

Using a GIS-based network analysis to determine Saudi and non-Saudi accessibility to the Primary Health Care Centers in Buraydah City, Kingdom of Saudi Arabia

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ABSTRACT: Primary health care centers (PHCCs) are the first choice for patients, according to health systems in the Kingdom of Saudi Arabia (KSA). Saudi and non-Saudi accessibility to PHCCs in Buraydah city was analysed using a network analysis in a geographical information system (GIS). This paper revealed that the Saudis, who represent the largest proportion of the population in the city of Buraydah, have 46.9% less access to PHCCs than non-Saudis. In addition, the use of network analysis in a GIS can be linked with statistical methods to support the decision-makers in detecting the accessibility and geographical distribution of health services.

KEYWORDS: PHCCs; accessibility; Network analysis; GIS; geographical distribution.

1. Introduction

The overall aim of this study is to analyse Saudi and non-Saudi accessibility to primary health care centers (PHCCs) in the city of Buraydah through a GIS-based network analysis. The PHCCs in the KSA are the main service in the defence against diseases and their most important responsibilities are preventive and curative. According to the World Health Organization (2008), in order for health services to be fair and efficient with universal coverage, they must be made available to all people according to their health needs regardless of their ability to pay. In 2009, the Ministry of Health in KSA began an important phase focusing on the renewal of PHCCs, and provided services at different standards; in addition it provided the service to all city areas. Thus, PHCCs play an important role in the delivery of health services and are intended to be available to all residents but uneven geographical distribution of health services may result in access deprivation them between Saudis and non-Saudis. Therefore, this study seeks to assess the accessibility ratio between Saudis and non-Saudis, according to the current status based on the locations of these services.

2. Background and Literature Review

2.1 Access to PHCCs

There are no specific criteria that can guide in the assessment of the access to PHCCs in the KSA, but there is a limitation on the size of a population that can be served by PHCC, as classified by the Ministry of Health; e.g. a PHCC classification (M1) can serve up to 32000 people, whilst in contrast, a PHCC classification (B3) can serve between 2000 and 12000 people (General Directorate of Health Affairs in Al Qassim, 2010). Although there have been a number of studies conducted on PHCCs in KSA, there are few studies that have evaluated accessibility and geographical distribution within cities. Al Ghamdi (1981) suggested developing a program for governmental medical centres that are accessible within a journey of not more than ten minutes for each population group in the neighbourhoods of the city of Jeddah, KSA. In addition, Al Rabdi (1990) presented the first study on medical services and the benefits from them in the Al Qassim province, by focusing on the characteristics of PHCCs. Moreover, Al Dlghan (1992) presented an analysis of the current pattern of spatial distribution and access to PHCCs in Riyadh city.

2.2 Access to PHCCs by using GIS

The Ministry of Health in KSA has focused in recent times on the importance of GIS maps in the field of health, where it has begun to establish a database for health services in some of the bigger cities such as Riyadh and Jeddah. In the face of the absence or unavailability of census data for smaller areas and buildings in KSA, some studies have relied on larger spatial units such as neighbourhoods or blocks, to assess the access or the geographical distribution of PHCCs. And the neighbourhoods that are residential areas are identified to divide the city into a number of areas, which in turn are then divided into number of blocks, which represent the smaller unit area of neighbourhoods. Typically, the average number of people in these neighbourhoods is between 5000 and 15000 people. For instance, Al Shahrani (2004) suggested several locations for PHCCs in Riyadh, according to the demanded 'catchment area' by using questionnaires and population density data. In addition, Al Dossari (2009) highlighted the use of GIS applications to evaluate accessibility to PHCCs in Riyadh city, by calculating the distance to, and a blocks' accessibility in a catchment area to, the nearest PHCCs.

GIS analyses of PHCCs have varied greatly. Some authors have focused on access to these centres, such as Møller-Jensen and Kofie (2001) presenting scenarios aimed at improving accessibility to health services in Ghana, using location-allocation modelling tools such as closest facility through a network. In addition, Luo and Wang (2003) offered an assessment of the spatial differences between access to PHCCs based on the attractiveness of doctors and several other variables in the Chicago region. Rosero-Bixby (2004) presented a GIS-based study evaluating equity in access to health care among Costa Ricans using traditional measurements, such as distance to the nearest health facility; and suggested that an index of access to healthcare should be based on the characteristics of the population and the nearest health facility. Tanser *et al.* (2006) presented an analysis of costs within the geographic information system in order to determine the time it takes (in any particular place) to reach a primary healthcare centre. Bagheri *et al.* (2006) demonstrated a new approach for access to primary healthcare by identifying the distance to the nearest primary healthcare facilities across the road network by using the centre of population distribution within each polygon. In the UK, Langford *et al.* (2007) showed the impact of alternative models, such as population distribution, to determine spatial access to primary healthcare services, for example, raster map data with database and mailing information in order to increase accuracy in determining the residential areas and primary healthcare centres in the study area of Cardiff, South Wales.

2.3 Access to health services by using GIS

The Locations of health services have been studied since 1960 by many sciences, for example, geography, spatial planning, industry, engineering, and public administration (Teixeira and Antunes, 2008). Accordingly, several authors have addressed locations of health services when trying to maximizing access to these facilities. For example; the use of models of network analysis methods such as travel time, rather than other traditional models such as Euclidean distance is an effective analysis to examine and to evaluate the supply and demand for health services (Walsh *et al.* 1997). Martin *et al.* (1998) used catchment areas analysis in GIS to calculate the travel distances to renal replacement therapy in England. They found that the use of travel distance more effective than the crow-fly distances. In addition, Schuurman *et al.* (2006) presented the methodology of the model of use of catchments areas with the network analysis based on travel time to reduce the costs of the locations of rural hospitals in British Columbia's. Moreover, Haynes *et al.* (2006) used the analysis of travel time in GIS to compare this estimates with the real access by car for some patients to the clinics of 8 hospitals in the North of England. They found that there was a strong association between the estimated time and real access.

Little research has been conducted that has examined geographic access to PHCCs for different ethnic groups. This paper shows that the use of network analysis in a GIS can be linked with statistical methods to support decision-makers to resolve disparities in health accessibility through analysis of the geographical distribution of these services in relation to demand. In addition, this study offers a further application for the method presented by Comber *et al.* (2008), when combining the network analyses in GIS with statistical analyses.

3. Method

3.1 Study area

Al Qassim province is one of thirteen areas in the KSA; Buraydah city is the largest city in Al Qassim Figure 1. According to the latest population census in 2004, the population of Buraydah city numbered 394,009 people, following the addition of new parts to the city. Additionally, according to this data it was estimated that Saudis comprise 85.5% of the total population of Buraydah. Non-Saudis make up the remaining percentage; they can be described as residents (non-citizens) males and females of any other nationality.

3.2 The data sources and network analysis

Data sources that were used in this study are listed in Table 1:

Table 1. The data sources

| Maps and Data | format | Produced by |
|---------------------|----------------------|---------------------------------|
| Road network maps | Shape file (line) | Al Qassim Municipality |
| Neighbourhoods maps | Shape file (polygon) | Al Qassim Municipality |
| PHCCs maps | Shape file (point) | Al Qassim Municipality |
| Demographic data | Excel file | Ministry of Economic & Planning |

The total number of PHCCs in the city of Buraydah is 32, distributed throughout 82 neighbourhoods. This information is based on a network analysis in GIS data, collected using the following steps:

1. Building the road network dataset.
2. Creating the PHCCs' access points.
3. Creating Output Areas neighbourhoods' centroids.
4. Analysing the origin–destination (OD)
5. Using the results of OD analysis (Output Areas) linked with census polygons to analyse accessibility.

Outputs of the previous steps in the form of tables were used in combination with a maximum distance applied of no more than 300 meters from the nearest PHCCs to the centre of the neighbourhoods, or a centroid point. The choice of 300 meters as a measure for analysis of accessibility relates to the small size of the most of neighbourhoods in the centre of the city of Buraydah and to demonstrate the method.



Figure 1. Buraydah city

4. Results

The results of applying a network analysis can be combined with Mosaic plots to detect the relationship between accessibility or deprivation, for Saudis and non-Saudis with regards to PHCCs. This analysis uses the set of '5% most deprived' and '5% least deprived', where Hartigan and Kleiner (1981) have proposed the first Mosaics plots for contingency tables. The scale which is applied in this analysis specifies no more than 300 meters from the nearest PHCCs to the centres of the neighbourhoods (Figure 2). Mosaic plots are a graph that can be used to study the relationship between two variables or more to clarify their relationship with other variables. In this study the Mosaic plots showed the Saudis and non-Saudis in terms of access: False or True and the percentage. They can use this analysis as applied by Comber *et al.* (2008), seen below:

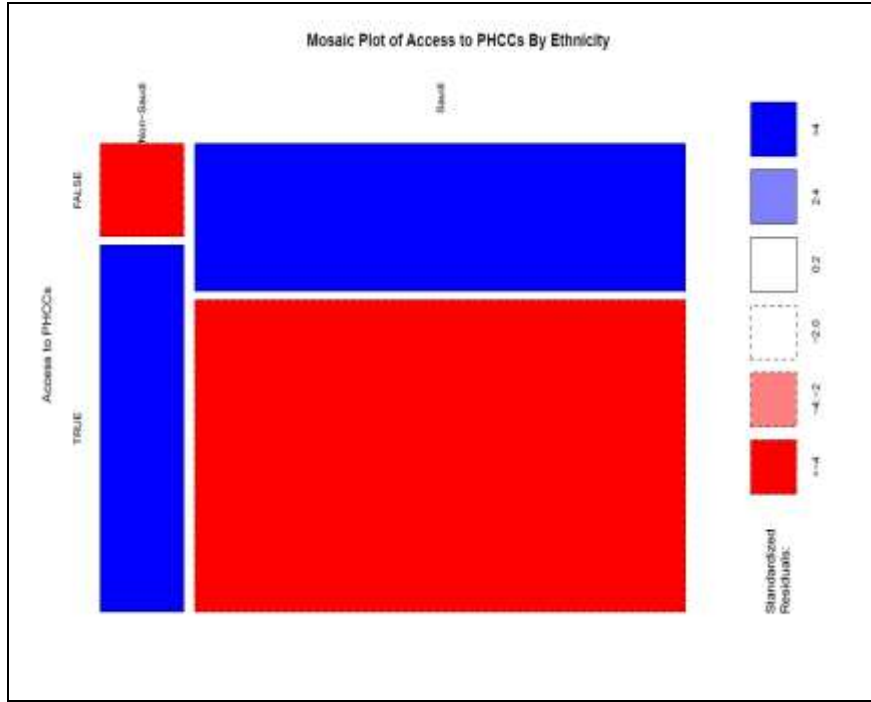


Figure 2. Access to PHCCs by Ethnicity in Buraydah city

Higher than average combinations of access and deprivation are represented by the blue tiles and those tiles shaded deep blue represent residuals greater than +4, and the red less than -4, upon comparison with a model of proportional access for deprivation.

- The Poisson regression model was applied through the following Equations; 1:

$$E(c_{ij}) = \log(r + A_i + F_j) \quad (1)$$

Where: c_{ij} is Poisson distribution, r is an intercept term, A_i is the effect of the column and F_j is the effect of the row. The comparison was made against the following model Equation 2:

$$E(c_{ij}) = \log(r + A_i + F_j + I_{ij}) \quad (2)$$

Where: I_{ij} is the impact of the interaction between the columns and rows, when there is a significant difference from zero; this indicates a degree of correlation between the effect of the column and the row. In addition, testing the relationship between deprivation and access to PHCCs, among Saudis and non-Saudis can occur with the previous model and information detailing access to PHCCs from Table 2:

| Access | non-Saudi | Saudi |
|--------|-----------|--------|
| False | 11450 | 108060 |
| True | 45645 | 228854 |

This work used an R statistical software package to estimate the value of I_{ij} and the data for deprivation by applying Equation 2. The index of access for Saudis and Non-Saudis used the following formula; Equation 3:

$$ACCESS = 100(\exp(I_{ij}) - 1) \quad (3)$$

Each column category j is compared with a 'reference' category; with 0 suggesting parity of access for category j and the reference category, +50 access is one-and-a-half times as likely and a value of -

50 that it is half as likely, etc. The reference categories used were in the median 50% of the scores for deprivation.

The results in Table 3 showed that Saudis have 46.9% less access to PHCCs than non-Saudis. This indicates that the largest proportion of the population in the city of Buraydah is about half as likely to have access to PHCCs, when compared to non-Saudis within a distance of no more than 300m.

Table 3 Percentage access to PHCCs within no more than 300 meters in Buraydah city

| Ethnicity | Estimate | Access true | Std. Error | z value | Pr(> z) |
|-----------|------------|-------------|-------------|--------------|-------------|
| Saudi | -0.6325067 | -46.8741 | 0.035026269 | -3.055360264 | 0.002247903 |

*Compared to the ‘non-Saudi’.

5. Discussion

The findings of this study can be explained by the concentration of non-Saudis and PHCCs in the older neighbourhoods that are located in the middle of the city; Figure 3. At the present the Saudi population lives in the new neighbourhoods in the east, north and west of the city. In the future data and analysis will be used to help to determine accessibility to PHCCs more accurately than has previously been possible in the majority of the studies in the KSA. For example, future work will estimate the population data by using areal interpolation techniques to estimate the number of people (demand for PHCCs) living in the neighbourhoods to the smallest unit area, i.e. in terms of blocks or parcels. In addition; future work will apply the new classifications of PHCCs, which will be implemented by the Ministry of Health in 2011, and will then determine accessibility, according to those classifications. These analyses can support the decision-makers in detecting the accessibility and geographical distribution of health services. In addition, identify the optimal spatial arrangement of health facilities that maximizes access to help planners to identifying the optimal location of health facilities according to the geographical distribution of population in urban centres.



Figure 3. PHCCs in Buraydah city

6. Conclusions

Planning for health services is important in many countries, and the majority of States make it a priority of any development plans. This work is to fill the gap in the literature pertaining to health service planning as has been identified in this study. In addition, this study is an important link to the studies of health services in general and GIS applications in particular. Moreover, this work will support the decision-makers by providing different methods for planning health services in the KSA.

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