Geospatial Accessibility Analysis of Primary Health Care Clinics in the Mbizana Local Municipality in the Eastern Cape

Matsubu Valentine Ragoasha[1,2], Johan Maritz[1], Antony K Cooper[1,2]

[1]Built Environment, CSIR, Pretoria, South Africa, vragoasha@csir.co.za, jmaritz@csir.co.za, acooper@csir.co.za
[2] Centre for Geoinformation Science, University of Pretoria, Pretoria, South Africa

Abstract

A key challenge in rural South Africa is providing social facilities such as clinics. This is difficult due to the nature of settlement distributions, especially in traditional authority areas. Geospatial accessibility analysis can help find suitable locations for facilities to serve the inhabitants. Settlements in South Africa's traditional authority areas often do not meet the minimum thresholds required for specific social facilities, therefore determining the best location can be daunting. This study applied a geospatial accessibility approach to primary health care clinics in the Mbizana Local Municipality in the Eastern Cape Province. The results of this accessibility analysis identified suitable locations to build the eight clinics that were proposed in the municipality's Integrated Development Plan for 2015-2016. We calculated facility catchments using approximate road-based travel distances to the nearest facility within the municipality. Two types of catchment area analysis were performed: one included distance and capacity constraints and the other excluded them. The unconstrained analysis showed that only 36% of the population is situated within the service reach of 5km. This decreased to 33% when distance and capacity constraints were considered. The remaining demand of 67% is significant, indicating high unsatisfied demand for additional clinics. Although the proposed eight clinics increased the overall accessibility to primary health care clinics, a large proportion of the population remains unserved, suggesting that more than eight clinics would be needed. The results of this analysis therefore also aim to support health care facility planning and distribution within the Mbizana Local Municipality.

Keywords: Clinic, Catchment area analysis, Geospatial accessibility, GIS, Primary health care

1. Introduction

The introduction of free primary health care (PHC) services by the democratic government in 1994 was intended to improve and maintain quality health for all. Despite its commitment and structural reform to provide free quality health, there are still some major challenges that limit the full implementation of quality primary health care; these amongst others include: shortages of health workers, inequities in resource distribution and inaccessibility to PHC services (Kautzky & Tollman, 2008). Although issues around priority setting, resource distribution and allocation are informed by medical, economic, political and ethical considerations, this research reported here considers a geospatial approach to aid in the decision-making process for fair health care facility planning and distribution.

Geospatial accessibility analysis is one method applied frequently to measure the degree to which equitable access is obtained (Mokgalaka *et al.*, 2013). Many studies have recognised geospatial access to health care services as a primary determinant of the extent to which social facilities are utilised (Chiu *et al.*, 2017; Domnich *et al.*, 2016; Nteta *at el*., 2010). Information about accessibility to facilities is of interest to planners and decision makers to achieve equitable services provision.

This research focuses on geospatial accessibility analysis to PHC clinics in the Mbizana Local Municipality in the north-east of the Eastern Cape Province in South Africa (see Figure 1). According to the review of the Mbizana Integrated Development Plan (IDP) for 2015-2016 (Mbizana, 2016), eight additional clinics need to be built in the municipality to meet the total demand. We chose Mbizana as the study area because of this identified need, focusing on clinics as the first point of entry into the national health system.

The aim of this research is to identify where in the municipality the population cannot be accommodated by the current clinics, when considering facility capacities and acceptable travel distances. The National Department of Health's standards (2000) specify an acceptable travel distance of five kilometres, implying that those further away have poor(er) access to clinic facilities. For context, please note that a main form of transport in these rural communities is *walking*. Based on the results of the geospatial accessibility analysis, the research suggests suitable locations for possible new facilities to serve as much of the unserved population as possible.

2. Literature Review

2.1 Requirements for provision of primary health care clinics in South Africa

Although providing primary health care in South Africa is intended to bring free quality health care services as close as possible to the population; planning for this is challenging in both rural and urban areas (Mokgalaka *et al.*, 2013; Nteta *et al*., 2010). In rural areas, the sparse and uneven geospatial distribution of settlements makes it difficult to site social facilities adequately, and they often do not meet the thresholds required for formal social facilities (Oosterveer & Young, 2015; Tanser *et al*., 2006). Nonetheless, there have been continuous efforts to support and guide social facility planning and provision in rural areas. The social facility toolkit developed by the Council for Scientific and Industrial Research (CSIR) is a good example of such support; it sets out the threshold populations required for each facility type. Information associated with planning for PHC clinics is provided in table 1.

Table 1: South African Clinic Provision Standards, Source (Green & Argue, 2012)

Facility type	**Population threshold**		**Distance & density required for minimum population threshold**	
	Min	***Max***	***Distance***	***Density (people/km^2)***
Basic clinic	5 000	9 999	5	63
Small clinic	10 000	19 999	5	127
Standard clinic	20 000	39 999	5	253
Large clinic	40 000	59 999	5	127

2.2 Accessibility components in a context of health care

Geospatial health care facility planning concerns identifying suitable locations for a given backlog of health facilities in a defined area, such that the health needs of a geospatially dispersed population are optimally served (Amer, 2007). Essential to this type of location planning is the concept of accessibility, which relates to the means for people to overcome physical barriers in order to utilize health services at certain fixed points in space. Access to health care comprises a demand and supply components. In most instances the uninsured population (those without health insurance or medical aid) are the main users of primary health services; therefore, they are a primary focus when planning for PHC facilities. In instances where the number of uninsured population is not known or where there is no sufficient data to determine this information, some studies have considered the whole population of the study area as the demand for health services (Amer, 2007; Munoz *et al.,* 2012; Oosterveer & Young, 2015; Tanser *et al.,* 2006). Another important component of accessibility is the road networks; these are the potential routes that get people from their origin to destination and improving the transport system can ultimately improve accessibility (Munoz *et al.*, 2012). The interplay of the three components (demand, supply and road networks) provides support to analyse, model and describe health care utilization patterns.

Another underlying element essential for assessing accessibility is the spatial units for the analysis. Many accessibility studies (DPSA, 2012; Maritz *et al.,* 2016; Mokgalaka *et al.,* 2013) prefer using smaller analysis units as opposed to the units associated with census data. This is mainly because, the geospatial detail or size of the Sub-places (or Small-Areas) derived from Statistic South Africa (Stats SA) for example, are considered too coarse for the purpose of accessibility. The process of creating these smaller geospatial units involves tessellating the study area into smaller zones. Hexagonal tessellation is favoured amongst researchers as opposed to (circles and squares for example) (DPSA, 2012; Mokgalaka *et al.,* 2013; Mokgalaka, 2015); this is because hexagons give better distance estimates. This theory is supported by the fact that hexagons nest (they do not have gaps in between) and the distance from the centroid of a hexagon to the sides is equal thus giving better distance estimates (Mokgalaka, 2015). Although the distance from the centroid of a circle to the sides is the same, circles do not nest. In a case of a square, the distance from the centroid to the sides has higher deviation resulting in longer distances calculated.

2.3 Previous studies

Geospatial accessibility analysis is an approach that gained popularity for determining utilization patterns of health service amongst researchers (Domnich *et al.*, 2016; Chiu *et al.*, 2017; Nteta *at el*., 2010). In simple terms, geospatial accessibility refers to a geospatial barrier (distance, cost and time) between the demand and supply; and in a context of health care, geospatial accessibility presents an obstacle to accessing health services (Munoz *et al.*, 2012).

Geospatial accessibility analysis is strongly linked to supporting effective planning and decision-making strategies (Tanser *et al.,* 2006; Amer, 2007; Munoz *et al.*, 2012; Oosterveer & Young, 2015). According to (Munoz *et al.*, 2012), health planning and evidence-based policy development can be improved when performance of the health system is well understood from a geospatial perspective. In an attempt to understand the performance of health care system in the Western Province of Rwanda, (Munoz *et al.*, 2012) used geospatial accessibility to model the coverage of the existing PHC network and from there estimated the unserved population. This was done by calculating the catchment area for each facility considering population coverage capacity.

In a research by Oosterveer & Young (2015), geospatial accessibility analysis was undertaken to identify and analyse barriers/challenges that the indigenous communities in Northern Canada face in terms of primary health care access. The study focused on semi-structured interviews with the PHC service providers and service users in five communities across North Canada. The selected communities varied according to remoteness, population, health care resources and ethnic composition. Due to a shortfall of qualified staff in the community and an increased dependence on aeromedical evacuations, it was found that access and service provision are less desirable in North Canada (Oosterveer & Young, 2015). The aim of both studies (Munoz *et al.*, 2012; Oosterveer & Young 2015) was to provide policy makers and decision makers with the necessary geospatial information to effectively plan for allocation of new resources that will optimally serve the identified demand.

Drawing from previous accessibility studies, it is apparent that GIS has successfully been used to conduct accessibility analysis thus offering support for efficient planning. Although a comparable methodological approach was followed in these studies, special attention is given to the types of accessibility measures and application tools used. Travel time and distance are the two widely used accessibility measures amongst researchers; this is due to an increased recognition that time and distance are the common impedances to services (Tanser *et al*., 2006; Munoz *et al.,* 2012). Moreover, distance and time are widely preferred because, (1) they are both relatively easy to apply by researchers with just a basic knowledge of GIS; and (2) they are easy to interpret and as such, can easily be understood by policy makers (Neutens, 2015). The World Health Organization (WHO) however, recommends using travel time over distance when assessing geospatial access (Munoz *et al*., 2012). This is mainly because this method accounts for roads conditions and in some cases, accounts for the mode of transport used; thus providing with adequate estimates. However, it is worth mentioning that in most cases, it can be difficult and time consuming to acquire information associated with travel time.

Flowmap is a suitable tool to incorporate in a GIS-based planning support system, particularly in the fields of facility planning and accessibility analysis due to its capabilities to model and analyse geospatial interaction or flow data (Geertman *et al.*, 2003). The Flowmap software application was developed by the Faculty of Geographical Sciences in Utrecht University, in the Netherlands (http://flowmap.geog.uu.nl/). According to Liu (2004), Flowmap is the only software package with a set of accessibility measures embedded and is not designed as a full GIS package. The accessibility analysis functionality in Flowmap involves computing distance from origin to nearest destination. This functionality is coupled with catchment area analysis method which essentially allocates all origins to the nearest destination along a road network.

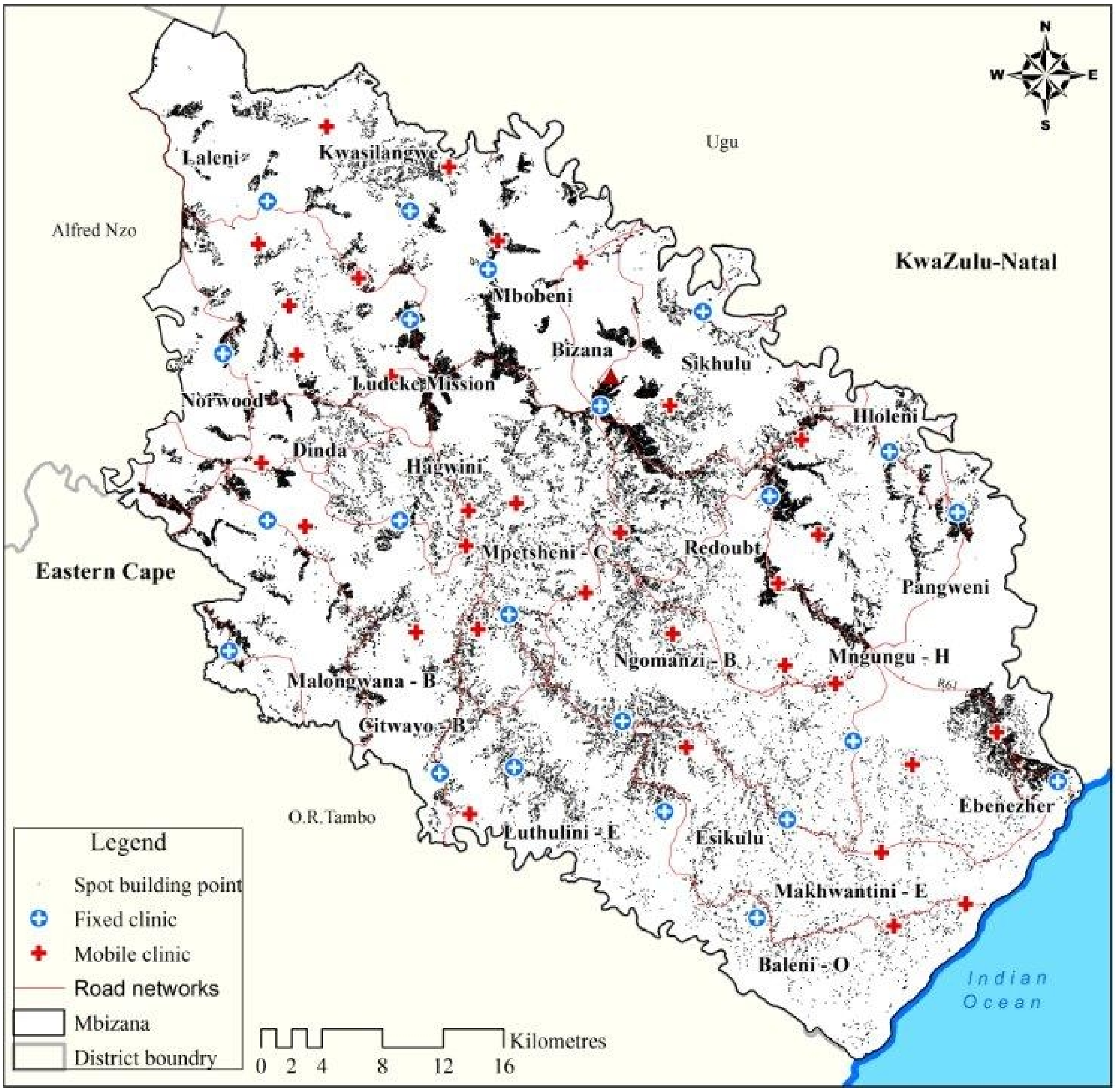

Figure 1: Study Area Overview – Mbizana Local Municipality

3. Methodology

3.1 Study area overview

The study area is Mbizana, a predominantly rural local municipality located in the north-eastern part of the Eastern Cape Province. The municipality covers an area of approximately 2416.72 km² with a population density of 116.65 km² and has a population size of 281905 (Stats SA, 2011). Females make up the majority of the population by 54.48% (Stats SA, 2011). Unemployment is amongst the major challenges in the municipality standing at approximately 43.6% as recorded by Stats SA in 2011. Figure 1 shows the distribution of PHC clinics in relation to the population.

Mbizana is located in one of the poorest districts in the country, namely the Alfred Nzo district which has an estimate of 40% of the population living below poverty line (Department of Social Development, 2015). The local municipality has only one town, Bizana, where the majority of the population resides. Currently the municipality has 22 fixed clinics and 2 mobile clinics servicing 32 sites across the municipality. The spot building points were used as a proxy for population distribution in this study (the process is explained in section 3.2.4). The black patches on the map in Figure 1 indicate the more densely populated areas.

3.2 Data and study preparation

3.2.1. Datasets

The data required for this study are obtained from different sources comprising demographic data, spot building points, road networks and PHC clinics locations. Each of these datasets is described in more detail in the subsequent paragraphs.

The analysis was performed for the entire municipal extent, therefore the results needed to be reflected and related to the geospatial layer of the municipality. The latest **municipal layer** was obtained from the Municipal Demarcation Board (2016).

To analyse the level of accessibility within the municipality, the **demand** for service needs to be considered; this is the number of people potentially visiting clinic facilities in the municipality. For this study, demand for PHC clinics was considered to be the entire population of Mbizana. The population information was extracted from the 2016 settlement layer obtained from the Department of Water Affairs (Department of Water Affairs, 2016). This layer is considered suitable for the purpose of accessibility analysis because it presents the population information at a fine level thus producing more accurate results. The small area (SA) layer produced by Stats SA also presents population information at a fine level which is sufficient to use for this study; however, there was a delay in acquiring this layer hence the study used the settlement layer.

A fully connected **road network** dataset was provided by the CSIR (2014) which for the analysis represents the potential routes people use to reach health care facilities. This is an important component as distances were measured from where the demand (population) is to the supply (clinics). It is worth noting that using a detailed road network dataset is more realistic as it already accounts for topographical barriers such as steep terrain and water-bodies. This reduces the need to reflect such impedances separately.

The **spot building count** (SBC) was supplied by Eskom (2013) and was used as a proxy layer for population distribution. The SBC points represent classifiable buildings within South African boundaries (Mans, 2012).

The project assessed access to two types of **PHC clinics** namely, fixed and mobile clinics. These were considered the “supply” points. Information on where the mobile clinics are located in the municipality was provided by the Mbizana mobile clinic team. The locations of the fixed clinics were obtained from ESRI South Africa (2015). The attribute information (i.e. clinic names) for this layer was verified against the information provided by the Eastern Cape Department of Health.

3.2.2. Software used

The two main software applications used in this study were ESRI’s ArcGIS desktop version 10.4.1 and Flowmap version 7.4.1. The ArcGIS software was mainly used to prepare data for the analysis and also to visualize the final results of the study. Flowmap was used to conduct the accessibility analysis as it contains a series of functions not present in ArcGIS. It is suitable to measure access to PHC clinics due to its capability to analyse and model the actual catchments data needed to successfully complete this study.

3.2.3. Hexagonal tessellation – Creating analysis units

In most instances, the existing units i.e. main-places (MP), sub-places (SP), small areas (SA) and wards to name the few, can vary greatly in size making it less useful for accessibility analysis. To overcome the size-distortion of these units, it is necessary to have smaller more uniform zones. To do this, a process of tessellation was applied where the whole study area extent was tessellated into equally sized hexagons of 30 hectares each. This tessellation set then served to represent both the demand and supply surface for the analysis. The analysis units (hexagons) are considered sufficient for measuring access since they give a more accurate distance measures compared to other uniformly shaped tessellation types. They also allow for the outputs to be produced on a more detailed level in places than working with for example, sub-places or wards (DPSA, 2012).

The choice of 30 hectares was influenced by the need to have a sufficiently fine analysis surface whilst working within the limits of Flowmap (related to the size of the distance matrix that can be calculated). A tessellation consisting of 11930 units was created. In order to serve as an analysis surface, the relevant population information then had to be related to these hexagons.

3.2.4. Adding demand to analysis units

For accessibility analysis the demand is considered as the amount of people living or potentially living in each of the analysis units (Maritz *et al.,* 2016). The process of assigning population information to the units is based on the principle of dasymatric mapping which is defined by Eicher & Brewer (2001) as “the process of depicting the underlying statistical surface by transforming data from the arbitrary zones of the aggregate dataset". In this study, the entire population of Mbizana was considered as the demand for service.

The process of assigning the population information to the analysis units involves the following two-step process:

Step1: The analysis units (hexagons) were joined to the SBC-points by using the spatial join tool. The number of SBC points per hexagon was then counted using the hexagon's unique identification number. It was assumed that each SBC point is a potential household, although this is not valid in all cases as some points represent schools and other building structures (Mans, 2012).

Step2: To consider the SBC as a proxy to population distribution a weight for each SBC has to be calculated. This represents the contribution of each SBC point to the total population. A weight was calculated by dividing the population (of each settlement) by the total number of the SBC points (counted in step 1). The weighted value was then assigned to the SBC point falling inside each settlement and is considered to be a probable household size (Mans, 2012).

3.3 Catchment area analysis

To identify possible sites for eight new clinics, the study first evaluated the current accessibility situation across the municipality. This was done by computing travel distances from the demand (population) to the nearest supply (clinic) using catchment area analysis. This process allocates all areas of the study area to the nearest facility using a transport network approach – creating a catchment area for each facility. This process can be performed without any travel distance of facility constraints. However, where facility standards or capacities have to apply, the catchments created will simply represent the extent made possible through those limitations and unallocated areas will remain. The standards relating to maximum acceptable travel distance and facility capacities/sizes where applicable, were sourced from relevant documents such as the National Department of Health Standards (2000) and the IDP (2015-2016). This resulted in two types of analysis namely; the unconstrained catchment area analysis, where distance and capacity do not limit access to facilities. The second one was constrained by distance and capacity, where access to facilities was therefore limited.

3.3.1. Unconstrained catchment area analysis

The unconstrained catchment area analysis was conducted to reflect on the maximum travel distance to each facility along a road network. This essentially implies that, the entire population of Mbizana was allocated only once to the nearest facility. Due to an increased recognition of the role that mobile clinics play in alleviating the current strains at the fixed clinics, the unconstrained catchment area analysis then also incorporated mobile clinic stops in the analysis to get a more comprehensive access situation in the area.

3.3.2. Constrained catchment area analysis

The constrained catchment area analysis was done to reflect a more realistic accessibility situation. The analysis was conducted for only fixed clinics since the norms and standards for mobile clinics were not known. This analysis applied two constraints, namely: travel distance and capacity constraints. The acceptable access distance was set to five kilometres as prescribed by the National Department of Health Standards (2000). The capacity constraint was set to 10000 people per clinic because the fixed clinics were identified in the municipality's IDP as basic clinics thus having the maximum capacity of 10000 people per clinic (IDP, 2015-2016). The results from the constrained catchment area analysis were considered a significant first step for identifying eight new clinic sites since the remaining demand resulting from this analysis would form the basis for the expansion analysis process.

3.4 Expansion analysis

Using areas of unserved and remaining demand, an expansion analysis was done to identify locations suitable to build the eight clinics. This analysis searches for sites where within a five kilometres distance the highest remaining demand can be identified. The possible locations were then mapped and added to the current facilities. Catchment area analysis was repeated to determine the extent to which the added facilities reduced the initial backlog.

4. Results and Discussion

4.1 Unconstrained accessibility analysis

The results of the unconstrained catchment area analysis for fixed clinics are illustrated in figure 2 and are presented per travel distance band in kilometres. When capacity and distance constraints are not taken into account, 36.46% of the population is located well within service reach at a distance of 0-5 kilometres. Since access to clinics was not restricted by capacity or/and distance, access within 5 kilometres was expected to be higher. This was however not the case. The most likely explanation to this low access is the proximity of the population to clinics. Settlements are generally located far from facilities thus making it hard to access.

Interestingly, the results showed that, on average, 4176 people can reach a fixed clinic within 5 kilometres. This average is exceptionally low, considering that each facility is designed to accommodate a maximum of 10000 people. This is an implication that distance rather than capacity is a major constraint. Furthermore, the average distance that residents can travel to reach a fixed clinic in Mbizana is 9.1 kilometres. This is considerably high, since the department of health recommends a travel distance of five kilometres (National Department of Health Standards, 2000). From this, it can be deduced that the distribution of fixed clinics in relation to the population distribution in Mbizana is poor. The most likely explanation for this is the low population densities across the municipality; settlements are sparsely distributed thus making it difficult to optimally plan for facilities and as a result, people tend to be situated far from these facilities. This is often a case in most rural areas especially remote rural areas as past studies have shown (e.g. Oosterveer & Young (2015) in a case of Northern Canada & Tanser *et al.* (2006) in a context of Hlabisa in Kwa-Zulu Natal).

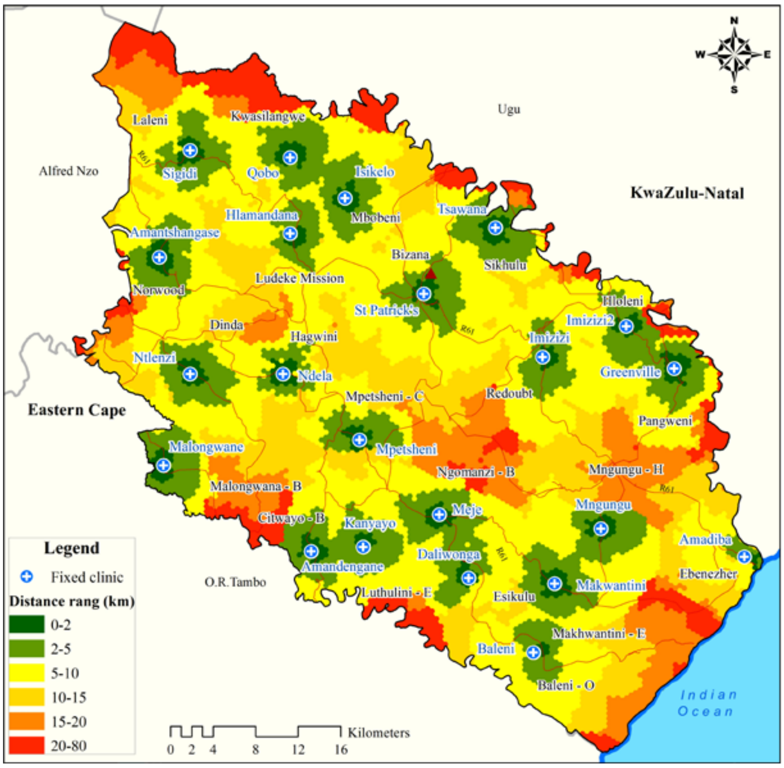

Figure 1: Travel Distances to the Closest Fixed Clinic – Unconstrained Travel Distance and Capacity

Mobile clinics supply health care services to residents that fall outside the health care coverage zones of fixed (permanent) facilities. Although services offered at mobile clinics are limited compared to those provided at fixed facilities, mobile clinics play a crucial role in alleviating the current strain at fixed facilities. To investigate the level at which mobile clinics improve the overall accessibility across the municipality, the second unconstrained catchment area analysis incorporated mobile clinics and the results are shown in figure 3.

From this analysis, access to clinics within five kilometres increased from 36.46% to 57.68%. This increase was expected and suggests that most mobile clinics across the municipality are well distributed and are placed in areas where they can provide PHC services to remote populations. This is consistent with planning of the mobile clinics as recommended by the National Department of Health (2000).

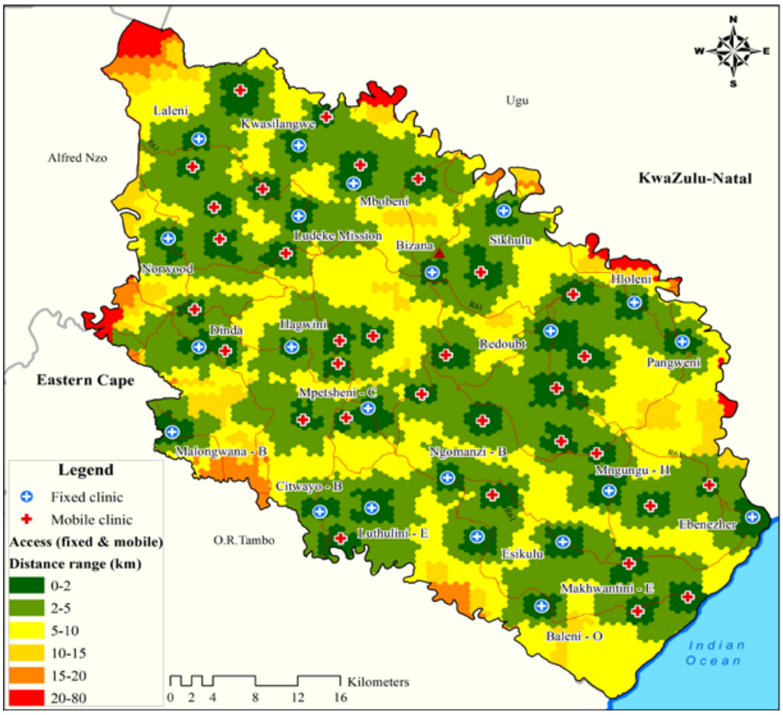

Figure 2: Travel Distances to the Closest Fixed or Mobile Clinic – Unconstrained Travel Distance and Capacity

4.2 Constrained catchment area analysis

A constrained catchment area analysis included both distance and capacity constraints. This analysis was guided by acceptable access standards to PHC clinics as specified by the National Department of Health Standards (2000). In this analysis, access to facilities was limited; and the remaining unallocated demand was described as "unserved". The unserved population therefore represents the focus for **intervention**. The analysis was conducted only for the fixed clinics. When capacity and distance are taken into account, 32.65% of the population is served. Expectedly, access to clinics overall decreased as a result of these constraints (compared to the unconstrained analysis). The results of this analysis are crucial since they act as an input into the process of proposing suitable locations for the eight new clinics.

4.3 Expansion analysis - identifying sites for new clinics

Considering the results of the constrained accessibility analysis, it is clear that there are some areas in Mbizana where clinics are still needed. Based on the remaining demand of 67.36%, an expansion analysis was carried out to identify locations suitable to site eight new clinics that were identified in the 2015-2016 IDP. Although the new facilities were placed in areas where the highest backlogs were identified, there was still a need to determine the level at which the new clinics could potentially reduce the identified unserved demand. Therefore, an unconstrained catchment area analysis was carried out and the results are shown in figure 5. The distribution of the eight new clinics appears to be relatively good and the new clinics minimized the unserved demand. The clinics are mainly located along road networks and also where most identified demand was located, this is consistent with the recommendations made by DPSA (2012) regarding planning for public facilities.

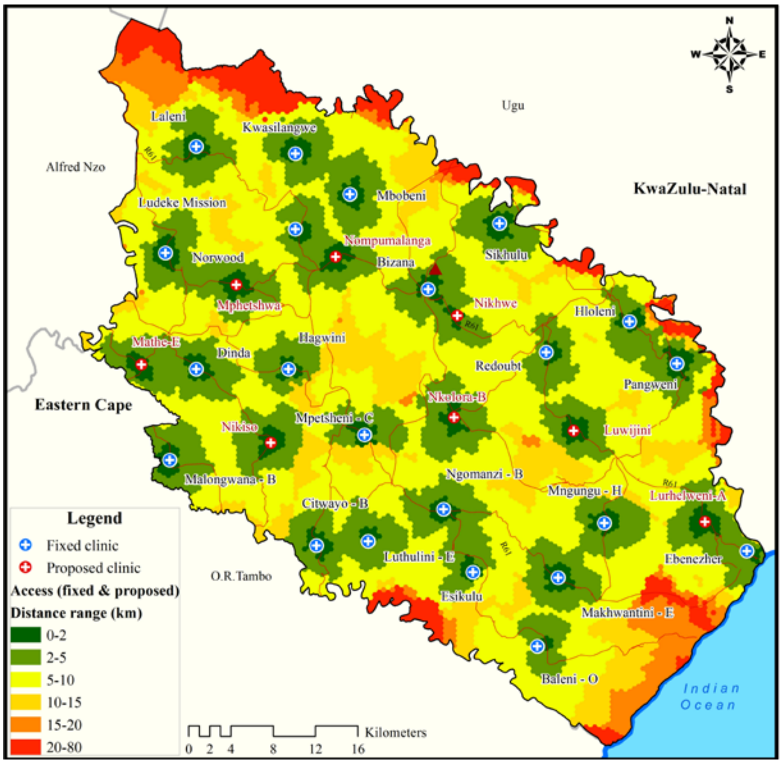

Figure 3: Travel Distances to the Closest Fixed or Proposed Clinic - Unconstrained Travel Distance and Capacity

Although the new facilities decreased the backlog by 11.87%, it should be emphasized that, a high proportion of the population (55.48%) is still not served within a 5-kilometre radius of the facilities when capacity is considered. This is an indication that the eight clinics that the municipality proposed in the 2015-2016 IDP are simply not enough to accommodate the full backlog.

5. Conclusion

In this study, GIS-based accessibility analysis was used to measure the level of accessibility in Mbizana local municipality. The results were then applied to aid in a process of identifying new sites for new clinics. Accessibility to clinics in Mbizana was calculated to be relatively low. Although the new proposed clinics alleviated the number of unserved demand in the area, there was still a shortage of PHC facilities in the area, indicating that, the eight proposed clinics are not enough to address the current unserved population. Measuring geospatial accessibility to primary health care facilities is considered to be the most effective approach for obtaining an insight into access situations. However, it should be emphasized that, GIS alone is not adequate to understand the levels of access and utilization behaviours of the facilities. Transport interventions for example although not considered here could also impact accessibility. Furthermore, GIS-based accessibility analysis contributed to understanding the geospatial access deficiencies. In other words, the proposed clinics were found to be optimal and addressed some of the unserved demand. This study can serve as an example of how geospatial analysis can provide inputs to support other possible facility planning in Mbizana. The methodology followed here is flexible and can also be applied to other social facility types.

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