Introduction to Geographical Information Systems (GIS) CRP 514

GIS: An Indispensable Tool in Health Applications

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SUMMARY

Mapping in public health planning and decision making processes is not new. The Cholera Map by John Snow marked a critical turn in the use of maps to understand the relationship between geography and disease. Recent developments in the field of Geographical Information System which ushered in more capability in its applications expanded the usage to different fields of human endeavors. This is sadly not true for the health sectors of Saudi Arabian like any other developing country, which are yet to explore and benefit from the immense potentials of GIS hence, this term paper aim at reviewing three useful studies explaining the possibilities and benefits of using GIS in health care facilities planning in Saudi Arabia. The studies, discusses planning issues, health demand and supply models that are related to a health center city and Public general hospital in Saudi Arabia by defining location, types of health demand and using GIS for manipulating and analyzing patients demand data.

INTRODUCTION

Application of mapping tools in public health planning to address the social welfare and epidemiological issues is not new. This is evident by the cholera outbreak map in Soho, England, in 1854 by John Snow which marked a critical turn in the use of maps to understand geographic patterns and diseases. Geographic Information System (GIS) technology is increasingly used by public health professionals, policy makers and other public health actors to better understand how geographic relationships affect disease transmission patterns, access to health care and health outcome. The use of GIS in public health is growing, a consequence of a rapidly evolving technology and increased accessibility to a wider audience.

Approaches to the geography of health take a variety of forms and methodological perspectives, some researchers choose to create statistical models of the incidence of disease, others adopting qualitative approaches to an understanding of ill health or exploring the geographical expression of the politics of health (Gatrell and Senior 2005). Hence, it is useful, to divide the geography of health into two broad areas: the geography of disease and ill-health; and the geography of health care. This term paper focuses on both aspects using of GIS and case studies from Saudi Arabia.

One of the basic responsibilities of any Government in an organized society is the provision and fair access to health services at the right place and time. In most countries, health facilities can be divided into primary and secondary health care. The former provided basic curative and preventive medicine while the later provides specialized health services. Today, local health planners have a myriad of responsibilities; these functions include monitoring of patient lists, monitoring of catchment areas, and assessment of health needs and facilities management. These functions can also be seen in the form of a checklist which includes:

(a) Where do their existing patients come from (by age, sex and specialty),

(b) What is the Potential for increasing the workload by attracting patients currently referred elsewhere,

(c) What are the implications of proposed contracts on the future viability of units and specialties within the organization, and

(d) Who are their main competitors of responsibilities (Murad, 2004).

There are several issues that hinder the proper implementation of health policies and usage of health establishments; the relationship between the distance to the health center and the need for health care, neighborhood, financial statues, social inconveniences, psychological stress of the time taken to get to the health facilities.

Using GIS in health care planning studies is well acknowledged by Western, European researchers and it is used for various health care issues at the developed countries. However, in Saudi Arabia this technology is still not very well explored by health authorities and researchers (Murad 2007). The following works of Murad gave useful insights into the possibilities of using GIS in health planning issues in Saudi Arabia using non-technical language in a step by step sequence. It provides good examples on how to use GIS in health planning issues in Saudi Arabia or any developing country with a peculiar case.

1. Defining health catchment areas in Jeddah city, Saudi Arabia (2008)
2. Creating a GIS application for Health services at Jeddah city (2007)
3. Using GIS for Planning Public General Hospital planning at Jeddah City (2005)
4. Creating a GIS application for Local Health care planning in Saudi Arabia (2004)

TERM PAPER OBJECTIVES

The aim of this term paper is to briefly discuss

1. GIS tools used in Health planning and epidemiological studies.
2. Summarize the findings of Murad 2004, 2005, 2007, 2008

BACKGROUND ON CASE STUDIES

The table below gives a brief summary of the stated objectives, issues addressed and methodologies used.

Table 1. Summary of case studies

Author	Objectives	Issues addressed	GIS Methodology Used
Murad 2004	• Outline the possibilities of using GIS in local health planning • A review of GIS functions relevant to health planning	• Local health planning • Catchment Area Analysis • Health facilities Management • Patient flow models	• Geocoding • Overlay analysis • Network analysis
Murad 2005	• Identifying the development and potentialities of GIS in the healthcare planning field. • Defining the role of GIS in monitoring hospitals service areas. • Using GIS for modeling health care accessibility and utilization.	• Spatial changes in health studies • Spatial epidemiology • Health facilities accessibility and utilization	• Buffer analysis • Network analysis • Site Suitability analysis
Murad 2007	• Evaluating the spatial distribution of hospital demand • Defining catchment/service area for a given health care facility	• Distribution of Health demand • Classification of hospital patients • Delimitation of hospital service area	• Network analysis • Overlay analysis
Murad 2008	• Creating a best fit application for modeling and visualizing health demand and supply data using GIS.	• Spatial distribution of health and supply data • Catchment area analysis	• Buffering • Overlay • Network analysis • Allocation functions

DATA COLLECTION

Data needed for the various studies where collected from different Management Information system (MIS) and Saudi Arabian Ministry of Health website; often incomplete without any spatial information, these system are built hold patient information for future uses such as addresses, medical history, age, sex, number of visit etc. In all the studies under review, data were not readily available in the digital format hence the author devised a means to digitize the data (maps) and geo-reference (addresses) them. These data are road network that shows all types of roads in the selected area, parcel map showing land sub division, and a neighborhood coverage showing the health service area boundaries.

- In the 2004 study, the MIS data obtained was geo-tagged which made it readily available for Network and catchment area analysis coupled with a model, $\mathbf{Pij = A_i \times R_i \times D_j \times f(C_{ij})}$Where Pij, is the flow of patient from residence i to health center j; Ri, is the patient demand in area i; Dj, is the number of doctors at health center j; Cij, is a measure of the cost of travel or distance between i and j, and Ai, is a balancing factor. Hence, the flow of patient was determined.
- Also, in the 2005 case study, the non-spatial data obtained from the MIS were linked to local census data which include coverage area, the hospitals size (capacity), number of people living in each district of the city, and the population density of this district. All of these data are then used for the modeling process of hospital accessibility.
- Similarly, Murad (2007) linked the MIS obtained data to demand coverage which he later used to calculate health demand.
- In 2008, The MIS data obtained were linked to the health centers using the Straight line allocation (SLA) function.

Murad in all these studies strongly demonstrated how insufficient and restricted data in a country like Saudi Arabia can be put into inferential and productive usage.

STUDY AREA

The table below summarizes the locations for each of the study. It is very important to identify the area in which the studies were carried out in other to understand the analysis of the findings that follows.

Table 2. The study areas

Author	**Study Area**
Murad 2004	A local health centre called Rusaifa Medical Centre at Makkah City, Saudi Arabia. This Centre is located on the Western part of the City and serves four local neighborhoods named as Gazzaz, Zahraa, Bador and UmmalJood.
Murad 2005	General hospitals in Jeddah, with the hope to evaluate their accessibility
Murad 2007	A major private hospital in Jeddah, based on factors such as accessibility and ease of obtaining data, size, relevance of planning issues to other hospitals, bed capacity and specialized doctors
Murad 2008	Major Hospitals in Jeddah city

Countries all around the world today have guidelines and regulation concerning health planning and social welfare, the author extensively depended on the regulations obtainable in Saudi Arabia. There are sets of standards that are produced in Saudi Arabia to evaluate and plan the location of health facilities. These indicate that every hospital should provide 2.5 beds for every 1000 persons with a catchment area of 4 – 8 km and health centers on the other hand should serve a catchment area of 2 – 4 km. A doctor should serve 2000 patients. These standards are going to be tested by these studies at the using GIS. This information becomes handy in understanding the results arrived at by the author.

GIS TOOLS IN HEALTH PLANNING

Several GIS techniques for health related analysis are readily available depending on the objectives of the study and the expertise. These studies have used basically four GIS techniques which include

OVERLAY ANALYSIS

Overlay analysis manipulates spatial data organized in different layers to create combined spatial features according to logical conditions specified in Boolean algebra. Overlay is accomplished by joining and viewing together separate data sets that share all or part of the same area. The result of this combination is a new data set that identifies the spatial relationships. In the case of feature-based data, Union, Interact and Identity are the major polygon overlay functions. These are used by planners to get new coverage that satisfy the required criteria. In the 2007 study intersect function was to analyze health demand which falls inside the created drive-time hospital service area. This overlay function creates a new output coverage that has only city districts that falls inside hospital service area. it was also used to determine the demand of a selected service area

NETWORK ANALYSIS

Network analysis is used for identifying the most efficient routes or paths for allocation of services. This involves finding the shortest or least-cost manner in which to visit a location or a set of locations in a network. The "cost" in a network analysis is frequently distance or travel time.

BUFFER ANALYSIS

Buffer analysis is used for identifying areas surrounding geographic features. The process involves generating a buffer around existing geographic features and then identifying or

selecting features based on whether they fall inside or outside the boundary of the buffer. For example, the author used buffer analysis to determine catchment area in his studies

GEOCODING

Geocoding is the process of finding associated geographic coordinates (often expressed as latitude and longitude) from other geographic data, such as street addresses, or zip codes (postal codes). With geographic coordinates the features can be mapped and entered into Geographic Information Systems, or the coordinates can be embedded into media such as digital photographs via geotagging.

RESULT AND DISCUSSION

The section summaries the major findings in all the studies, due to the heterogeneity and the fact that the studies where basically written as non-technical pieces to educate those who are not aware of the immense benefits of GIS, it was difficult to make any comparative and cost analysis. However the findings pointed out to key issues in health planning and academic research in Saudi Arabia. Presented below are the findings of the author in his own words.

MURAD 2004

Murad A., (2004) in his paper titled “Creating a GIS application for local health care planning in Saudi Arabia Carried out this study in a public health care center (Rusaifa center in Makkah)” focused on three issues which are;

- Catchment area
- Patient profile
- Patient distribution and flow

FINDINGS

Network analysis was preferred overlay technique in this study because it can incorporate planning and demand/supply data. Using the local census data, there are 20975 people in the predefined area. However, the Saudi Arabian Health planning standards stipulates 1 doctor to serve 2000 individuals. The Rusaifa center had only 3 doctors which is grossly insufficient for the predefined catchment area as indicated by the author's spatial analysis.(FIG 1)

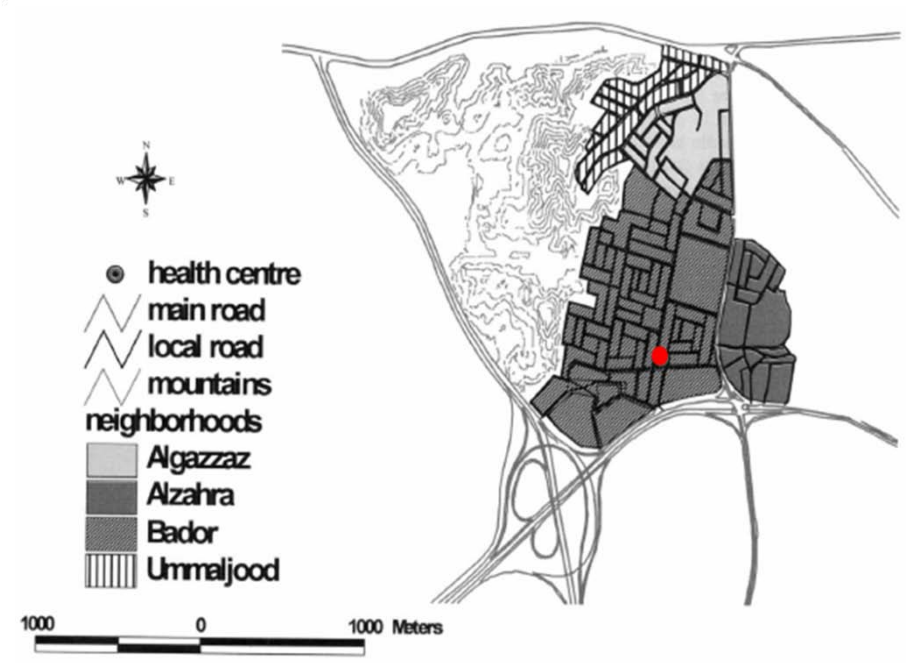

FIGURE 1 RUSAIFA CATCHMENT AREAS

Population is highest in Bador followed by Al-Zahraa and comparatively low at UmmalJood and Al-gazzaz. Demand and supply data were used to arrive at such conclusion: demand here is defined as the number of people while supply is the available health workers. In other to test if the spatial distribution has any anomaly in disease spread, the author asked a question, "Does pattern of diseases follow population density?" He answered this question by comparing health diagnosis data from the catchment area based on the demand data. He selected diabetic, blood pressure and asthma patients. The spatial distribution was similar to the population density spread and hence the result agrees with the hypothesis that such

conditions are higher in densely populated locations. The ranking is as follows Al-Zahraa - Badoor-UmmalJood–Al-Gazzaz. Al-Zahraa and Badoor, are two neigbourhoods characterized by the presence of commercial buildings, government offices, apartment building and as such the result was in agreement.

FIGURE 2 DISTRIBUTION OF DIABETICS AND BLOOD PRESSURE DISTRIBUTION

Spatial interaction model was also made to show the impact of increasing health supply at the study area from 3 to 6 doctors. This is a kind of, what if, modeling that is made to identify the impacts of having certain changes regarding health service provision at the study area. The result of this model not only shows the improvement in the center catchment area, but also describes the predicted spatial distribution of health demand for Rusaifa Centre. For example the model indicates that the eastern parts of this center will produce more demand due to the expansion of health supply. The author concluded that same technique can be applied at the other health centers of Makkah City, and by doing so health care planning would be more effective in Makkah City.

MURAD 2005

This study selected the catchments area technique that is based on planning standards and uses GIS to define hospitals catchments area based on the predefined area by local authorities. According to the standards of Saudi Arabia, every hospital should have a service area of 4 to 8 km depending on its bed size. Small hospitals with a 50-bed size serve a 4 km area. Medium (100 bed) and large (400+ bed) hospitals serve 6 and 8 km area respectively. These standards were applied and the following conclusions were arrived at.

Table 3. Showing the relationships of bed size to catchment coverage

Size	**Beds**	**Catchment Area (km)**
Small	50	4
Medium	100	6
Large	400+	8

Table 4 Catchment areas of major hospitals found in Jeddah.

Hospital name	Supply (no. of beds)	Catchments area (km)
King Fahad	932	8
King Abdulaziz	417	8
Al Thagher	90	6
King Saud	50	4

1. About 75% of Jeddah city is falling inside hospitals catchments areas and therefore, people falling inside these areas should be served by these hospitals.
2. About 25% of the city is located outside hospitals catchments area and these areas show the

3. Non-served parts of the city. These results can be further analyzed when hospitals demand is included in the analysis.

Such a step looks at the available demand for every hospital, and then defines a more detailed catchments area where the extent of hospital catchments area is subject to its supply. Further, the author applied the “What if Model”, the purpose of this model is to test the impacts of increasing Al Thagher hospital size from 90 beds to 400 beds. This what if model shows the changes in hospitals catchments area that will result from adding more new beds into such hospital. The result showed that city hospital catchments area is increased to cover the southern parts of the part of the city. This sort of modeling is very useful to health authorities because it can predict the spatial impacts of any health care planning policy and therefore, the required action towards such policy can be defined before implementing the policy. He concluded that health services provisions in Jeddah city is insufficient and that the Government should establish more health centers, atleast 2 with a bed capacity of 2000 to serve the northern parts of the city.

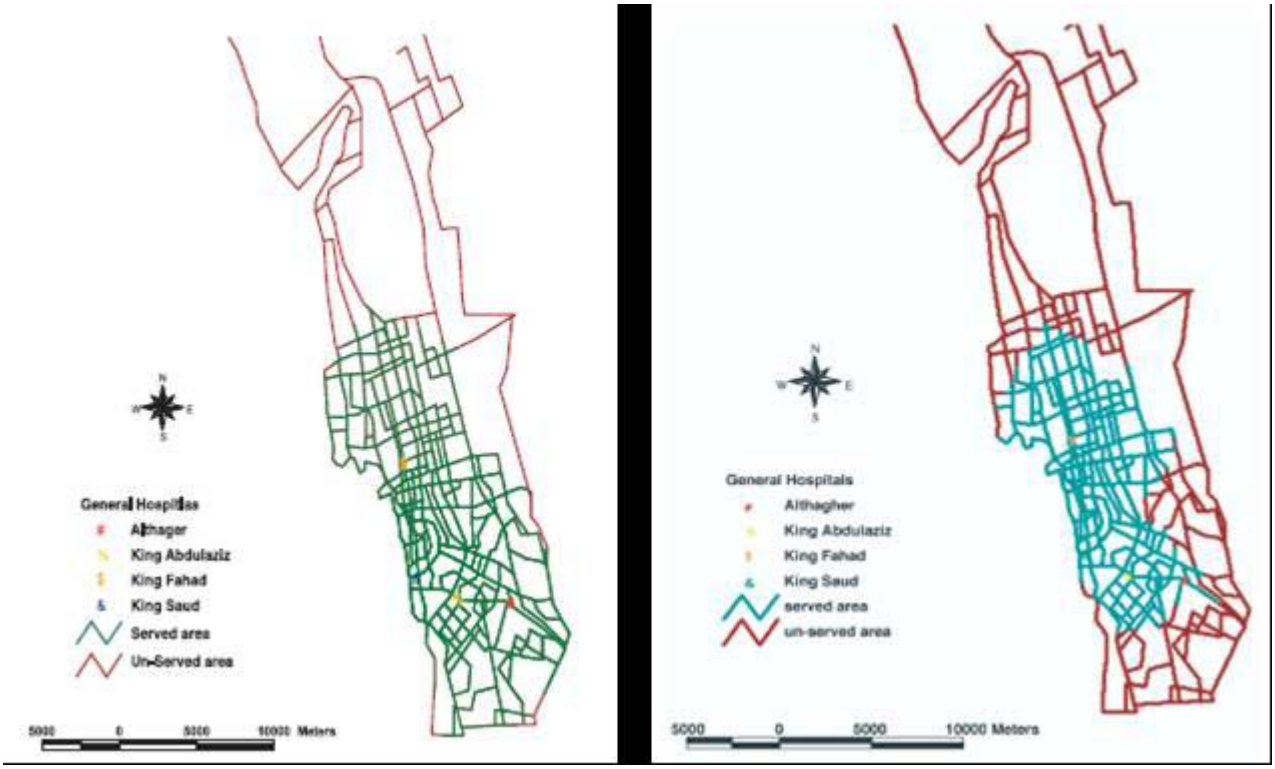

FIGURE 3. BEFORE AND AFTER THE CALCULATED 15MIN CATCHMENT AREA

MURAD 2007

In 2007, Murad Created a GIS application for Health services at Jeddah city and used patient demand data find:

- spatial distribution of health demand
- Classes and type of Health demand
- Accessibility to the hospital

Data were collected from MIS (management information system) and hence lack spatial references, also the available maps were paper maps. The author remedied the situation by first building a geo-referenced database using the patients address and also used a digitizer to create the area polygons corresponding to the predefined catchment area.

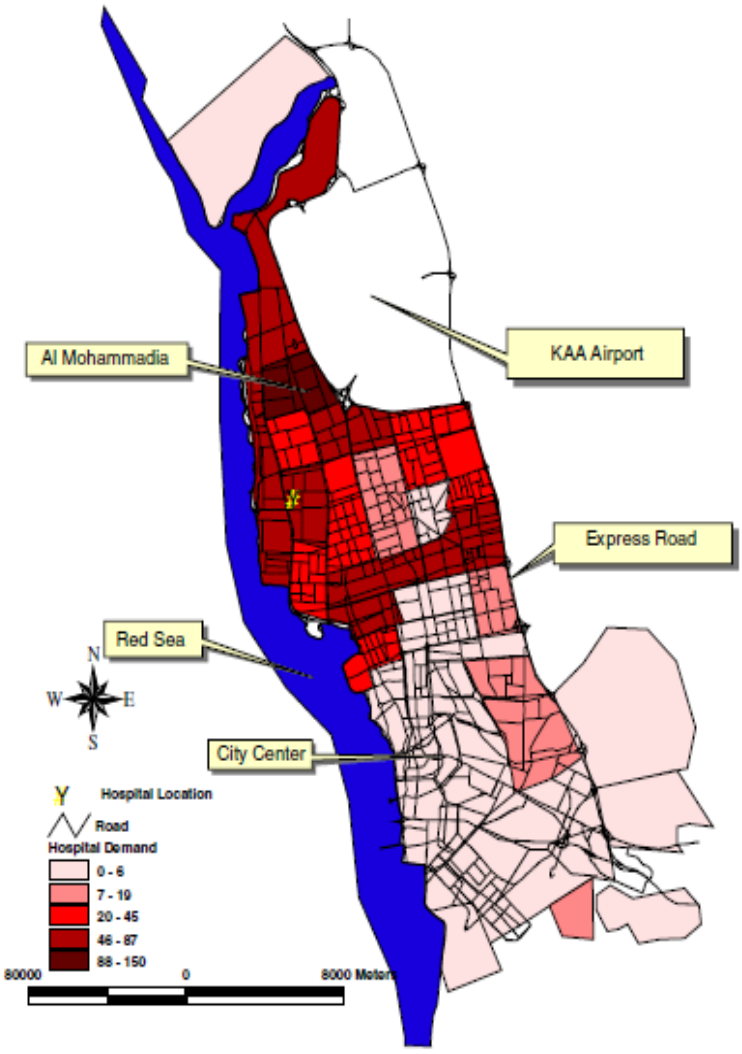

FIGURE 4 DISTRIBUTION OF HOSPITAL DEMAND

The author concluded that Patients come mainly from the Northern parts of the district and that the central and southern neigbourhoods are not performing well: given reasons such as the proximity to the hospital and standard of living (income status) of people in this environment. The author also classified health demand data into groups namely general and specialized services, emergency and hospitalized. Al-mohammedia had the highest number of hospitalized patients and hence the author suggested a more thorough investigation of possible factors that might have prompted such observation. Also, female patients were discovered to use the health facility more often than male patient, females than male patients from all areas close to the hospital which further suggest the need for specialized doctors in female related cases. The areas Alzahra and Alnahda, although within the predefined catchment area had no patronage, and to further understand why, the author calculated the market penetration index and concluded that:

$$\text{Using } market\ penetration\ = \frac{Size\ of\ patient\ in\ an\ area}{number\ of\ household\ in\ the\ service} \times 100$$

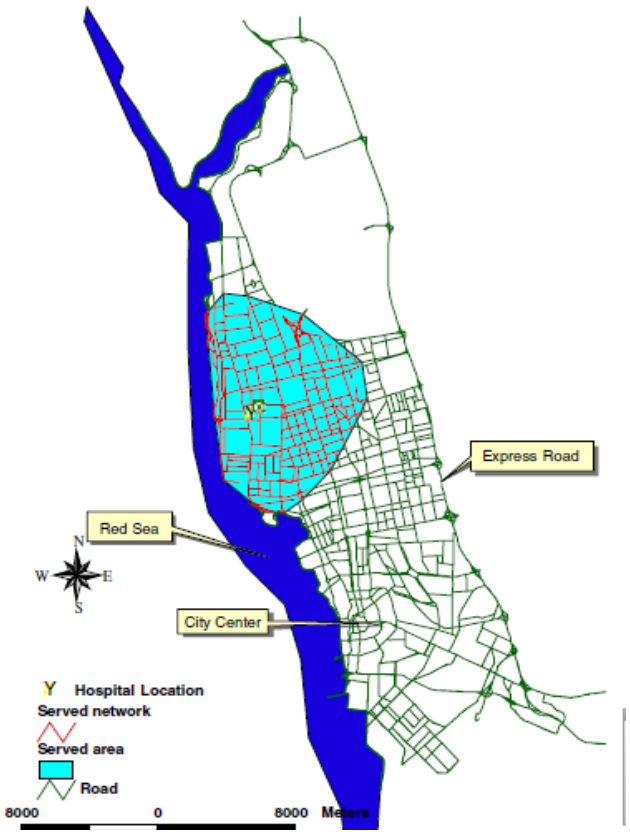

FIGURE 5 15 MINUTES DRIVE CATCHMENT AREA

Three new more areas where discovered which the facility can take opportunity of in its future planning: Alsalmah, Albawadi, Alrawdah. Finally, he calculated a 15mm travel time for the facility to account for the most effective and serviceable catchment area for the center.

MURAD 2008

Murad in 2008 attempted to solve the issues some critics identified in the use of planning standards for health related spatial analysis (catchment area). The use of planning standards for catchment area analysis alone has some limitations due to the following assumptions usually made

- That People within a region have equal access to physicians within that same region
- And that people do not venture beyond their own region to seek care.

In other solve this problems, Murad (2008) used a more analytical method (Straight line allocation method) to define health catchment areas. The straight line allocation function assigns each cell the value of the source to which it is closest; the nearest source is determined by the straight line distance (measures the straight line distance from each cell to the closest source).

The paper concluded with the following remarks “In conclusion, the present paper demonstrates that a series of health care planning issues can be effectively handled and managed by existing GIS software packages. Specific GIS-based models, related to two main health-service planning aspects, have been created for Jeddah city. A remarkable difference in the amount of health supply of every center was found. Single and multiple spatial search GIS functions have been applied to produce a health supply model. Based on the SLA function, a new health service area model for every centre has been produced and then compared with the actual local health authority service area. It was noted that a considerable

improvement of the size of the service areas could be achieved when implementing the SLA service area model for the city health centers."

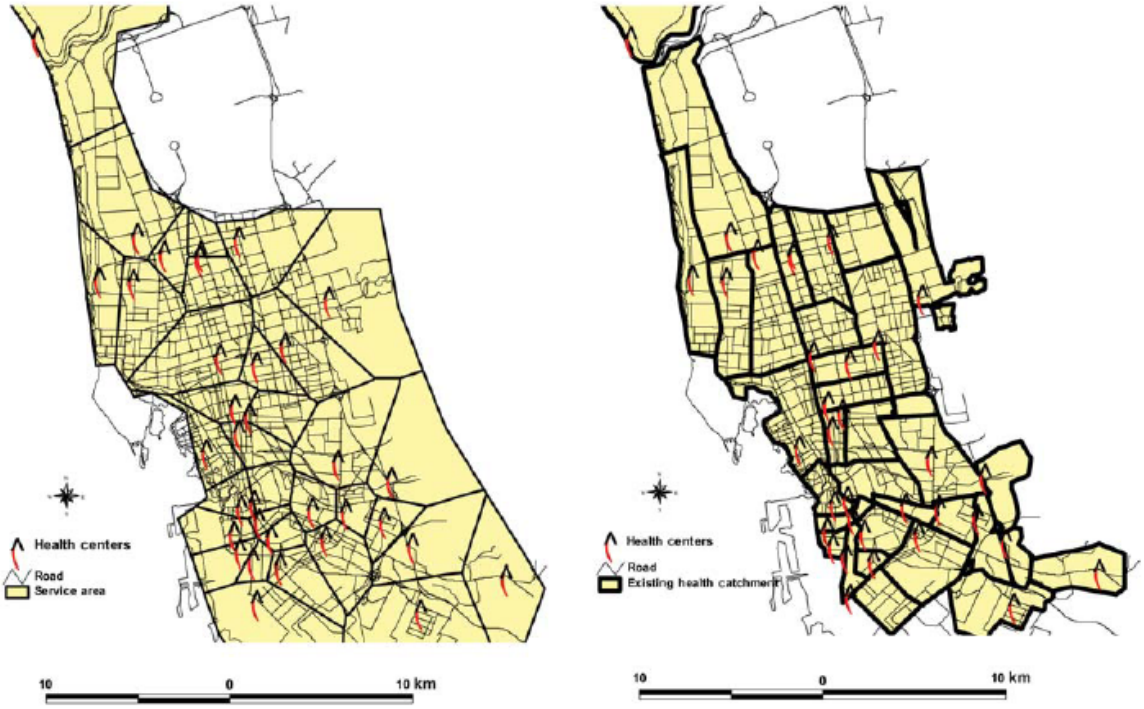

FIGURE 6 CATCHMENT ARE USING SLA FUNCTION AND THE DEFAULT CATCHMENT AREA

DISCUSION AND CONCLUSION

The four studies under review touch most issues relevant to health planning but spared spatial epidemiology little word. At the end, the catchment area applications appears to be the most important in health planning as it appears in all the cases studies. The author describe how different techniques and data sources ranging from demand/supply data, health planning standards can be used to make reasonable inference in the relationships that exist between health application and geographical information system even to an absolute beginner.

However, I strongly feel more information can be passed across if only the author can concentrate on a topic at a time with less ambiguity. The studies explored in detail, all forms

of available health data in the Kingdom and how these can be put to a visual and productive use. He also stressed on the difficulties encountered in obtaining data in Saudi Arabia also, which often discourage researchers from conducting a thorough study. However, he failed to considered some other factors obviously interacting in his choosing locations and was quick to make recommendations on spatial distribution of female patients in relation to male for example (the health facility might have better dispositions towards females, friendly doctors who listen more, large number of nurses and even success stories).

It is pertinent to note that such studies would have a far reaching impact in my country (Nigeria). Nigeria is a republic with three levels of Government; the federal Government has allocations for state and states allocate to the local government areas for local health planning. The federal government although have mega health projects built all around the country based on politics. Such studies would help to present a solid case by a community/local government/state for better representation. An example is a community which have abundant distribution of endemic poisonous snakes but the specialist hospital that manages cases of venomous snakes was (and still is) located in a different State in the country that the locals am sure don't know about. This type of study would help to convince the government to expand its health investments in areas not properly covered. Again, after reading through all this studies, I felt GIS can serve as warning tool for Health Planners/Government not to invest in areas where facility is not needed

Furthermore, there was no mentioning of whether or not the findings are adopted by the concerned health centers/government. Finally, probably due to the small scale of the studies, there was also no mentioning of the cost. This would have assisted Researchers/decision makers to know the gravity of what they are getting into (cost-wise)

REFERENCES

- John Snow (physician) http://en.wikipedia.org/wiki/John_Snow_%28physician%29 (accessed 26.12.2010)

- Gatrell A., Senior M., (2005) Health and health care applications. In Geographical Information Systems: Principles Techniques Management and Applications. 2 Abridged editions. Edited by: Longley PA, Goodchild MF, Maguire DJ, Rhind DW. New York: John Wiley & Sons; 2005.

- Murad A., (2007). A GIS application for modeling accessibility to health care centers in Jeddah city. In: GIS for Health and the Environment: Development in the Asia Pacific Region. C Lai, A Mak (eds). Springer, Berlin, Germany, pp. 57-70.

- Murad A., (2004) Creating a GIS application for local health care planning in Saudi Arabia, Int. J. Environ. Health Res. 14 (3) 185–199.

- Murad A., (2005) Using GIS for planning public general hospitals at Jeddah City, J. King Abdulaziz Univ.—Environ. Sci.

- Murad A., (2008) Defining health catchment areas in Jeddah city, Saudi Arabia: an example demonstrating the utility of geographical information systems. Geospat Health. 2008 May ;2(2):151-60