Analysis". *Proceedings of the Sixth Planning Africa Conference*, Editors: Y. Patel, N. Minyuku, C. Van Der Bank, K. Mohan and A. Ogra. Publisher: SAPI, October 2014. ISBN: 978-0-9921820-0-7

7.5 Recommendations

There is still a continued need for more robust planning to achieve a more equitable distribution of services in response to the growing need for healthcare. While it is important for the sectors responsible for the provision of healthcare services to locate facilities in such a way as to serve the majority of the population, it is also important to note that metropolitan areas are, however, dynamic and continue to develop and expand with time.

The last few years have seen South African metropolitan areas experience increases in population densities thus putting more pressure on already overburdened service delivery systems. The challenge for health care planners is thus to adequately plan for the provision of health care services to the greatest number of people and make projections of future demand while efficiently using the current deficient resources. It is therefore essential that planning for health care services incorporates future population growth and changes in activity trends occurring in the areas to be served. Hence, the location and operation of these healthcare services must be carefully planned for to ensure improved long term accessibility targeting current and future potential users.

The recommendations are made based on the limitations that hindered more accurate results from the analysis, as well as considering additional work that can be done to ensure better accessibility modelling results. Future research should look into the following areas as identified in this study:

- Develop or calculate the probability variance of rational choice versus actual choice to further enhance the model's capabilities.
- Write a script or a batch file for the distribution of the visits or uninsured population onto analysis units.
- Improve the algorithm for estimating service demand.
- Develop detailed patient registers or databases.
- Develop spatially linked population employment data so that analyses can be undertaken by computing the measure separately for different trip purposes; that is from workplace and / or place of residence.
- Situational analysis or sample surveys should be conducted with regards to people's choice of facility use so that more understanding of the realities upon which assumptions in this study are made are validated.

CHAPTER 8

8 REFERENCES

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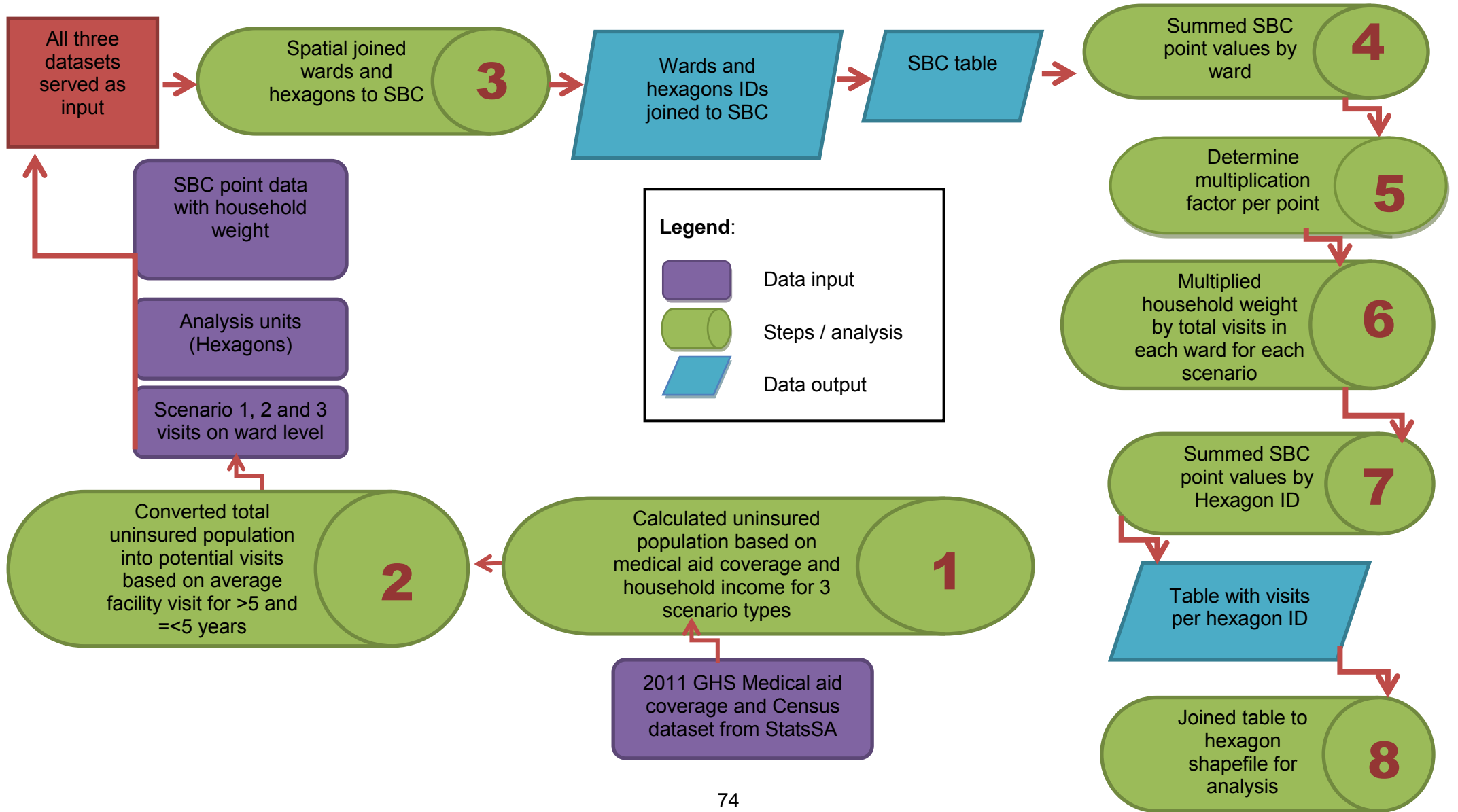
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9 ADDENDA

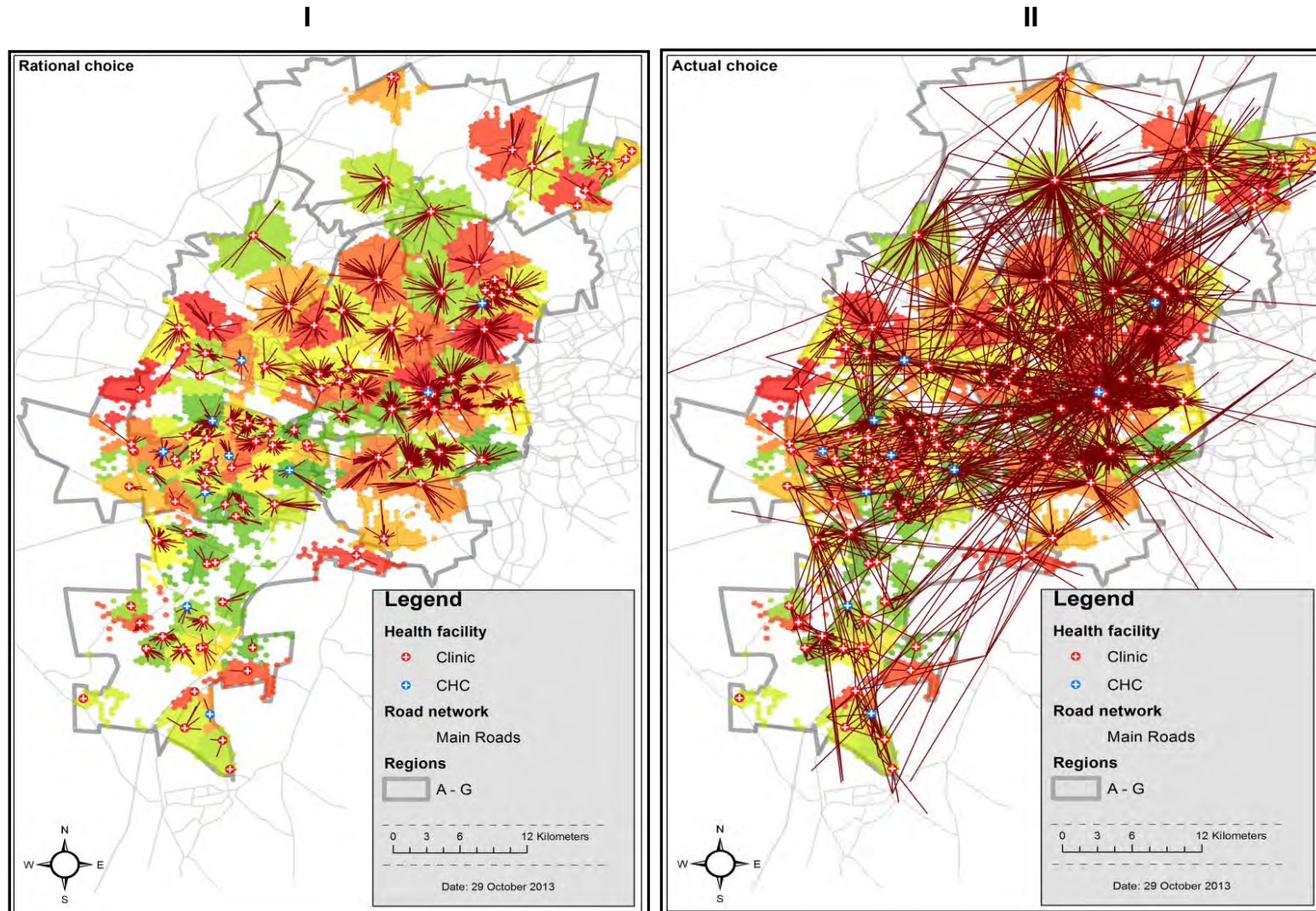
A: Data sources

| Dataset | Description | Format | Feature | Year | Source |
|---|--|---------------|----------------|-------------|---|
| Transport network | Street centre lines, feeder routes and highways | Vector | Network set | 2010 | CSIR (AfriGIS) |
| Eskom Spot Building Count (SBC) | A point per building digitised from SPOT imagery | Vector | Points | 2010 | CSIR |
| ETR.Net Data | Electronic Tuberculosis Register data | Database | Table | 2011 | Gauteng Provincial Department of Health |
| JHB Boundary | Local municipality boundary | Vector | Polygon | 2009 | Municipal demarcation board |
| Census and General Household Survey Data | 2011 population dataset | SuperCROSS | Table | 2011 | StatsSA |
| Gauteng Station | Locations of the Gautrain stations | Vector | Points | 2011 | City of Johannesburg |
| BRT Lines | Bus rapid transport system lines | Vector | Lines | 2011 | City of Johannesburg |
| Metrorail Stations | Location of all Metrorail stations | Vector | Points | 2011 | City of Johannesburg |
| Facility Data | Spatially referenced PHC facility data | Vector | Points | 2011 | Gauteng Provincial Department of Health |

B: Analysis steps to reassign the population demand onto the analysis units



C: Flows of patient from the register in a (i) rational choice scenario against (ii) actual choice scenario



D: Ethics assessment in research projects

EBE Faculty: Assessment of Ethics in Research Projects (Rev2)

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee; submit to Ms Zulpha Geyer (Zulpha.Geyer@uct.ac.za; Chem Eng Building, Ph 021 850 4791). NB: A copy of this signed form must be included with the thesis/dissertation/report when it is submitted for examination.

This form must only be completed once the most recent revision EBE EIR Handbook has been read.

Name of Principal Researcher/Student: Hunadi Millicent Mokgalaka Department: Geomatics
 Preferred e-mail address of the applicant: Hunadi.Mokgalaka@uct.ac.za
 If a Student: Degree: MSc (Eng) Supervisor: Professor Julian Smit

If a Research Contract Indicate source of funding/sponsorship:

Research Project Title: The relevance of GIS-based accessibility analysis to determine public primary health care demand

Overview of ethics issues in your research project:

| | | |
|--|--|----|
| Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)? | | NO |
| Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2. | | NO |
| Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3. | | NO |
| Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4. | | NO |

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate. Ensure that you refer to the EIR Handbook to assist you in completing the documentation requirements for this form.

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research, and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

| | Full name and signature | Date |
|---|--|--------------------|
| Principal Researcher/Student | <u>Hunadi Millicent Mokgalaka</u> Signed by candidate | <u>24/05/2012</u> |
| Supervisor (if applicable) | <u>Professor Julian Smit</u> Signed by candidate | <u>24/05/2012</u> |
| HOD (or delegated nominee). Final authority for all assessments with NO to all questions and for all undergraduate research. | <u>Signed by candidate</u> | <u>27/5/2012</u> ? |
| Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions. | <u>Signed by candidate</u> | <u>27/5/2013</u> |

This ethics approval is given on an understanding that the research work has not yet been undertaken and that the data has been ~~stored~~ kept with an appropriate level of confidentiality.

Signed by candidate