Spatial and Multidimensional Visualization of Jeddah Health Resources
A Community Health Assessment of Jeddah City

by

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ABSTRACT

Jeddah public health resources are struggling to meet the demand of the large populations. The city is suffering from insufficient public health resources along with other health problem, like high rates of some disease, which resulted in an amount of dissatisfaction among some of the health facilities visitors. The absence of a comprehensive Community Health Assessment study of Jeddah public health resources and the fact that health resources are not meeting the needs of the large population created the need to conduct this study.

This is an exploratory study that will use the guidance of two frameworks, Mandala of Health and "Access as fit" theories, and take into account all public hospitals and primary clinics provided by the ministry of health (MOH). Availability and accessibility of MOH resources will be assessed according to the Saudi planning standards for the years 2006 – 2010. Furthermore, health professionals' numbers will be assessed against the demand of some prominent disease cases in each census tract for the years 2006 – 2010.

A multidimensional exploration of the data is needed to answer the queries of this study. Thus, Spatial OLAP Visualization and Analysis Tool (SOVAT) is utilized. This tool has the capability of integrating multidimensional databases to maps. It also answers complex queries easily and rapidly and gives results in maps, spreadsheets, and graphs.

The exploration resulted in determining that primary clinics are allocated in accordance with populations' densities with few exceptions. In addition, parts of the city were found to be lacking some facilities or health professionals while few parts were found to be over-served with resources. Finally, it has been found that there is a need to increase the number of hospitals. Additional patterns of the resources have been uncovered due to the multidimensional capability of SOVAT.

The tool proved to be efficient and established a much better comprehensive understanding of the health resources. Additionally, it helped interpreting the interaction between the dimensions of the "Access as fit" framework. Nevertheless, some technical skills were needed for a successful data preparation and integration. It could be implemented by MOH as few requirements must be met.

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1.0 INTRODUCTION

The Saudi health system is a three-tier referral system with primary, secondary, and tertiary healthcare facilities corresponding to Primary Health Care, General Hospitals, and Specialist Hospitals respectively (WHO, 2006b). Patients seeking treatment start at the Primary Health Care centers (primary clinics), and if the condition requires further care, then they are referred to the General Hospitals and ultimately to Specialist Hospitals for the most serious conditions. The Saudi governmental health care system, which provides 60% of the health care to the population, takes up more than 7% of the annual budget of the country.

The Ministry of Health (MOH) in Saudi Arabia is the governmental site that is responsible for all health-related decisions in the country. In addition to providing most health care services, they supervise all health care services, whether they are provided by the MOH, other governmental agencies, universities, or even the private sector. Each health care provider in Saudi Arabia has to adhere and comply with MOH regulations. In a Country Cooperation Strategy devised by the World Health Organization (WHO) and Saudi Arabia (WHO, 2006a), the mission of MOH is described as "The provision of comprehensive health care comprising preventive, curative and rehabilitative components commensurate with the Saudi Arabian culture, health ethics, citizens, approval and having equitably distributed health services in addition to taking care of the health personnel in a means that will influence an acceptable performance".

Like many other countries, health resources, like hospitals, provided in Saudi Arabia usually tend to be concentrated in certain areas more than others. In fact, three major cities have the lion's share in terms of health resources (Al-Kahtani, 1991) , and some resources are only available in major cities, such as specialist public hospitals (WHO, 2006a). Moreover, some big cities are better served than others of approximately the same size. For instance, a city like Riyadh is provided with more health care facilities than many cities of equal size – like Jeddah. And despite the availability of resources, larger cities like Jeddah are still in great need of more resources from the Ministry of Health (MOH) to meet the growing demand.

There exist a number of studies that have investigated health-related issue in Saudi Arabia from different perspectives. Some of these studies focused on the spatial perspective using the Geographical Information System (GIS) technology. For example, Murad (2005) used GIS to model the accessibility to four of the public hospitals in Jeddah city, and Alharthy (2007) used GIS to investigate the distribution of the black hole devices to monitor and control dengue fever cases in Jeddah city. Other studies have focused on patient satisfaction levels. For example, Banakhar, et al (2006) conducted a study to investigate patients' satisfaction level with the primary health care services provided in a primary clinic.

However, there are a lot of remaining unanswered questions. No study has investigated the health resources provided to a city (Jeddah) as a hole according to the needs of the populations. There is also no study that has investigated the improvement of all of the provided health resources over several years. In other words, there is no comprehensive study that is conducted as a Community Health Assessment (CHA) on all the health resources provided by MOH. Without such a study, the understanding of the health resources would be incomplete.

This study will take a gradual approach by using two frameworks as guidance to the assessment process. The Mandala of Health model will be used as a broad framework to begin. The focus will be on assessing the medical care system part of that framework. Particularly, access to health care system will be assessed. Thus, another framework called "Access as fit" will guide the assessment of health care accessibility. This framework specifies five interactive dimension to measure access to health care; availability, accessibility, accommodation, affordability, and acceptability. Two of these dimensions are used to divide the explorations of this study. Other dimensions were covered in the review of the literature. However, it is crucial to distinguish between those dimensions and the data dimension, like health professionals, hospitals, and primary clinics.

The driving force behind the need to conduct this study is the absence of the comprehensive study that provides a better understanding of Jeddah public health resources. And the need for a tool that is able to integrate scattered date from various sources and gives a clear interpretation of those integrated data. Fortunately, Spatial OLAP Visualization and Analysis Tool (SOVAT) is a novel technology that exists and capable of handling such diverse data and answering complex questions. This tool has never been introduced to the researchers of the Saudi health field before. It will allow for answering numerical-spatial questions easily and rapidly. Much better understanding of the health data will be gained. And, new patterns and trends of the data will be uncovered that might remain hidden otherwise. Thus, better decision could be made by MOH officials as better interpretation of the data will emerge from using the novel tool.

1.1 STATEMENT OF NEED

The review of the literature indicates that there is no comprehensive study that has investigated the health resources of the whole city provided by MOH. Researchers have to rely on scattered or incomplete data and limited studies when investigating health resources in Jeddah city. The few studies which have investigated issues related to the health resources in Saudi Arabia have found deficiencies in the resources. It seems there is a need for more resources due to population size. In addition, different geographical locations in Jeddah are served by different kinds of health resources, with some locations being underserved or completely un-served by the MOH (Murad, 2005, 2007, 2008b). This is causing an amount of dissatisfaction among health facilities visitors (Banakhar, et al., 2006). Demand for health services is increasing with population growth, and the city is facing health problems such as high incidence rates of hepatitis cases, dengue fever, and heart disease (MOH, 2007). Despite the efforts and money spent by the government to enhance the health resources, the city hasn't met with the population demand (as argued previously). So, based on the population needs and Saudi health planning standards, is there parity between different locations in terms of health resources? What are the exact needs for underserved locations?

Given these issues, this study will start by investigating the allocation of health resources across the census tracts according to population densities. Such resources include public hospitals and primary clinics. Then it will investigate the progression of services provided by both hospitals and primary clinics using the number of health professionals for the years 2006 - 2010. Next it will investigate the need for additional hospitals and primary clinics based on location. Finally, it will assess census tract readiness to medically serve cases of diabetes, hypertension, asthma, and dengue fever.

Therefore, upon the completion of this study, there will be a better understanding of the health status and demands of Jeddah. Additionally, specific health problems will be investigated to determine the city's readiness to deal with them. For example, is the city ready to provide medical care to a person with diabetes and which locations of the city are underserved? Finally, the need for any additional resources will be determined by specific location.

1.2 AREA OF INVESTIGATION

Jeddah city is the second largest city in Saudi Arabia, with a population of more than 3 million. It is a coastal city located on the western coast, and it is considered the business capital of the country. Some major health issues are more prevalent in Jeddah than in the rest (average) of the country. According to the Ministry of Health statistics yearbook (MOH, 2007), communicable diseases rates – like those of Hepatitis B and C and dengue fever - are very high in Jeddah compared to the national average. Specifically, Jeddah has 35.2% of Hepatitis C cases, 23.9% of Hepatitis B cases, and 49.6% of dengue fever cases in Saudi Arabia.

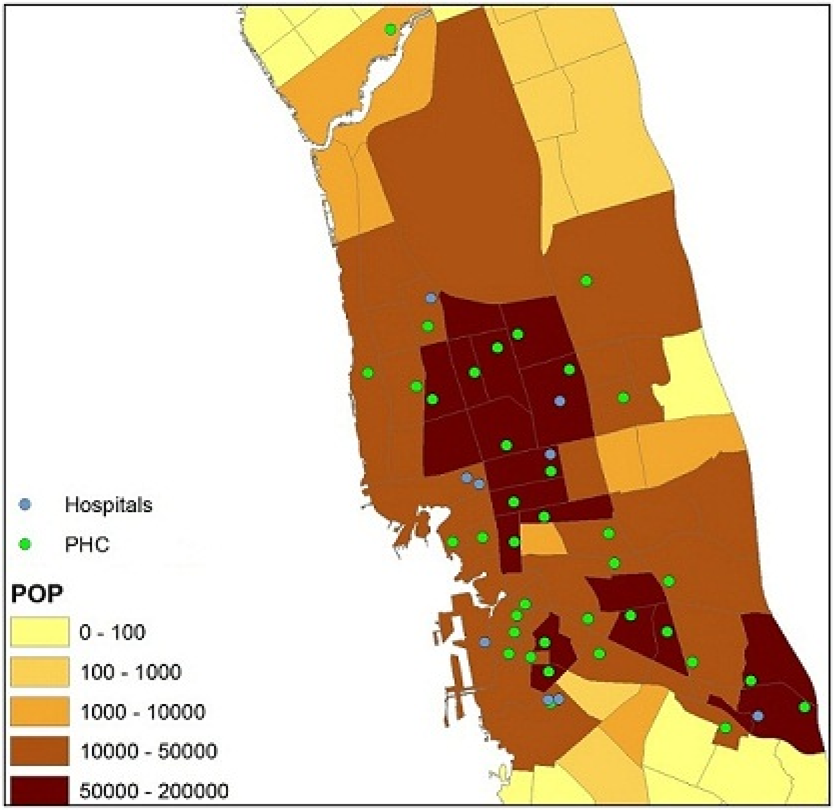

Figure 1. Jeddah City Map

The Saudi Administrative Division is divided as follows: Administrative Regions, Governorates, Municipalities, Cities, Sub-municipalities, and census tracts respectively (CDSI, 2004). Jeddah city consists of 10 sub-municipalities and 117 census tracts. Each sub-municipality contains a number of census tracts under it. Population is mostly concentrated in the middle part of the city with expansion towards the north. Current health resources are unable to meet the current health needs of the population. Researchers and officials have acknowledged this fact(MOH, 2009a) and (Murad, 2005, 2007, 2008a, 2008b). In fact, there have been 37 primary clinics for the past 12 years (MOH, 2002). According to the initial data that have been obtained from the information and Statistics Department at Jeddah Health Affairs, each primary clinics is providing health care to 73,779 populations on average. Each primary clinic is planned to provide health care to a population from 7000 – 25,000 (MOH, 2006b). This indicated that, on average, primary clinics are providing health care to the triple of the maximum number of populations they were planned to serve.

On the other hand, there are 9 hospitals in Jeddah city providing a bed for every 1172 populations. The Saudi planning standards indicated that there should be 2.5 beds serving every 1000 populations (Murad, 2004). This indicates that hospital beds are serving triple the planned amount of populations. An increase in the number of hospitals and primary clinics has been recommended by officials (MOH, 2009a). Additional studies discussed later will elaborate on the insufficiency of resources. Therefore, it is assumed that the city cannot meet the growing demand of its population with the currently available health resources.

The Health Committee of Jeddah has put in place a strategic plan to enhance the health resources and services provided to Jeddah city by the MOH. They have acknowledged deficiencies in the health resources provided to the city in addition to the increased incidents of some communicable diseases (MOH, 2009c). Many resources were discussed in the plan including hospitals, primary clinics, physicians, nurses, beds, and technicians. Unfortunately, no specific locations in the city that need increase in any of the resources were named. The plan was discussing the city of Jeddah in general. Thus, there is a need for a comprehensive community health assessment study to assess the health resources provided to every location of the city against the population needs. The next chapter will explain the Saudi health planning standards followed by community health assessment and the typical routines that usually take place during such assessments.

1.3 RESEARCH DIMENSION EXPLORATIONS AND QUESTIONS

Four dimension explorations were formulated on the basis of the “Access as fit” framework dimensions and the geographical level of census tracts and the MOH medical resources provided to the city of Jeddah. They are also based on the literature on the medical resources of the city and the data available from the MOH Information and statistics department. These dimension explorations are named; Populations’ Accessibility, Professionals Availability, Facilities Availability, and Disease Professionals Availability. Each dimension exploration is followed by a number of sub-questions which will help answering them. It should be noted that dimensions explorations differ from data dimensions. The latter are based on the data collected for this study, like health professionals and facilities data. The following dimension explorations will be answered:

Populations’ Accessibility: Are health resources allocated in accordance with the populations’ densities.

1. Rank census tracts by their population density.
2. Rank the accessibility of population densities.

Professionals Availability: Have the Numbers of health professionals been increasing over the years 2006 - 2010 in primary clinics.

1- For each primary clinic, compare the number of health professionals / 10,000 populations in their catchment areas for the years from 2006 - 2010.

2- For each primary clinic, compare the number of family medicine / 1000 female population in their catchment areas from 2006 - 2010.

3- For each primary clinic, compare the total number of visits in their catchment areas from 2006 - 2010.

Facilities Availability: Is the city in greater need for hospitals than for primary clinics according to planning standards

1. For every census tract, compare between the number of hospitals, primary clinics, and health professionals/1000 pop.

2. For every census tract, compare between the overall hospital beds/1000 pop.

3. Compare the number of population reside outside the catchment areas of hospitals and primary clinic?

4. Compare the numbers of visits / physician for hospitals and primary clinic?

Disease Professionals Availability: Have health resources improved over the years 2006 – 2010 Based on the demand of diabetes, Hypertension, Asthma, and dengue fever cases.

1. What is the ratio of primary clinics' and hospitals' health professionals / 1000 dengue fever cases in every census tract for years from 2006-2009?

2. Based on the dengue fever data, rank the top 10 census tracts that are in greater need for more health professionals?

3. What is the ratio of primary clinics' and hospitals' health professionals / 1000 diabetes cases in every census tract for years from 2006 - 2010?

4. Based on the diabetes data, rank the top 10 census tracts that are in greater need for more health professionals?

5. What is the ratio of primary clinics' and hospitals' health professionals / 1000 hypertension cases in every census tract for years from 2006 - 2010?

6. Based on the hypertension data, rank the top 10 census tracts that are in greater need for more health professionals?

7. What is the ratio of primary clinics' and hospitals' health professionals / 1000 Asthma cases in every census tract for years from 2006 - 2010?

8. Based on the Asthma data, rank the top 10 census tracts that are in greater need for more health professionals?

1.4 SIGNIFICANCE OF THE STUDY

The rationale for carrying out this study is based on the urgent need for a comprehensive assessment of the health resources available in Jeddah City by the MOH. Such a study cannot be conducted using a traditional GIS tool due to the complex nature of the questions of this study. Only a few researchers have been conducting studies at a fine geographical level (Murad, 2005, 2007, 2008a, 2008b). In addition, the rapidly growing populations of the city along with the rising incidence of a number of serious health issues require an assessment that is based on population needs. Specifically, from the methodological perspective:

The utilization of a multidimensional database, allows for investigation of the data from different dimensions. Such an approach has never been used in research conducted in the area of interest.

And from the public health perspective:

- Provide a more comprehensive assessment of the health resources based on population needs.
- Allow for the exploration of any trends of resources against the population over time.
- Identify the exact needs for any type of health resources for any location in the city.
- Uncover health resources issues that might be unseen.

1.5 PURPOSE OF THE STUDY

This study will address the issue of accessibility and availability of health resources provided to the city of Jeddah by the MOH based on the dimensions of the “Access as fit” framework. This will be accomplished by introducing a novel GIS tool (SOVAT) that has a unique feature of handling multidimensional database. The study will discuss the resources throughout the years 2006 - 2010 in accordance with the Saudi planning standards and the population needs from the perspective of a health care services provider. In addition, some major health problems (e.g. diabetes and hypertension) the city suffers from will be investigated to assess the city’s readiness to deal with such cases given the current health resources available. Specifically, the purpose of this study is:

- To explore and analyze the distribution of health resources (Hospitals, Primary Clinics, Health Professionals, and Beds) provided by MOH to Jeddah census tracts, focusing on their capacity and current population.

- To examine the number of health professionals provided by the MOH to the whole population through a five years period to detect whether these numbers have improved or not.

- To determine the current needs (Hospitals and Primary Clinics) of the whole population in accordance with the Saudi Planning Standards.

- To assess the health resources through the years 2006 – 2010 and determine the needs based on the demand of diabetes, hypertension, asthma, and dengue fever cases.

A complete understanding of the current health resources provided to Jeddah city doesn't exist as the previously conducted research studies are insufficient as mentioned earlier. This study will help enable the researcher to provide a clearer picture by investigating the resources from many dimensions. This study aims to explore and detect any patterns of concentration of health resources within the dimensions of the Jeddah health services data. It also aims to measure the sufficiency of the current medical resources provided to the population and to determine the needs at the census tract level. By exploring health resources provided to Jeddah city by the MOH on the city census tracts levels, a more detailed picture of the level of services each area of the city and what they lack can be created. Additionally, current health resources will be assessed based on the population and diseases statistics on all the previously mentioned geographical levels. The results of this study will be used to assess current resources according to the Saudi Health Planning and Standards, and determine the status quo and what needs to be added and where it needs to be added. Finally, additional step will be taken by exploring the relationship between health resources and some of the health problems (Sharma, 2003). The focus will be specified to some of the major health-related problems of the city such as dengue fever, diabetes, hypertension, and asthma cases. This will be done by assessing each census tract's incidence rates and health professional per disease cases.

The fourth dimension exploration (the final part) in this study will assess the availability of health professionals against the visiting cases of the diseases; Diabetes, Hypertension, Asthma, and Dengue Fever. Each of these diseases requires continuous medical care and has a particular importance in Saudi Arabia. Diabetes, hypertension, and Asthma are amongst the top 10 causes of visits to the primary clinics nationally with diabetes being the third (MOH, 2009b). Furthermore, diabetes is more prevalent among people living in urban areas with 25.5 % prevalence rate (Al-Nozha, et al., 2004) and 27.9 % for hypertension in urban population as well (Al-Nozha, et al., 2007). On the other hand, there was a significant increase in the prevalence rate of Asthma during a 9-year period from 1986 to 1995 (Al Frayh, et al., 2001). Finally, there are numbers of dengue fever cases reported in Jeddah city each year. According to WHO (2009), dengue fever fatality rates can exceed 20% if not treated properly. In addition, infection rate are often from 40 to 50 %. This indicates that each of these diseases poses a threat to the population and an assessment is needed to better provide medical care to the underserved census tracts in Jeddah city.

1.6 STUDY FRAMEWORK

The dimensions of the "Access as fit" framework will guide this exploration and assessment process. This study will explore the health resources available to the city of Jeddah throughout years on many geographical levels using a novel numerical-spatial analysis tool (SOVAT). Starting at the catchment areas level, each catchment area will be explored in terms of health resources availability and accessibility to its population by its designated primary clinic and hospital. Going down one geographical level, resources will be thoroughly assessed at the census tracts level using health resources, population, and visits data. Finally, this study will focus on some of the diseases' incidents that are of particular importance (as discussed in the purpose of the study in more detail) and explore and assess the census tracts with health services and resources availability for such cases. These diseases will be diabetes, hypertension, asthma, and dengue fever. Data will be collected from their official sources, as will be explained later in detail, and integrated into a decision support system to answer the research questions. Data required for this study are ready as they were obtained from their official sources to guarantee consistency. Later there will be a section that describes data sources and data elements which will be used in this study.

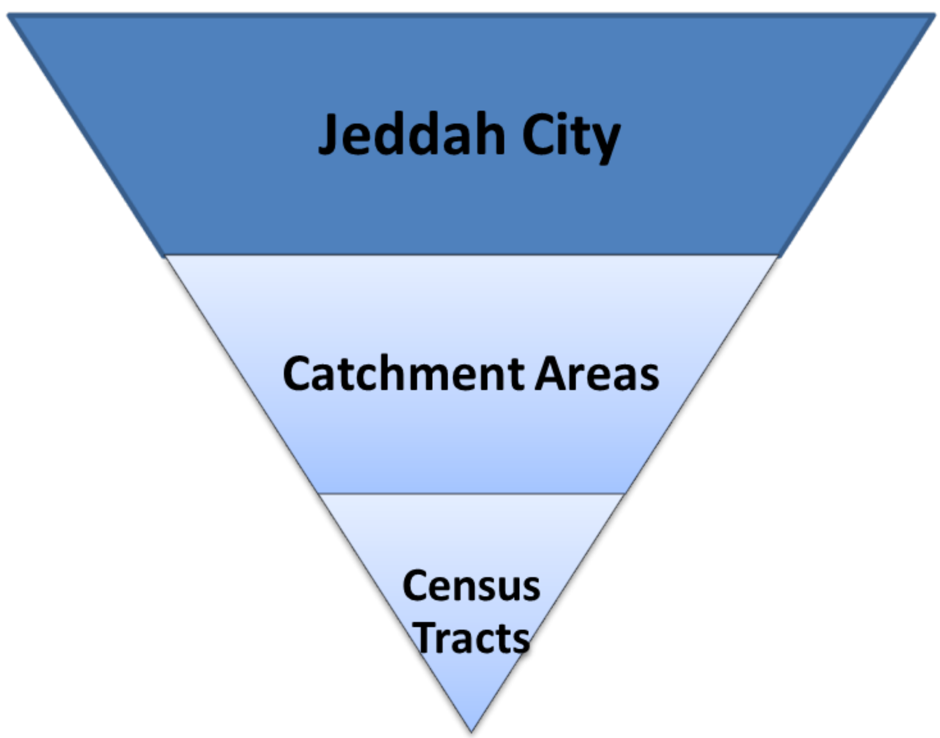

Figure 2. Jeddah City Investigated Geographical Levels

Many GIS tools exist but they are unable to perform numerical spatial queries efficiently. However, for our research, using SOVAT is the optimal choice as our research questions contain many dimensions that need to be queried. For example, one of the research questions to be explored is: Compare the census tracts of Jeddah in terms health professionals / 100,000 populations for the years 2006 - 2010. In this query, three dimensions need to be accessed. The first is the Geographical dimension, which contains census tracts level data. The second is the Years dimension, which contains the years 2006 to 2010 as sub-dimensions. The third is the Measures dimension, which contains ratios calculations. Therefore, performing such a query with a tool that doesn't support multi-dimensions would not be optimal. ArcGIS, then, is not a good candidate for our study because it only supports conventional (two dimensional) databases. In fact, the only optimal way to perform complex queries is to use a tool that supports multidimensionality. Thus, SOVAT is the optimal choice.

A multidimensional OLAP database will be used to facilitate the handling of data collected from various sources and then incorporated into a cube (see the sample cube figure). Data dimensions are hierarchically down to a level of granularity or detail (Rivest, et al., 2005). The main goal is to be able to view the data to the finest granularity possible, at the level of the individual, thereby allowing for the solving of complex questions more easily and quickly.

Using the SOVAT tool for this research would be the optimal choice as with its GIS and OLAP capabilities, handling spatial and multidimensional data can be accomplished effectively and easily. In addition, SOVAT's features such as drill-out, statistical calculations, and save as community would help with transition between geographical levels and data. No additional tool will be needed in addition to SOVAT.

2.0 BACKGROUND AND LITERATURE

2.1 SAUDI HEALTH PLANNING STANDARDS

The Ministry of Health has put in place a set of standards to regulate the capacities and locations of primary clinics and hospitals in Saudi Arabia. Thus, each health facility has a predefined standards and catchment[1] area and is expected to provide health care to a predefined number of populations. However, these standards are for ideal situation. Health facilities are serving more than they are planned to due to the large populations and limited numbers of health facilities. For example, primary clinics have catchment areas more than standards demand (Murad, 2008b). However, the standards are as follows:

There should be a physician per 2000 populations, a nurse per 1,500 populations. In cases of hospitals, there should be 2.5 beds per 1000 populations. Catchment areas have been defined in the standards as follows; Every Primary Clinic is planned to provide health care for a population from 7000 – 25,000 and to cover an area from 2 – 4 Km (MOH, 2006b). On the other hand, (MOH, 2006a) indicated that hospitals are expected to provide health services as follows: small hospitals of 50 beds should serve an area of 4 Km and a population of 10,000 – 50,000. Medium hospitals of 100 beds should serve an area of 6 Km and a population of more than 50,000. Finally, large hospitals of 400 beds and more should serve an area of 8 Km.

1 Catchment areas are areas designated to be served by a Health Facility.

2.2 COMMUNITY HEALTH ASSESSMENT

Community Health Assessment (CHA) is identifying the health status, needs, and resources of a community in order to describe the health of the community and develop strategies and plans to meet the needs of this community. CHA has been defined in a variety of ways. Sharma (2003) defined CHA as a process of understanding the communities' perception of priority health issues in conjunction with the objective collection and analysis of health status data. Scotch, et al (2006) describe a typical routine of CHA that involves both numerical and spatial steps as follows:

1- Identify geographical community of interest.

2- Identify health factors within the community.

3- Identify bordering communities of interest.

4- Identify health factors within bordering communities.

5- Compare factors within community against factors of bordering communities.

6- Identify aggregate communities.

7- Identify health factors within aggregate communities.

8- Compare factors within community against factors of aggregate community.

This CHA study will start with the Mandala of Health model as a broad framework. Among the health determinants of Mandala is the medical care system which will be the focus of this study. Specifically, the access to health care will be assessed using a narrower framework called “Access as fit”. Health resource and demands in Jeddah city will be explored within the “Access as fit” dimensions as will be explained in the next paragraphs of this section.

There exist many human health models that act as systematic frameworks that were designed to guide the community health assessment processes (Sharma, 2003). Among which is the Mandala of Health Models. In this model, Hancock (1985) represented human as existing within three nested circles symbolizing family, community and man-made environment, and culture, in that order. Four subgroups are specified within the family and community circles that influence the individual’s health. These subgroups are; human biology, personal behavior, psychosocial environment, and physical environment. It is an interactive model as various components of the model interact with each other. Medical care system is placed as a health determinant under the community circle influencing personal behavior and human biology only. This model did not overstate the importance of health care system (VanLeeuwen, et al., 1999). The Mandala model will be used as broader framework to guide this CHA study. Specifically, the focus will be on the access to medical care system part. This will be conducted using Jeddah public health resources and population data to explore and assess the availability and accessibility of resources.

Access to medical care is an important concept in health care delivery. There exist many theoretical frameworks that support the studies of access and measure how access to health care is meeting standards (Ricketts and Goldsmith, 2005). Such frameworks usually determine some dimensions by which accessibility can be measured. For this study, “Access as fit” framework will be used as a narrower framework.

Penchansky and Thomas (1981) define access as degree of “fit” between the client and the system. They specify five dimensions to measure access as follows; availability, accessibility, accommodation, affordability, and acceptability. Data are collected with a patient satisfaction questionnaire. Each of the dimensions was precisely defined. Availability was defined as the volume of health services available to the client. Accessibility is spatial locations of services and clients. Accommodation is the organization of the health service that allows it to accept client, like clinical hours and telephone services. Affordability is the ability of clients to pay for the services. And, acceptability is the attitude of clients towards the health services. The interaction between these dimensions would determine the access to service as dimensions affect each other. For example, availability will always affect accessibility and accommodation.

This framework has been selected for this study as it fits the literature, type of data available, and exploration queries of this study. Specifically, accommodation and acceptability dimensions are discussed in the review of the literature as will be seen. The availability and accessibility dimensions will be investigated for the city of Jeddah in a multidimensional approach.

However, this framework will be used as a concept of interactive dimensions in this study along with a novel technology (SOVAT) as a tool of method. So instead of the authors suggested questionnaire, we will explore and analyze the dimensions to verify whether they meet the Saudi planning standards. Health care data are collected for this purpose and will be explored within the dimensions of this framework; availability and accessibility.

2.3 HEALTH SYSTEM ORGANIZATIONAL STRUCTURE

The Minister of Health, who is appointed by the King for four renewable years, is the head of the MOH. Under the Minister there are two Deputy Ministers appointed by the Council of Ministers after a Minister of Health recommendation (the reader is referred to the MOH Organization Structure map). These two deputy ministers are Deputy Minister of Health for Executive Affairs and Deputy Minister of Health for Planning and Development (WHO, 2006b).

The MOH is represented by 13 health regions across Saudi Arabia, and every health region is led by a Regional Director who reports directly to the Deputy Ministers. Each region directs at least one Health Province through a Provincial Health Directorate. Each Provincial Health Directorate supervises and manages at least one General Hospital and a number of primary clinics, and supervises the private health sector in that region. Other sectors which provide health services, like the military and universities, are linked to MOH through sectoral coordinators (WHO, 2006b).

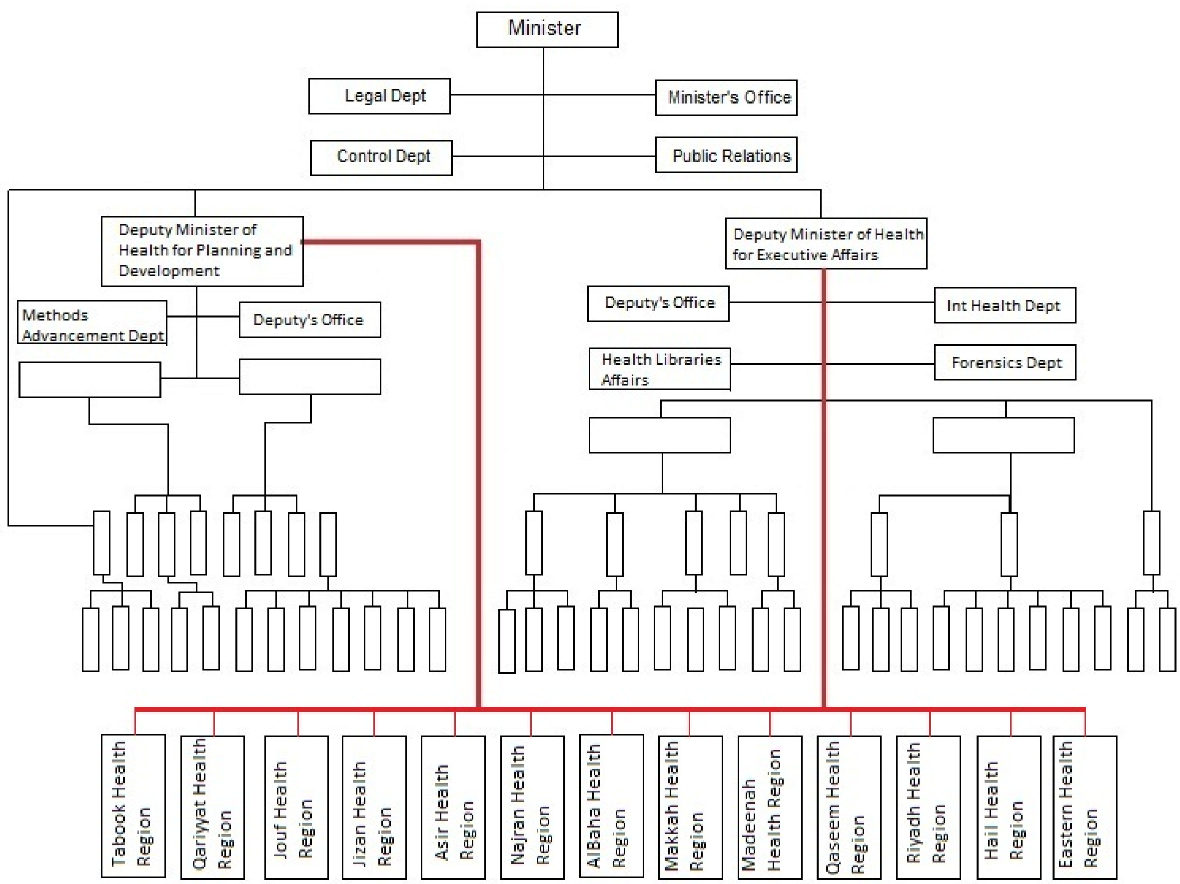

Figure 3. Saudi Ministry of Health Structure Map

2.4 HEALTH CHALLENGES

Despite recent Improvements in health outcomes, there are some growing problems that the MOH has to overcome. There has been an alarming increase in non-communicable diseases such as cardiovascular disease and diabetes. According to the World Health Organization (WHO, 2006a), cardiovascular disease is responsible for 19% of deaths in Saudi Arabia. In addition according to the Ministry of Health (MOH, 2007), diabetes is the third leading cause for primary clinics visits in Saudi Arabia. At the same time, there is a shortage in human resources. The number of Saudi workers in the health field is insufficient, with 61% of these workers being expatriates. This brings instability to the provided health services as expatriates are required to leave after fulfilling their short-term contracts. Moreover, there is a level of dissatisfaction with the services provided by the MOH. El-Shabrawy and Mahmoud (1993) conducted a study to estimate the patients' satisfaction with respect to primary health care services in Riyadh city. The author found that 33.3% of the sample complained about the primary clinic being too far; 19.4% complained about the hours of operation; 38.9% complained about the absence of specialty clinics in the primary clinics; 63.9% complained about the delays in the primary clinic; 16.7% expressed no confidence in the primary clinic; 19.4% complained about the cost of coming to the primary clinic. Regarding returning to the same primary clinic, 27.8% of the unsatisfied group indicated that they would not return. In another study conducted by Mansour and Al-Osimy (1993) to assess the satisfaction of patients with primary health care services in Riyadh, the author found out that waiting time was reported as the item most dissatisfying. An additional study by Mansour and Al-Osimy (1996) evaluated the resources available in three large health primary clinics in Saudi Arabia. Two of the conclusions of this study were as follows: first, the primary clinics were overstaffed in certain manpower categories and understaffed in others.

Second, some of the primary clinics studied were inadequate in terms of equipment and the facility itself. Another study by Saeed, et al (2001) estimated quantitatively consumers' satisfaction of services provided by primary clinics. Thirty nine percent of the sample reported that they thought the distance to the primary clinic was far or very far. In fact, the longer the distance traveled, the lower the satisfaction scores. And the overall mean satisfaction score was 3.77 out of five. Another study by Mahfouz, et al (2004) examined the pattern of utilization of primary health care services and satisfaction among elderly people in Asir region in Saudi Arabia and found that the two leading causes of dissatisfaction were the long waiting times and not enough specialty clinics in the primary clinics. In an unpublished study by Banakhar, et al (2006) determined patients' satisfaction level with the primary health care services offered in Al-Balaad Jeddah primary clinic, 58.6% of those surveyed responded that that the number of physicians was insufficient. Also 19.5% of the sample responded that number of nurses was insufficient. Moreover, 65.3% of their respondents considered the waiting time to be too long and 46.2% considered the primary clinic to be too busy.

Most of these types of studies have been conducted in settings other than our area of interest. However, their results can be taken into consideration due to the fact that the health services provider is the same in all the regions. In addition, the situation in Riyadh is very close to that in Jeddah in terms of population and city size, but Riyadh is, in fact, much better served than Jeddah (MOH, 2007). Many issues were investigated in the above reviewed researches, with concentration on staffing and accessibility (how far is the health service is from patients) as main dissatisfaction causes. Other issues were also investigated that are beyond the scope of this study, such as physicians and nurses skills. These studies suggest that health services do not meet the expectations of the patients and most of them recommended further research. Finally, the studies investigating the health services in Jeddah city are limited and focused on one major health primary clinic. Thus, more studies are needed to assess the health services in the city and to answer our research questions.

2.5 GEOGRAPHICAL INFORMATION SYSTEM

Geographical Information System (GIS) is a technology that has been used for many years in fields like businesses, government, education, and health. It allows for the capture, management, analysis, and display of geographical references information[2]. This technology provides some powerful functions that enable better analysis of the geographical data such as buffering (surrounding a map feature by a distance) and geocoding (plotting an address as a point on a map). Maps are entered as layers and inserted on top of one another to display a detailed map. Many tools are available today and some of them are expensive such as ESRI ArcGIS which is used on a wide scale compared to the rest of the available tools as found by Scotch, et al (2006).

2 http://www.esri.com

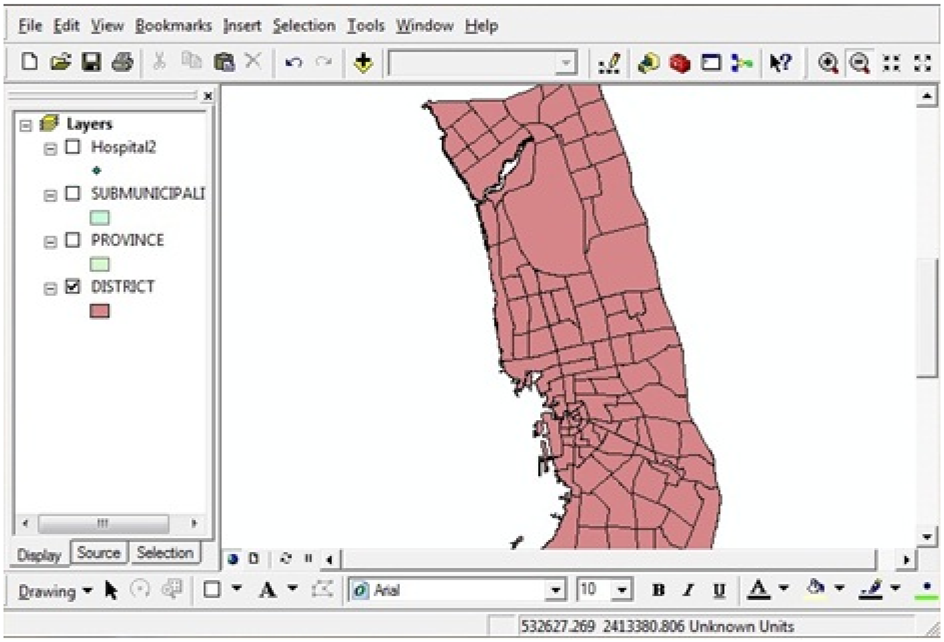

Figure 4. ArcGIS Application

GIS technology is very helpful in public health research. Melnick (2002) reported that GIS applications are quite useful in assessing the geographic relationship between the location of potential client and services utilizations. In fact, the technology has been used by many researchers in the health field. For example, it was used for data exploration by Chaikaew, et al (2009), where the author used GIS to analyze the pattern of spread of diarrhea in northern Thailand. Another study conducted by Borden and Cutter (2008) explores the spatial pattern of natural hazard mortalities in the US. Also, in another a study by Noor, et al (2009), the author maps health services providers and then analyzes the disparities in geographical access to public health in Kenya. Even Google Earth has been used by Kamadjeu (2009) to track the polio virus in the Congo.

2.6 GIS AND HEALTH CHALLENGES

Health resources availability and sufficiency is a universal problem as it exists in many places all around the world. First world countries as well as developing countries are dealing with such problems. Many researchers have used the GIS technology in addressing such problems and assessing health services of their interest. Bamford, et al (1999) used GIS to measure the distance between general practitioners and populated localities in a non-metropolitan area in Australia. It was found that 15 % of the population lived 89 km away from the nearest general practitioner. Another study conducted by Perry and Gesler (2000) assessed the accessibility to primary health care in three remote and impoverished areas in Bolivia. It was found that the accessibility was poor in one of the areas as only 50.1 % of the population live within 1-hour walking distance from the primary clinics. It also found that the accessibility was extremely poor in another area as only 16 % of the population lives within 1-hour walking distance from the primary clinics.

There are also many studies that addressed such issues using GIS technology on Cities' levels. In a study conducted by Phillips, et al (2000) the author defined medical service areas in Boone county, Missouri. It was found that 13.1% of Boone County adults reported health care access problem. Of those adults, 60% live in urban districts. Another study by Lin, et al (2002) determined travel distances between patients and hospitals. It was found that overall; distances to hospitals are inversely related to hospitalization rates. Another study by Rosero-Bixby (2004) assessed the equity of health care access in Costa Rica and how the health reform impacted the accessibility. It was found that 12-14% of the population is underserved. While the reform somewhat decreased the in-equitability, areas with no reform had an increase in the underserved population from 7% to 9%. Another city level study conducted by Alshuwaikhat and Aina (2006) assessed urban sustainability in Dammam city, Saudi Arabia. The researcher applied GIS technology and a set of sustainability indicators such as the 400 meters walking distance criteria. It was found that there is a need to improve access to health facilities as 27% of population were outside the 400 meters circle, and thus, had no access to health facilities. Follows is a review of studied conducted in our area of interest addressing problems with the same nature.

A number of researchers have conducted studies related to the health resources and health problems of Jeddah City that utilize GIS. Each study has a different focus, as will be explained in the next paragraphs. However, there is no comprehensive study that takes into account all of the health resources available to the city. In fact, some of them are so narrow that they cover only one health facility. For example, Murad (2007) selected only one private hospital and claimed that the results can be generalized to any other private or public hospital. Thus, there are a lot of questions regarding the health resources in Jeddah that need to be answered. And there are a lot of ambiguities in the picture of the current health status and resources in the city of Jeddah as no study has taken into account the complete health resources provided by the MOH. Following are the available studies conducted using GIS technology and related to the area of interest.

One of the studies that used GIS in the health field in Saudi Arabia was conducted by AlKahtani (1991), the author's aim was to evaluate the pattern of regional distribution of health facilities in Saudi Arabia. This was done by correlating various techniques such as population to health facility ratio, chi-square test, and standard deviation. Data used for this study about health resources was provided by the MOH and the private sector.

The study found that the facilities are uniquely distributed across the health regions. Makkah (includes Jeddah city), Riyadh, and the Eastern regions have greater shares of facilities and staff. On the other hand, the Jizan region in the south, which has the largest population density, has only 5% of the total hospitals and beds in the country. A Chi-Square test indicated significant differences between regions. The ratio of medical staff and bed to population further proved variations in regions. The author concluded that spatial provision of health facilities apparently follows economic orientation. Unfortunately, the study was conducted on the regional level (administrative regions) and gives no details on city levels.

One of the studies conducted by Murad (2001) the author used GIS on Jeddah City to measures accessibility to health care facilities. The author indicated three important factors that affect the level of accessibility to any facility location: the capacity of the facility, the amount of demand for such a facility, and the communication network that communicates such a demand to the relevant capacity. The spatial model used to analyze accessibility was a shortest path model. This is to enable the inclusion of the hospitals' demand in the network analysis.

There were two steps to this research. First, the catchment areas of the hospitals were determined based on the Saudi Planning Standards criteria for hospital planning. Completion of this part of the research revealed that the northern part of the city is located outside the hospitals catchment areas; thus, the hospitals are not serving the entire city. Secondly, the size of the demand within each hospital catchment area was defined. The following was found: hospitals are serving population more than the planning standards criteria demands. Also, the size of the demands within each hospital catchment area is more than the hospital capacity.

Another study conducted by Alrabeah and Alanezi (2005) the author investigated the geographical distribution of 15 notifiable diseases in Saudi Arabia from 1990 to 1999. The study resulted in maps to compare the density of the reported cases across all the health regions. Jeddah health region reported maximum levels of some of the diseases like Mumps, hepatitis C, and Tetanus. Unfortunately, the study was conducted at the regional level (health regions) with no details on cities' levels. In addition, health care resources were not discussed in this study.

Murad (2005) conducted a study similar to (Murad, 2001) in using a GIS to model health care accessibility and utilization. Data for public hospital locations, hospital capacities, population, and road networks were used in this study. Three GIS models were created in order to process the collected data: a hospital catchment areas model, an allocation model, and a what-if model. The author used the network analysis module to enable the inclusion of a hospital demands network analysis function. From the network analysis module, the Allocate function was used.

The hospital catchment areas model, which used the Saudi health planning standards, resulted in interesting findings. First, about 75% of the city falls inside the hospitals' catchment areas; thus, people who live within these catchment areas should be served by these hospitals; however, about 25% of the city falls outside the catchment areas; thus, people living within this area are not served by the hospitals.

The hospital Allocation Model takes into account the supply of hospitals and the demand for those hospitals. The use of this model has shown that incorporating the demand and supply data would result in the reduction of catchment areas for every hospital according to its capacity. This would lead to the reduction of the served area of the city from 75% to 40%, with the un-served part then being 60%.

The What-If Model was used to test the impact of increasing one hospital's (Al Thagher) number of beds from 90 to 400 beds. This model resulted in the inclusion of the southeast part of the city to the catchment area. Thus, the total catchment areas coverage would increase.

Those two papers had some limitations; one of them is that the author only focused on 4 governmental hospitals out of 9 and didn't take into account other governmental health facilities such as primary clinics and other governmental hospitals. Such facilities might be filling the void that this study seems to show. Another limitation is that the study was conducted in 2001. A lot of changes have occurred in hospital capacity and population since then. Thus, this study's results might not be applicable to the current situation.

In a study conducted by Greer, et al (2005), the author links Congenital Heart Defects (CHD) cases to a GIS system. The focus was on the development of the system and initial results. The data used in this study were CHD cases, which were analyzed in groups to avoid errors that might result from the small number of cases for some specific diagnoses.

Data included were from the Congenital Heart Disease Registry (CHDR) at King Faisal Hospital and recorded between 1 January 1998 and 1 November 2002 and they summed up 5209 cases. Two hundred cities (this may refer to an actual city, town, or a small village) were linked to its cases.

The geographical distribution of the CHD cases reflects the regional population density. On the other hand, a thematic map based on cities population shows that the cases are focused around three cities: Dammam, Riyadh, and Jeddah. The distribution of cases per 100,000 was positively skewed, with the exception of AlBaha as an outlier. This GIS study supports the claim that heart disease cases are focused in Jeddah City. On the other hand, more studies are needed to assess the distribution of the cases within the city and to assess the city's medical resources readiness to provide health care to those cases.

In a study by Murad (2007), the author discusses three main health planning issues; distribution of health demand, classification of hospital patients, and definition of hospital service area. One major private hospital is selected as a case study, with the author claiming that the results from the study are generalizable to other hospitals.

With respect to the distribution of health demand, the study found that the demand comes mainly from areas with close proximity to the hospital. This study created two types of hospital demand classifications. First, it divided patients into three hospital utilization groups: general/specialized clinic patients, emergency clinic patients, and hospitalized patients. Second, it classified patients based on gender. Finally, a 15-minutes' drive time service area was created.

It was found that 60% of the patients lived inside the hospital service area. Market penetration rate was defined in this study, which indicated that some census tracts located inside the hospital service area are not producing high demands.

Unfortunately, the author only focuses on one private hospital as a case study, without taking into account other governmental hospitals with larger resources. It was claimed that results from this study can be applied to any other hospital (including governmental). This is unlikely since the main difference between public and private hospital is cost which affects the demand.

A study by Alharthy (2007) discussed the methods for an effective distribution of Black Hole Devices, also known as CO2 generators, as part of a surveillance program to monitor and control dengue fever cases across Jeddah City. In this study, three parameters are considered for best distribution of the devices: population density, dengue infected cases, and optimum distance between the allocated devices (optimum distance between devices is between 200m – 300m).

The author first uses Point Density technique to generate a raster from population, and then dengue cases locations were superimposed to find a positive relationship. Secondly, the Kernel Density technique was used to generate a raster of dengue locations. Both of these raster maps were used to generate an overlay which suggested effective positions for surveillance devices.

This surveillance system resulted in a decrease in dengue fever cases. As findings of this surveillance program, high density populated areas with dengue cases should be treated as high-risk areas and under constant surveillance. Additionally, construction sites were shown to be major breeding environments and as such, should always be under surveillance.

The author's focus in this study was environmental since it was a part of a surveillance program. There is no mention of health services required to deal with dengue fever. Since the paper's (program) goal was to develop an effective way to control the cause (mosquitoes), the focus was locations of surveillance and environmental conditions that could help spread the disease. Thus, the health resources perspective was not discussed.

Another study by Murad (2008a) used GIS on diabetes patients registered in Jeddah City primary clinics. Three steps were covered in this epidemiological study: defining the spatial distribution of diabetes patients, determining the relationship between population density and diabetes locations, and modeling of spatial variation of diabetes locations. Data collected for this study included locations of primary clinics, road networks as lines, and diabetes patient data, which was aggregated to the level of primary clinics location.

Spatial distribution results indicated that diabetes patients were mainly concentrated in AlRabwa, Bani Malik, and AlSabil districs which are located in the northern, central and southern parts of the city, respectively. The author calculated the Standard Diabetic Rate (SDR) for the city, with results indicating that the areas with the highest SDRs tended to be in the central and southern parts of the city in addition to two other census tracts (AlRabwa and AlBawadi) located on the north side of the city.

The second part of the study indicated a positive relationship between diabetes cases and population density. Three main density groups were labeled in Jeddah City: low density, medium density, and high density. High population density census tracts were shown to have a high number of diabetes cases.

Third step of the study was to model diabetes cases using the Kriging model. It showed that diabetes cases are spread all over the city but in different numbers. Specifically, the area surrounding census tracts with high number of diabetes cases are getting high values.

This study is limited in that the author focused on only one health issue that faces the inhabitants of the city of Jeddah: diabetes. There is no examination of the health resources that are provided which could help those patients. No recommendations or suggestions are given to help improve the current health resources.

In 2008, Murad (2008b) used an analytical method of defining the catchment areas of the primary clinics using Straight-Line Allocation (SLA) function. The author then identified the method used to establish a catchment: the neatest feature catchment using a straight-line distance. The resulting catchment areas were then compared to the existing catchment areas created by health authorities. It was found that almost every existing catchment area was reduced (some by 40%). Thus, people inside the new catchment areas will receive better health care service.

As limitation to this study, the author only focused on primary clinics and excluded other health care sources such as public hospitals. The author only mentioned the existing standard for number of physicians required and suggested that it may be used with the new catchment areas population to calculate the needed number of physicians, but gave no actual results of needed physicians. Finally, while this paper might have contributed to a reduction in size of the catchment areas, the populated areas will still suffer from shortage of professionals.

All of the studies reviewed above were conducted using GIS technology to explore the health field in Saudi Arabia. As can be seen, some issues related to our study have been investigated. For example, catchment areas of public hospitals and primary clinics were discussed in three studies by the same author. However, such studies were not sufficient to answer questions presented in our study as they investigated some aspects of the resources rather than all of them; for example, Murad (2001) investigated only 4 hospitals out of 9. Instead, this study investigates the health resources of Jeddah City more comprehensively by including all the related data. So instead of investigating only the hospital beds supplies of 4 public hospitals, for example, this study will include hospital bed supply of all the public hospitals to have a better understanding of the capacity of health resources provided by the MOH in the city of Jeddah. Thus, this study's aim is to help provide the researcher with a clearer picture by investigating Jeddah's health resources more thoroughly. (The reader is referred to table 1 for a summary of reviewed papers).

Table 1: Summery of GIS papers on Jeddah city

Author	Year	Purpose	Findings	Limitations
Al-Qahtani	1991	Evaluate the pattern of regional distribution of health facilities	• Jeddah is one of three regions that have larger number of health facilities • Health facilities follows economic orientations	Study conducted on regional level, no details on city levels
Murad	2001	measures accessibility to health care facilities	• hospitals are serving population more than the standards criteria demands • demands within each hospital catchment area is more than the hospital capacity	Only 4 out of 9 governmental hospitals
Alrabeah and Alanezi	2005	Geographical distribution of 15 notifiable diseases from 1990 - 1999	Jeddah had maximum levels of Hepatitis C, Mumps, and Tetanus	Study conducted on the regional level, no details on the city levels No health care resources discussed
Murad	2005	measures accessibility to health care facilities	about 25% of the city falls outside the catchment areas	Only 4 out of 9 governmental hospitals
Greer, Sandridge, AlMenieir,	2005	Linking CHD cases to a GIS system	Jeddah is among three cities with CHD cases concentrations	Study conducted on the national level, no details on the city

AlRowais				levels No health care resources discussed
Murad	2007	• distribution of health demand • classification of hospital patients • and definition of hospital service area	demand comes mainly from areas with close proximity to the hospital	• only one private hospital • no governmental hospitals with bigger resources
Alharthy	2007	surveillance program to monitor and control dengue fever cases across Jeddah City	• decrease in dengue fever cases • high density populated areas with dengue cases should be treated as high-risk areas • construction sites were shown to be major breeding environments	This is an environmental study with no mention to health resources
Murad	2008	• spatial distribution of diabetes patients • population density and diabetes locations	• diabetes patients were mainly concentrated in 3 census tracts • positive relationship between diabetes cases and population density	No mention of health resources, only modeling diabetic patients
Murad	2008	defining the catchment areas of the primary clinics	almost every existing catchment area was reduced	• Only primary clinics • Population density wasn't considered

For this study, large amounts of data will be gathered from various sources and incorporated into a database with multi dimensions. This will enable for more complex queries to be answered. Unlike the previously reviewed GIS papers, which two dimensional databases were used. Thus, On-Line Analytical Processing cube will be used to handle our data sets. The next paragraph will explain On-Line Analytical Processing technology and how it is the optimal option for this study.

2.7 ON-LINE ANALYTICAL PROCESSING

On-Line Analytical Processing (OLAP) is a data warehouse that stores data in multidimensional model. A conceptual cube is created to incorporate data from various sources. (The reader is referred to the OLAP figure). An OLAP cube usually contains dimensions, members, and measures (Rivest, et al., 2005). Dimensions represent the theme of interest of the user, for example, Health Professionals and Geographical location. Dimensions are organized hierarchically into levels of granularity or details. For example, geographical dimension includes city, municipalities, and census-tracts as levels, where the city is the most general level and census-tracts as the most detailed level. Each dimension contains members, for example, health professionals dimension contains physicians and nurses as members. Finally, measures are the numerical results analyzed against the different dimensions (Rivest, et al., 2005).

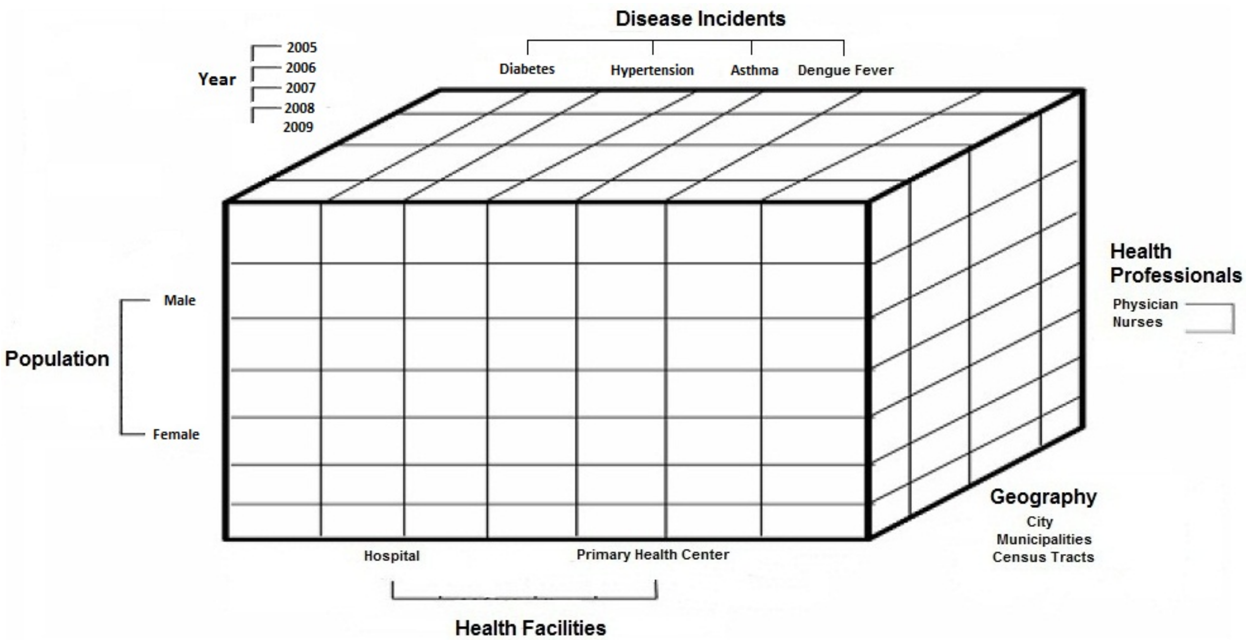

Figure 5. A Sample Multidimensional OLAP Cube

OLAP support fast and efficient ad-hoc queries since the data are in the cube is pre-aggregated (Scotch and Parmanto, 2006). Four functions that OLAP can perform during analysis are; drill-up, drill-down, slice, and dice. Drill-up is going from a low level to a higher level of the data (For example, going from the census-tracts level to the city level). Drill-down is going from a high level of the data to a lower level (for example, going from city to census-tracts). Slice and dice is retrieving a sub-section of the data.

2.8 SPATIAL OLAP VISUALIZATION AND ANALYSIS TOOL

Scotch and Parmanto (2006) developed SOVAT, which is a combination of GIS and OLAP technologies. The Spatial OLAP Visualization and Analytical Tool (SOVAT) is a Decision Support System (DSS) designed to address numerical-spatial problems in the community health assessment domain. The authors developed the tool to fill a major void; as the majority of the available public health, GIS tools do not incorporate some components of the decision support system. The majority of tools had also lacked features that make numerical-spatial problem solving easy and effective. For example, most available tools do not utilize an OLAP database, which made them incapable of handling multidimensional data sets efficiently.

Scotch, et al (2008) discussed the potential of SOVAT for addressing community health assessment problems in an effective manner. First, SOVAT comprises all the components of a decision support system. It has the capability of handling numerical-spatial problems, and the researchers will not be forced to use other tools for statistical analysis. Furthermore, SOVAT is an easy to use tool that a user can utilize regardless of his/her familiarity with GIS or OLAP. Finally, OLAP, which is a component of SOVAT, can effectively handle large multidimensional environmental data sets and process ad-hoc inquiries more effectively than relational databases.

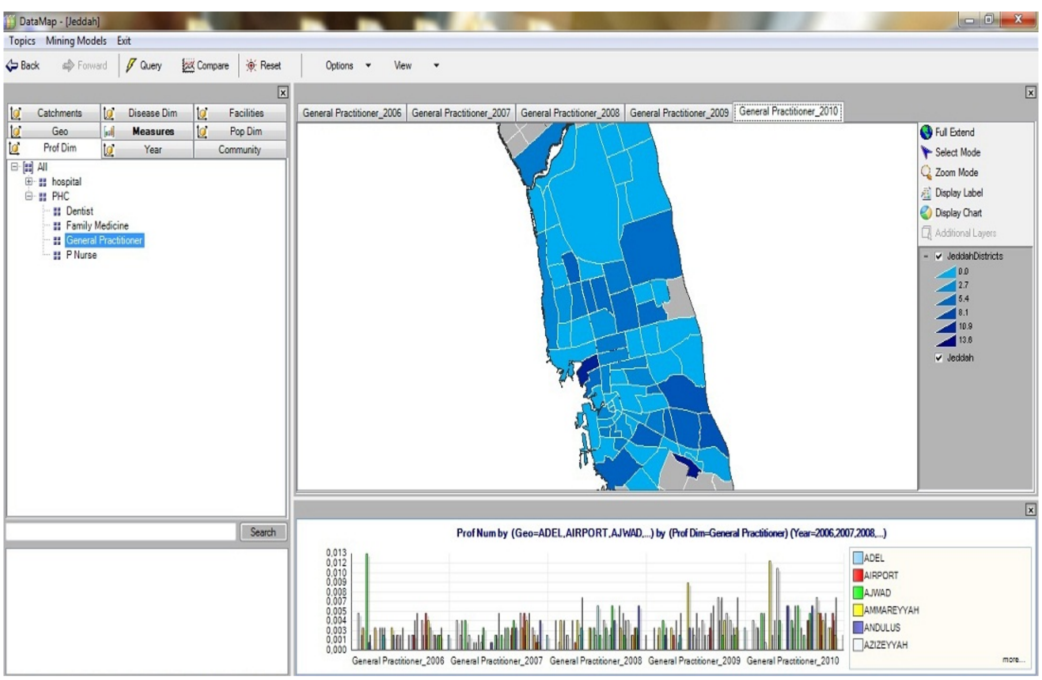

Figure 6. A Screenshot of SOVAT with real data

Several technologies are utilized to build decision support systems. Scotch and Parmanto (2006) identify the technologies frequently used in decision support systems which support spatial or numerical problem solving. These technologies include: statistical software, data mining, GIS, relational database, and OLAP. Additionally, SOVAT incorporates a number of unique features that enable community health assessment researchers to conduct their research more quickly and effectively. All of the OLAP features – like drill-up and drill-down, which - are included in SOVAT. Moreover, an additional feature called drill-out is added to the tool to allow comparison of the community of interest to the bordering communities. Drag and drop, statistical calculations, and save as community are also unique features of SOVAT. Previously, a decision support system tool that is capable of effectively handling large multidimensional data sets in an easy way and capable of performing numerical-spatial analysis did not exist. Most of the available tools for public health assessment lacked some of the features that exist in SOVAT which allow users to effectively solve numerical-spatial problems. In fact, Parmanto, et al (2008) conducted a study to demonstrate the potential of SOVAT for facilitating the CHA process in developing countries. The author presented two study cases in this paper: First is the distribution of physicians in Indonesia, and second, a comparison of mortality numbers due to malaria disease in rural and urban areas. Such case studies are similar to our research questions due to the fact that each case presented in this paper contains dimensions and members under those dimensions. For example, the health care professionals dimension includes physicians, nurses, and mid-wives as members. Our research will use the same method, as there will be dimensions and members which will be used to answer the questions of this study.

2.9 RATIONALE FOR USING SPATIAL AND MULTIDIMENSIONAL VISUALIZATION ANALYSIS

The explorations and questions to be addressed in this study require an integration of data on multiple dimensions. Such dimensions include geography, populations, health resources, and disease incidents. Due to the multidimensional and spatial nature of the questions, it is required to utilize a tool that is capable of conducting both numerical and spatial analysis at once. In addition, this analytical tool is required to be easy to use, efficient, and has OLAP features. Follows is a description of SOVAT features

2.9.1 Numerical and Spatial problems

Question in this study consist of numerical and spatial steps. GIS software is usually better at handling and presenting the spatial steps but is not as effective with numerical steps. There are, on the other hand, tools that can handle both the spatial steps and the numerical steps effectively like (Bedard, et al., 2003) and (Scotch and Parmanto, 2006). To give an example of a numerical-spatial query, a query as seen in figure could be: for each census tracts compare between the numbers of General Practitioners in each primary clinic for the years from 2006 – 2010. Determining the census tracts is the spatial steps which its results will render in the map display. The number of General Practitioners is a numerical step and will be rendered in the Charting Area. Each question in this study involves both numerical and spatial steps and SOVAT is the optimal choice.

2.9.2 Ease of use and efficiency

The ease of use, speed, and interactive analysis features suggest SOVAT as the best tool that suits the nature of our study. As can be seen from the figure, the user can simply pick the dimension in question, and then select the required members from those dimensions. Results will be acquired instantaneously in the visualization components on the right side SOVAT screen. In addition, there are some analytical features in SOVAT which allow for more tailored results. These features include sorting the results in an ascending or descending approach and viewing the top five or ten results. Furthermore, the visualization components provide different approaches to view the results such as maps, spreadsheet, and charts. Hence, allow for the exploration of hidden trends and/or pattern in the data.

To further clarify the efficiency and ease-of-use of SOVAT, the previously mentioned complex query example will be performed using ArcGIS so that the reader can get a sense of how frustrating and time consuming it is to solve a single complex query. The query will be: For each census tracts compare between the numbers of General Practitioners in each primary clinic for the years from 2006 – 2010?

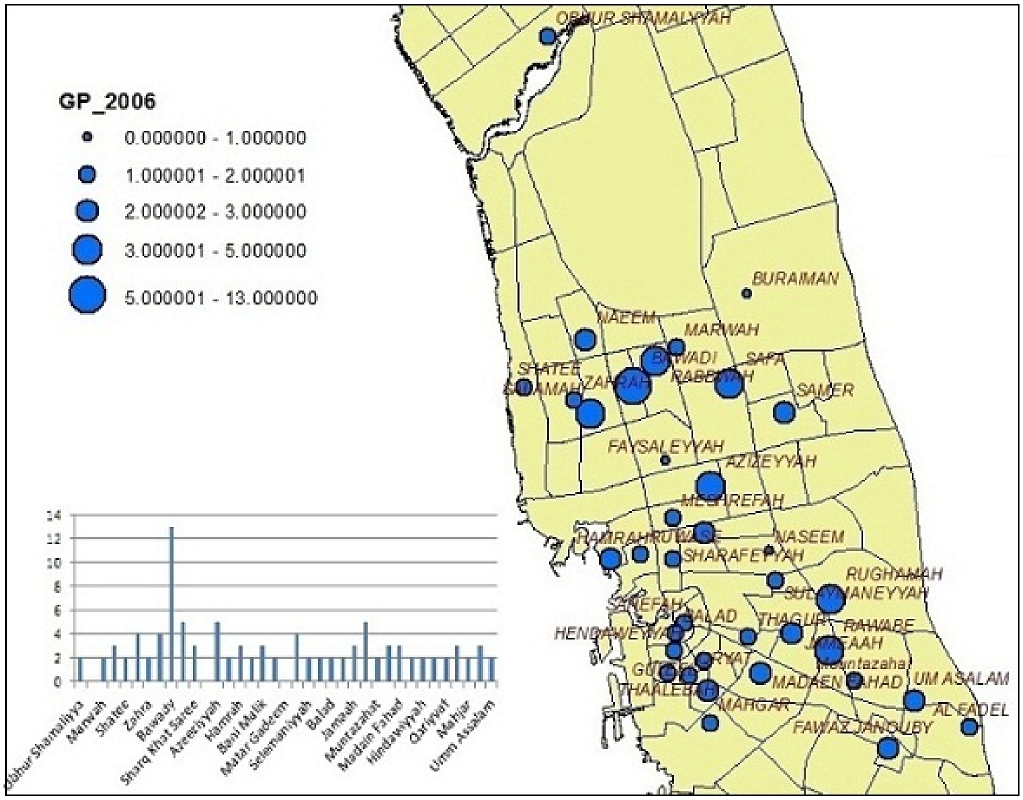

Figure 7. A Screenshot of ArcGIS results

The steps taken to conduct this complex query in ArcGIS are as follows:

1- Pick the field to be displayed from the database. In this case, General Practitioner 2006.

2- Determine how to symbolize the results. In this case it is Graduated Symbols.

3- Label features on the map. In this case Census Tracts’ names are used.

4- Add a legend to explain the symbols.

5- Export the map to a picture file.

6- Export the map’s database to an excel file.

7- Create a chart that includes the name of each census tract and the number of GP in 2006.

As can be noticed, it is inefficient to conduct such complex queries in ArcGIS, especially when there are many queries required to complete a study. Previous steps should be repeated five times in order to generate the results for the years from 2006 – 2010. Thus, it takes approximately 35 steps to conduct one complex query. Not to mention, a lot of time is consumed for organizing and exporting maps and data, In addition to creating graphs. On the other hand, it only took few second to conduct this same complex query with SOVAT (the reader is referred to the maps in the results section to compare).

2.9.3 OLAP features

It might be expected the use of ESRI ArcGIS tool to answer the questions of this study as it is used on a wide scale compared to the rest of the available tools as found by Scotch, et al (2006). Unfortunately, the underlying database in ESRI ArcGIS is the relational two-dimensional database. There are tools that use OLAP as an underlying database (Bedard, et al., 2003) and (Scotch and Parmanto, 2006). According to Microsoft (2008b) the principal difference between OLAP and two-dimensional database is the ability to retrieve data from OLAP by almost any number of dimensions. Thus, due to the variety and complexity of the data required for this study, it is optimal to integrate them into an OLAP cube. This way multiple dimensions can be created (ex: Geography, Health professionals, Disease Incidents) and used towards queries. To further clarify this point, the previous example will be used; for each census tracts compare between the numbers of General Practitioners in each primary clinic for the years from 2006 – 2010? To answer this research questions, we need to access these dimensions; Geography, Health Professionals, Year, And Measures. Then the query required to answer this question will be as follows:

```
SELECT
{ Year.[2005], Year.[2006],Year.[2007],
Year.[2008],Year.[2009] }                    ON COLUMNS,
{ [Measures].[Prof Number],
 [Health Professionals.[General Practitioner] }     ON ROWS
FROM [Jeddah]
```

As can be seen, the question is answered by performing only a single query on the OLAP cube. Not to mention that this query will be performed automatically in SOVAT with only few mouse clicks. On other hand, we cannot answer such a question with the relational two-dimensional database by performing a single query. At least five SQL queries will be needed to answer this example. It would also be more efficient to handle data dimension and create numerical measures (ex; ratio of health professionals to population) under an OLAP cube. Thus, OLAP is the optimal choice that will be used for this study. As mentioned earlier, there are tools that use OLAP as an underlying database (Bedard, et al., 2003) and (Scotch and Parmanto, 2006).

3.0 METHODOLOGY

The research methodology section of this study will consist of four parts. The first part is obtaining the data set from various sources in Saudi Arabia. The second part is the design of the data OLAP cube, which will contain all the collected data from various sources. This cube will then be integrated into SOVAT. The third part will be solving the research questions (queries) using SOVAT. Finally, the fourth part will be the analysis and discussion of the results.

3.1 RESEARCH DATA SETS

In this research the following data sets are used:

- Number of hospitals under MOH and their locations.
- Number of primary clinics under MOH and their locations.
- Hospitals and primary clinics' and catchment areas.
- Shape file of Jeddah city census tracts.
- Shape file of Jeddah city catchment areas of hospitals and primary clinics.
- Number of physicians in every hospital and primary clinic (by specialty for primary clinics).

- Numbers of nurses in every hospital and public clinic.

- Numbers of beds in every hospital.

- Census by census tract.

- Population grouped by gender.

- Number of visits to hospitals and primary clinics.

- Visiting disease incidents by census tracts.

  A. Diabetes.

  B. Hypertension.

  C. Asthma.

  D. Dengue fever.

3.2 DATA SOURCES

Data for this study have been obtained from various governmental sources. Depending on the type of data, the official source was approached. Starting with the geographical data, the maps of the city were obtained from the GIS center at Jeddah Municipality (Alharthy, 2011). This GIS center is responsible for all geo-spatial projects that belong to Jeddah Municipality. Data pertaining to health resources and diseases are obtained from the General Directorate of Information and Statistics at the Ministry of Health and Jeddah Health Affairs (Othman, 2011). This directorate is responsible for presenting detailed and simplified information about health status, health services, and health resources in Saudi Arabia. Jeddah City detailed populations are obtained from the Central Department of Statistics and Information at the Ministry of Economy and Planning (CDSI, 2011). This agency is responsible for the collection, analysis, and distribution of the statistical information in Saudi Arabia. This guarantees data consistency, accuracy, and validity as they were obtained from official sources. Table shows a summary of the obtained data and their sources.

Table 2: Summery of the data sources

Data sets	Source
Population Data	Central Department of Statistics and Information, Ministry of Economy and Planning
Health Resources Data	General Directorate of Information and Statistics, Ministry of Health
Diseases Data	General Directorate of Information and Statistics, Ministry of Health
Geographical Data	Jeddah Municipality

3.3 DATA ELEMENTS AND DESCRIPTION

The data used in this study can be divided into four categories as follows: (1) population data; (2) health resources data; (3) diseases data; and (4) geographical data. Using these four categories in this evaluation will help provide useful insight about spatial patterns and trends of the current health resources and how they are serving the population. Following are detailed descriptions of each category and the data elements each will contain and their availability.

1- Population Data:

Population data include data that pertains to the population and their characteristics. It includes the census data for Jeddah City grouped by gender. This section of the data has been obtained from the Central Department of Statistics and Information as explained earlier.

2- Health Resources Data:

Health resources data are numeric data which pertains to the number of health facilities and health professionals provided to the populations of Jeddah city for the years from 2006 – 2010. Health facilities include public hospitals and primary clinics. Health professionals include the number of doctors and nurses who work in these health facilities. Primary clinics physicians will be detailed by their specialty (General Practitioner, Family Medicine, and Dentist). (The reader is referred to Appendix A for Manpower data sample). Finally, the number of visits for both hospitals and primary clinics is collected for the years from 2006 – 2010. This section of the data has been obtained from the General Directorate of Information and Statistics at MOH.

3- Diseases Data:

Diseases data include data for visiting diabetes, hypertension, asthma, and dengue fever cases in the population for the years from 2006 – 2010. This section of the data has been obtained from the General Directorate of Information and Statistics at MOH. (The reader is referred to Appendix B for Visits data sample).

4- Geographical Data:

Geographical data includes information about the boundaries of the city's census tracts obtained from Jeddah Municipality as base maps. The census tracts boundaries will used for the analysis of the resources on a detailed geographical level. This section of the data has been obtained from the GIS center at Jeddah Municipality as explained earlier.

3.4 METHODS

Numerical data (for example; populations and hospital visits) about Jeddah health system is collected, in spreadsheet format, from various sources and integrated into the decision support system SOVAT. The following dimensions will be created in SOVAT: Geography, Population, Health Facilities, Health Professionals, Disease Incidents, Catchment Areas, Year, and Measures. Each dimension includes sub dimensions which will be used to perform the queries. (Readers are referred to table 3 for the list of dimensions).

First, a multidimensional database (OLAP Cube) will be created to integrate all the numerical data being used in this research. The following dimensions will be created: a Geography Dimension includes the boundaries of Jeddah city's census tracts as members; the

Population Dimension includes Male and Female as members; Health Facilities Dimension, which will include hospitals and primary clinics as members; the Health Professionals Dimension includes physicians, family medicine, dentists and nurses as a member; a Disease Incidents Dimension, which will include Diabetes, Hypertension, Dengue Fever, and Asthma cases as members; a Catchment Areas Dimension includes Hospital and primary clinics as members; Year dimension which include years from 2006 – 2010 as members. Finally, the last dimension is the Measures which include the following ratios:

- Health professional/ 100,000 population.
- Family medicine / 100,000 female populations.
- Number of Hospital Beds.
- Hospital Beds/ 1000 population.
- Total Visits for Hospitals and primary clinics.
- Visit / physician for Hospitals and primary clinics.
- Health Professional / 1000 Disease cases.
- Population Density / Square Mile.
- Distance (census tract to primary clinic)

Table 3: Summery of the data dimensions

Dimensions	Members
Geography	City + Census Tract
Population	Male + Female
Health Facilities	Hospitals + Primary Clinics
Health Professionals	Physicians + Nurses + Family Medicine + Dentists
Disease Incidents	Diabetes + Hypertension + Asthma + Dengue Fever
Catchment Areas	Hospitals + Primary Clinics
Year	2006 + 2007 + 2008 + 2009 + 2010
Measures	Health professional/ 100,000 population Family medicine / 100,000 female population Number of Beds Hospital Beds/ 1000 population Total Visits Hospital Visit / physician Primary Clinic Visit / physician Health Professional / 1000 Disease cases Populations’ densities Proximities to primary clinics

3.4.1 Populations' Accessibility method

This dimension Exploration assesses whether the primary clinics are allocated in accordance with the populations' densities. It consists of 2 queries:

1. *Rank census tracts by their population density.*
2. *Rank the accessibility of population densities.*

For the first query, the populations' densities per square miles were calculated by dividing the population of each census tract by the area of that same census tract. The results were then stored in a measurement named population density which was constructed in SOVAT. To perform this query, the following will be selected in SOVAT; census tracts member from the Geography dimension; population density member from the measures dimension. To rank the census tract according to their densities, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

For the second query, the following steps were taken. First, the distance between each census tract centroid and its primary clinic was calculated. Then an index was created to classify the level of accessibility each census tract has to a primary clinic. This index was based on the Saudi planning standards, and can be seen in the following table:

Table 4: Proximities classifications according to planning standards

Proximity	Classification
0 – 1 Km	Very close
1 – 2 Km	Close
2 – 4 Km	Far
> 4 Km	inaccessible

A measurement named distance has been constructed in SOVAT. To perform this query, the following will be selected in SOVAT; census tracts member from the Geography dimension; distance member from the measures dimension. To rank the census tract according to their accessibility, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

3.4.2 Professionals Availability method

This dimension Exploration assesses the increase in the number of health professionals in public clinics for the years 2006 - 2010. It consists of 3 queries:

1. *For each primary clinic, compare the number of health professionals / 100,000 populations in their catchment areas for the years from 2006 – 2010.*

2. *For each primary clinic, compare the number of family medicine / 100,000 female population in their catchment areas from 2006 – 2010.*

3. *For each primary clinic, compare the total number of visits in their catchment areas from 2006 – 2010.*

For the first query, a measurement named health professionals / 100,000 populations has been constructed in SOVAT. Health professionals consist of General Practitioners, Family Medicine, Dentists, and Nurses. To perform the first query, the following will be selected in SOVAT; Primary Clinic member from the Catchment areas dimension; health professionals/100,000 populations' member from the measures dimension; and 2006 – 2010 members from the year dimension. Results are shown instantaneously on the visualization components in SOVAT.

For the second query, a measurement named family medicine/100,000 female populations have been constructed in SOVAT. To perform this query, the following will be selected in SOVAT; Primary Clinic member from the Catchment areas dimension; family medicine/100,000 female populations' member from the measures dimension; and 2006 – 2010 members from the year dimension. Results are shown instantaneously on the visualization components in SOVAT.

To perform the third query, the following will be selected in SOVAT; Primary Clinic member from the Catchment areas dimension; Visits member from the measures dimension; and

2006 – 2010 members from the year dimension. Results are shown instantaneously on the visualization components in SOVAT.

3.4.3 Facilities Availability method

This dimension Exploration assesses whether the city needs more hospitals or primary clinics. It consists of 4 queries:

1. *For every census tract, compare between the number of hospitals, primary clinics, and health professionals/100,000 pop.*

2. *For every census tract, compare between the overall beds/1000 pop.*

3. *Compare the number of population reside outside the catchment areas of hospitals and primary clinic?*

4. *Compare the numbers of visits / physician for hospitals and primary clinic?*

For the first query, a measurement named health professionals / 100,000 populations has been constructed in SOVAT. Health professionals consist of Physicians and Nurses for hospitals and primary clinics. To perform the first query, the following will be selected in SOVAT; census tracts member from the Geography dimension; health professionals/100,000 populations' member from the measures dimension; and hospitals and primary clinics members from the health facilities dimension. Results are shown instantaneously on the visualization components in SOVAT.

For the second query, a measurement named hospital beds / 1000 populations has been constructed in SOVAT. To perform the first query, the following will be selected in SOVAT;

census tracts member from the Geography dimension and hospital beds /1000 populations' member from the measures dimension. Results are shown instantaneously on the visualization components in SOVAT.

For the third query, the following will be selected in SOVAT; census tracts that don't fall under the catchment areas of hospitals and primary clinics as members from the Geography dimension. Results are shown instantaneously on the visualization components in SOVAT.

For the fourth query, two measurements named hospital visits / physician and primary clinic visits / physician have been constructed in SOVAT. To perform the first query, the following will be selected in SOVAT; census tracts member from the Geography dimension; hospital visits / physician and primary clinic visit / physician as member from the measures dimension. Results are shown instantaneously on the visualization components in SOVAT.

3.4.4 Disease Professionals Availability method

This dimension Exploration assesses the availability of health resources based on selected diseases. It consists of 8 queries:

1. *What is the ratio of primary clinics' and hospitals' health professionals / 1000 dengue fever cases in every census tract for years from 2006-2009?*

2. *Based on the dengue fever data, rank the top 10 census tracts that are in greater need for more health professionals?*

3. *What is the ratio of primary clinics' and hospitals' health professionals / 1000 diabetes cases in every census tract for years from 2005-2009?*

4. *Based on the diabetes data, rank the top 10 census tracts that are in greater need for more health professionals?*

5. *What is the ratio of primary clinics' and hospitals' health professionals / 1000 hypertension cases in every census tract for years from 2005-2009?*

6. *Based on the hypertension data, rank the top 10 census tracts that are in greater need for more health professionals?*

7. *What is the ratio of primary clinics' and hospitals' health professionals / 1000 Asthma cases in every census tract for years from 2005-2009?*

8. *Based on the Asthma data, rank the top 10 census tracts that are in greater need for more health professionals?*

For the first query, a measurement named health professionals / 1000 dengue fever cases has been constructed in SOVAT. Health professionals consist of Physicians and Nurses for hospitals and primary clinics. To perform the first query, the following will be selected in SOVAT; census tracts member from the Geography dimension; health professionals/1000 dengue fever cases member from the measures dimension; and 2006 – 2009 members from the year dimension. For the second query, the distribution of the dengue fever cases is performed by selecting census tracts member from the Geography dimension; dengue fever member from the Disease Incidents dimension; and 2009 members from the year dimension. To rank the top 10 census tract, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

For the third query, a measurement named health professionals / 1000 diabetes cases has been constructed in SOVAT. Health professionals consist of Physicians and Nurses for hospitals and primary clinics. To perform the third query, the following will be selected in SOVAT; census tracts member from the Geography dimension; health professionals/1000 diabetes cases member from the measures dimension; and 2006 – 2010 members from the year dimension. For the fourth query, the distribution of the diabetes cases is performed by selecting census tracts member from the Geography dimension; diabetes member from the Disease Incidents dimension; and 2010 members from the year dimension. To rank the top 10 census tract, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

For the fifth query, a measurement named health professionals / 1000 hypertension cases has been constructed in SOVAT. Health professionals consist of Physicians and Nurses for hospitals and primary clinics. To perform the third query, the following will be selected in SOVAT; census tracts member from the Geography dimension; health professionals/1000 hypertension cases member from the measures dimension; and 2006 – 2010 members from the year dimension. For the sixth query, the distribution of the hypertension cases is performed by selecting census tracts member from the Geography dimension; hypertension member from the Disease Incidents dimension; and 2010 members from the year dimension. To rank the top 10 census tract, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

For the seventh query, a measurement named health professionals / 1000 Asthma cases has been constructed in SOVAT. Health professionals consist of Physicians and Nurses for hospitals and primary clinics. To perform the third query, the following will be selected in SOVAT; census tracts member from the Geography dimension; health professionals/1000 Asthma cases member from the measures dimension; and 2006 – 2010 members from the year dimension. For the eighths query, the distribution of the Asthma cases is performed by selecting census tracts member from the Geography dimension; Asthma member from the Disease Incidents dimension; and 2010 members from the year dimension. To rank the top 10 census tract, results are sorted using the Sort Descending function in SOVAT. Results are shown instantaneously on the visualization components in SOVAT.

4.0 RESULTS

4.1 POPULATIONS' ACCESSIBILITY

Primary Clinics are not allocated in accordance with the population density.

1. Rank census tracts by their population density.

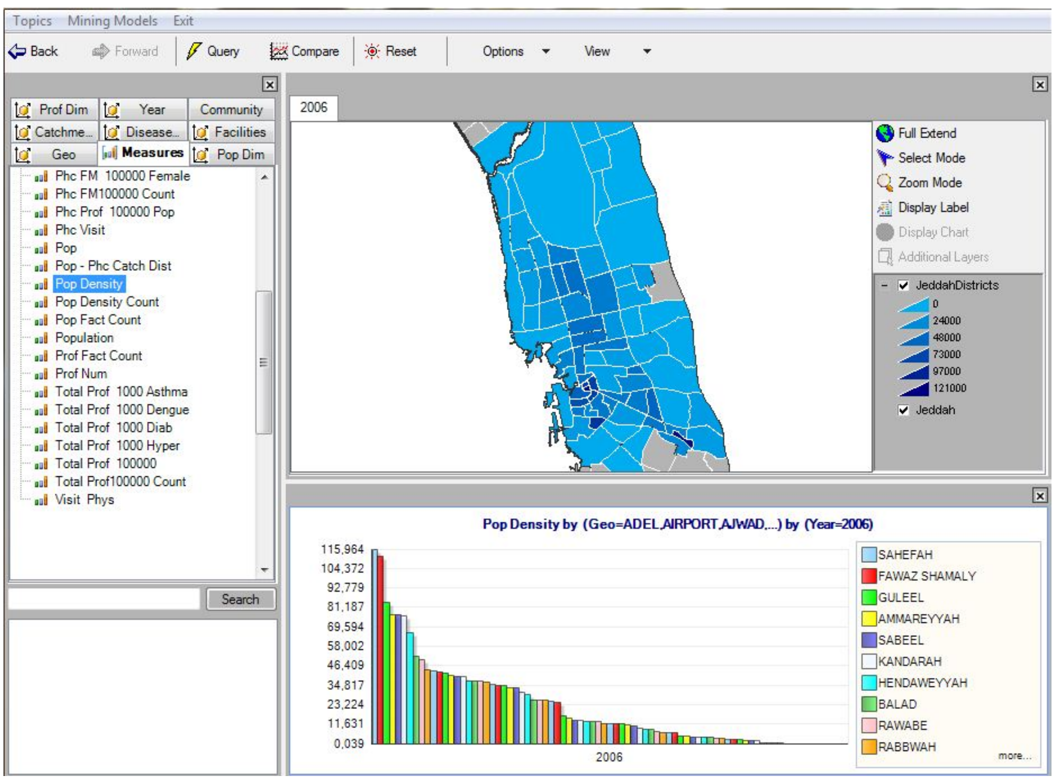

Figure 8. Top and Bottom 10 populations' densities

Population density is the concentration of the population regardless of the actual number of people. The map in figure 2 depicts the populations' densities for all the census tracts ranked from highest to lowest. As can be seen from the map, 8 out of the 10 top dense census tracts are located closer to the middle part of the city. These census tracts are represented by darkest colors. Only one census tract, which is Rabbwah, is located closer to the northern part. On the other hand, most of the bottom 10 dense census tracts are located in the northern part of the city. Two of the least dense census tracts, Senaeya and Wazeeriyya, are located in the southern part. The map in figure 2 shows that population' densities tend to increase in the middle then the southern part of the city and decrease in the northern part. A more detailed reading comes from the charting area. The graph sorted the census tracts by their populations' densities. It started with Sahefah as the most densely populated census tract and listed all the populated census tracts. However, due to the large number of census tracts, the graph is only showing the top 10.

2. Rank the accessibility of population densities.

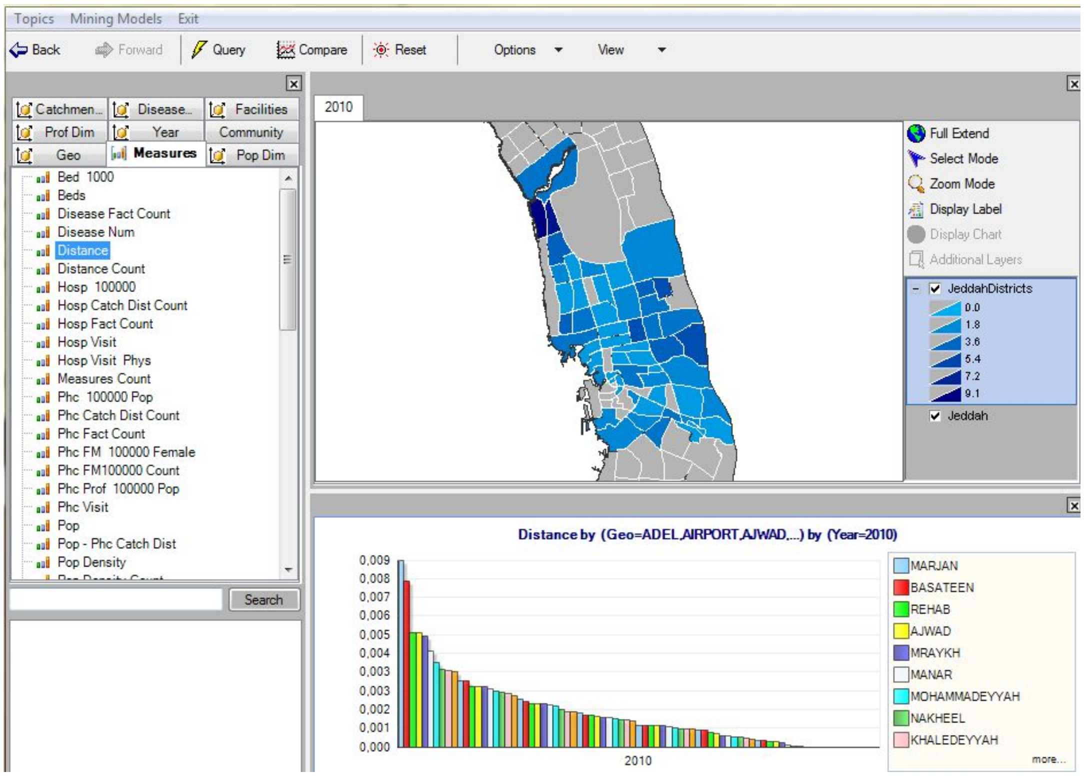

Figure 9. Top and Bottom 10 distances to Primary Clinics

The accessibility of a census tract refers to the distance from that census tract to its designated primary clinic. The map in figure 3 depicts the populations' accessibility to the primary clinics. Census tracts represented by the darkest color are far away from their primary clinics. As can be seen from the map, most of the top 10 census tracts with high accessibility are located closer to the middle part of the city. On the other hand, most of the bottom 10 census tracts with low accessibility are located closer to the northern part. However, there are some of the top 10 census tracts located closer to the north, like Shatee and Bawady. And some of the least accessible census tracts are located in the northern part of the city, like Marjan and Basateen. A more detailed reading comes from the charting area. The graph sorted the census tracts by their accessibility. It started with Marjan as the least accessible to its designated primary clinics. The spreadsheet is showing the bottom 10 census tracts accessibility.

4.2 PROFESSIONALS AVAILABILITY

Numbers of health professionals have been increasing over the years 2006-2010 in primary clinics.

1- For each primary clinic, compare the number of health professionals / 100,000 populations in their catchment areas for the years from 2006 – 2010.

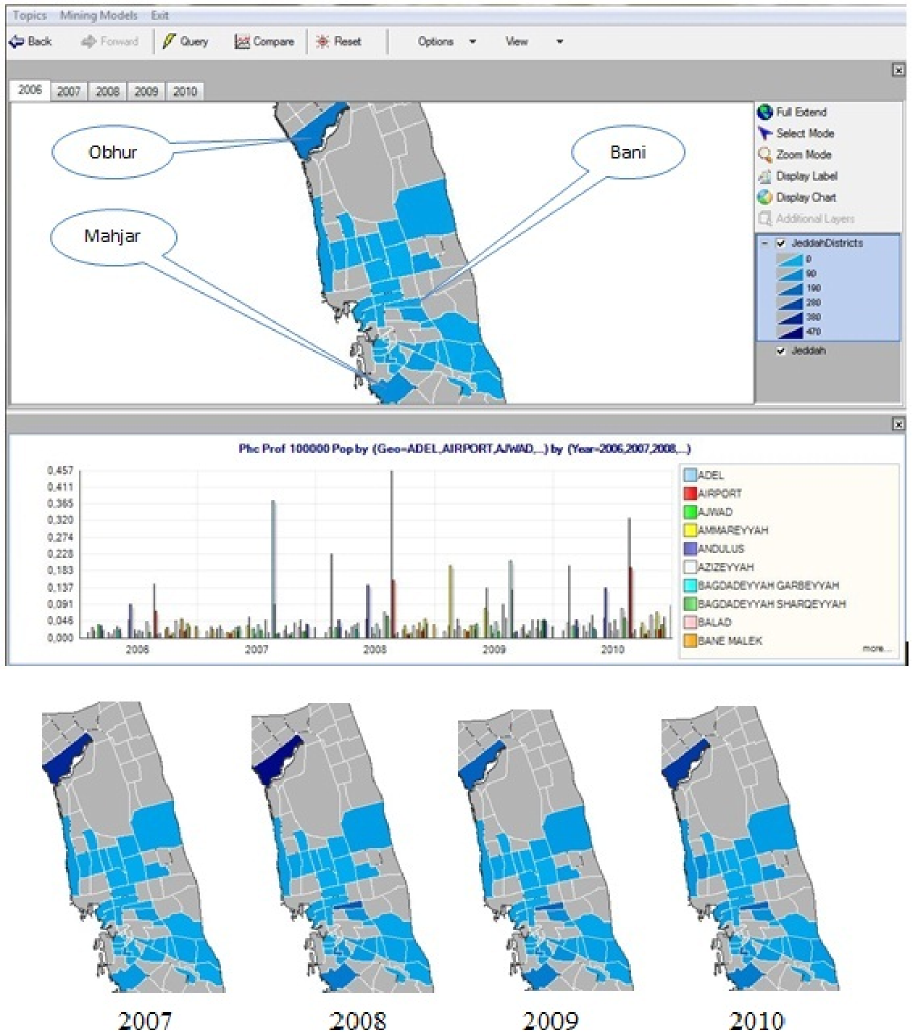

Figure 10. Health Professionals / 100,000 populations (2006 – 2010)

Health professionals / 100,000 populations ratio refers to the number of professionals that provide medical care to those populations. These professionals include physicians and nurses working at the primary clinics. The maps in in figure 4 depict the availability of health professionals per populations in the catchment areas of every primary clinic for the years from 2006 to 2010. Catchment areas represented by darker colors have the highest ratios. As can be detected on the map, it appears that changes in ratio of professionals per 100,000 populations have been limited to some of the catchment areas. The catchment area of the Obhur Shamaliyya primary clinic has been provided with the highest number of health professionals per population for all the years. Its professional's ratio has been increasing until 2008 when the ratio started to decrease slightly. Following is the Mahjar primary clinic catchment which has been improving throughout the years except for the 2007 which shows a decrease in the number of Professionals per population. Qryat primary clinic also have had an increase through the 5 year period. The primary clinic of Bani Malik witnessed a large increase in 2008, and then decreased slightly. The rest of the catchment areas appear to be maintaining the same ratios over the 5 year period comparison.

A more detailed reading of the results comes from the charting area. Observing the chart will give a more detailed translation of the results. It appears from the chart that almost all catchment areas have had an increase except for Jamaah and Thaghr. The ratio in these catchment areas have decreased in 2010 compared to 2006. However, changes in the ratio that are only observed in the charting area are very small compared to the changes that can be observed on the map.

2- For each primary clinic, compare the number of family medicine / 100,000 female population in their catchment areas from 2006 – 2010.

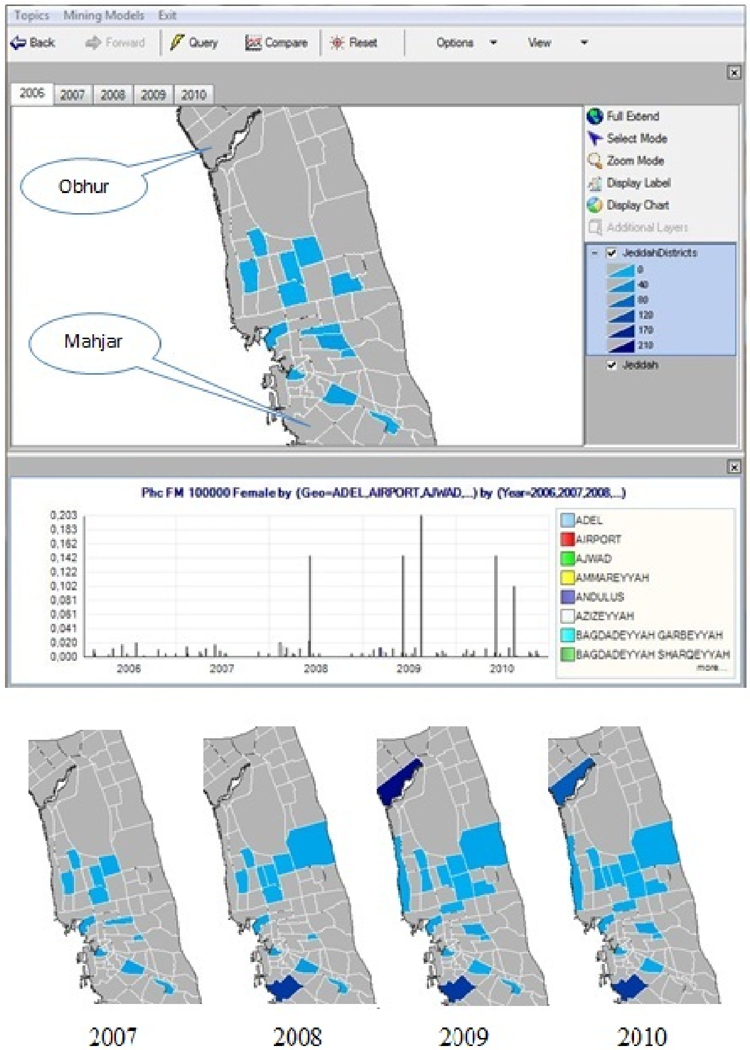

Figure 11. Female medicine / 100,000 female populations (2006 – 2010)

The maps in in figure 5 depict the ratio of family medicine per 100,000 female populations in the catchment areas of every primary clinic for the years from 2006 to 2010. Catchment areas represented by the darkest colors are the highest in this ratio. As can be detected on the map, it appears that in the years 2006 and 2007 there was a serious deficiency in the ratio of family medicine per female populations as most of the primary clinics catchment areas showed zero ratios. In other words, they had no family medicine at all. In addition, some census tracts appear to have had a decrease in the ratio of family medicine per populations. Among the largest ratios observed on the map, it can be detected that in 2008 the ratio of Mahjar catchment area showed a large increase from zero. In 2009 the ratios have gotten better as a number of catchment areas showed increases, with Ubhor Shamaliyya showing a large increase. In 2010 the ratios appear to remain as they were in 2009 except that Ubhur Shmaliyya showed a decrease. On the other hand, a catchment area of Fawwaz Janouby, Bani Malik, and Faysaliyya showed the worst results as their ratios reached zero after having family medicine during the 5 year period.

A more detailed reading of the results comes from the charting areas. A detailed translation of the results comes from observing the charting area. It appears from the chart that 16 of the catchment areas have never had any family medicine. Other catchment areas showed small decreases in their family medicine ratios. Finally, some catchment areas have had family medicine ratios but ended with zeros ratios.

3- For each primary clinic, compare the total number of visits in their catchment areas from 2006 – 2010.

Figure 12. Visit / Primary Clinic (2006 – 2010)

The maps in figure 6 depict the number of visit each primary clinic have had from their catchment areas. Primary clinics in the middle and southern parts of the city have more visits than the rest. Still there is an overall increase that can be detected from the maps from 2006 to 2010. However, Primary clinics like Um Asalam, Safa, and Almontazahat have had big increases in their numbers of visitors from 2006 to 2010. On the other hand, some health centers, like Madaen Fahad, have always had large number of visits throughout the years.

A more detailed reading of the results is translated in the charting area. The chart shows that there is an overall increase in the numbers of visits. However, there are also primary clinics that had a decrease in their visits. There is a primary clinic that had a large decrease which is Madaen Fahad. However, this primary clinic has one of the highest numbers of visits throughout the years.

4.3 FACILITIES AVAILABILITY

The city is in greater need for hospitals than for primary clinics.

1. For every census tract, compare between the number of hospitals, primary clinics, and health professionals/100,000 pop.

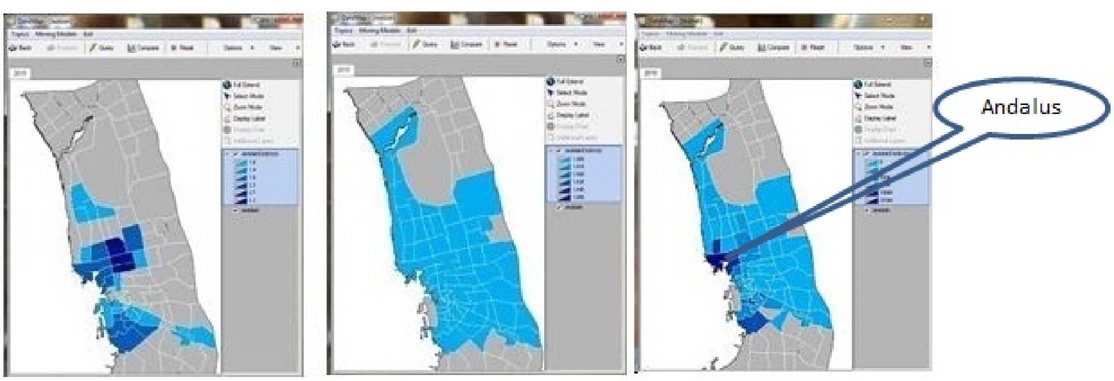

Figure 13. Hospitals, Primary Clinic, and Health Professionals / 100,000 populations

The maps in figure 7 depict the number of hospitals, primary clinics, and the ratio of health professional per 100,000 populations respectively for each census tracts for the year 2010. Starting with the number of hospitals, it appears from the map that only 31 census tracts are located within the catchment areas of the hospitals. And of those census tracts only 3 are located within the catchment areas of 3 hospitals (each census tracts is served by 3 hospitals). Those census tracts are Faysaliyya, Azizeyya, and Meshrefah. Other census tracts, like Safa and Andalus are located within catchment areas of 2 hospitals. As seen on the map, the assertion will be that the census tracts located in the middle part of the city are most benefiting from hospitals and the northern part is the least benefiting from hospital services.

On the other hand, there are 68 census tracts located within the catchment areas of primary clinics. Each of those census tracts is located within the catchment areas of only one primary clinic. As seen on the map, the assertion will be that northern part of the city is the least benefiting from primary clinics services.

Finally, number of health professionals per 100,000 populations for census tracts tends to be higher in census tracts that are located with the catchment areas of both hospitals and primary clinics. Thus, census tracts located in the middle part of the city, like Andalus, have a high number of professionals per population compared to a census tracts located in the northern part of the city like, Muhammadiyya. As seen on the map, the assertion will be that census tracts located within the catchment areas of hospitals are benefiting the most.

2. For every census tract, compare between the overall Hospital beds/1000 pop.

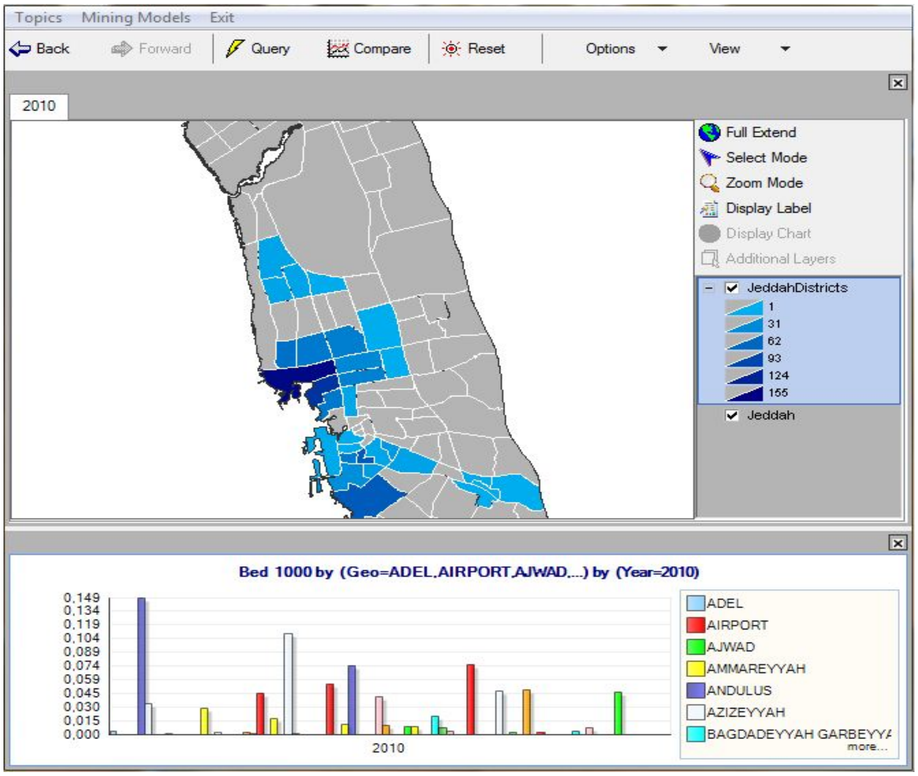

Figure 14. Hospital Beds / 1000 populations

The maps in figure 8 depict the number of beds per 1000 populations for census tracts located within the catchment areas of hospitals. It appears from the map that the numbers of hospital beds per 1000 populations tend to be high in the census tracts in the middle of the city. As seen on the map, the assertion will be that the census tracts located in the middle part of the city are most benefiting from hospitals' beds and the northern part is the least benefiting from hospital services.

3. Compare the number of population reside outside the catchment areas of hospitals and primary clinic?

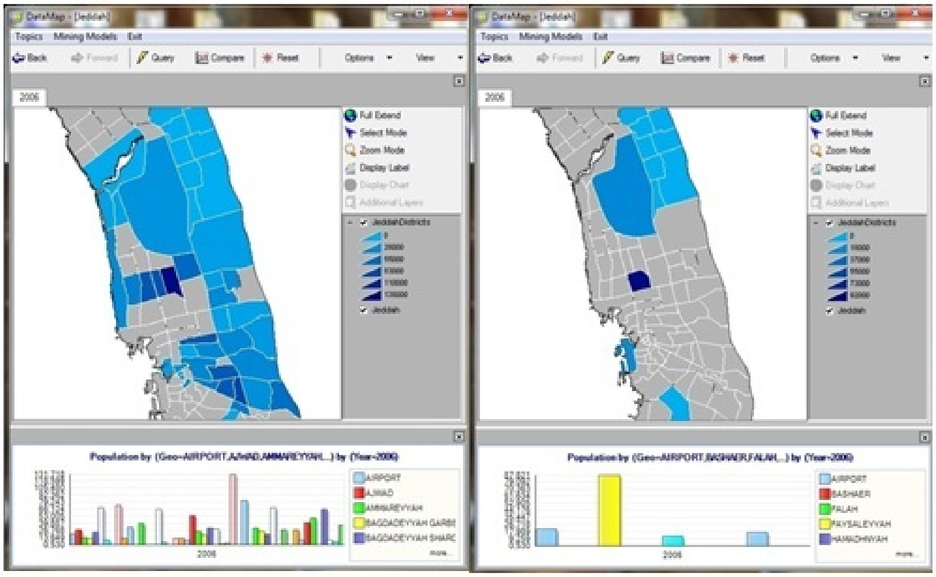

Figure 15. Populations outside the catchment areas of hospitals and primary clinics

The maps in figure 9 depict the number of populations reside outside of the catchment areas of both hospitals and primary clinics respectively. As can be detected, hospitals' catchment areas are covering less census tracts compared to primary clinics. In fact, the number of census tracts located outside the catchment areas of hospitals is 49 with a population of 1,257,832 while census tracts located outside the catchment areas of primary clinics is 14 with a total population of 57,112. It can be detected from the maps that the northern contain the largest part of uncovered census tracts.

4. Compare the numbers of visits / physician for hospitals and primary clinic?

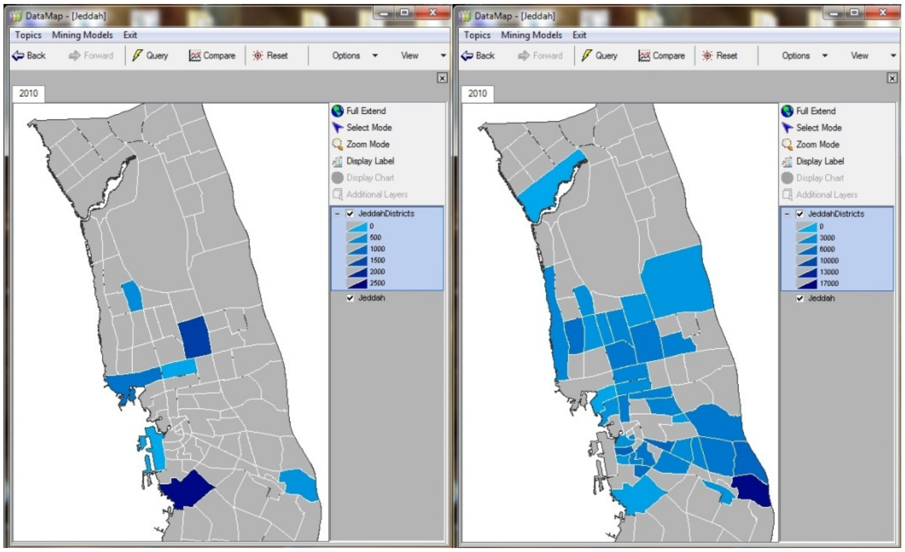

Figure 16. Visits / Physician for hospitals and primary clinics

The maps in figure 10 depict the number of visits per physician for both hospitals and primary clinics. Starting with visits for hospitals' physicians, it appears from the map that Nafsiyya hospital in the southern part of the city is having the highest number of visit per physician followed by Eyoon hospital. As seen on the map, the assertion will be that those hospitals' areas need attention in terms of physicians' numbers. On the hand, primary clinics in the southern part of the city appear to be having higher numbers of visits per physicians followed by the primary clinics in the middle part of the city. Umm Salam has the highest number of visits per physician.

4.4 DISEASE PROFESSIONALS AVAILABILITY

Based on the demand of diabetes, Hypertension, Asthma, and dengue fever cases; health resources have improved over the last five years.

1. What is the ratio of primary clinics' and hospitals' health professionals / 1000 dengue fever cases in every census tract for years from 2006-2009?

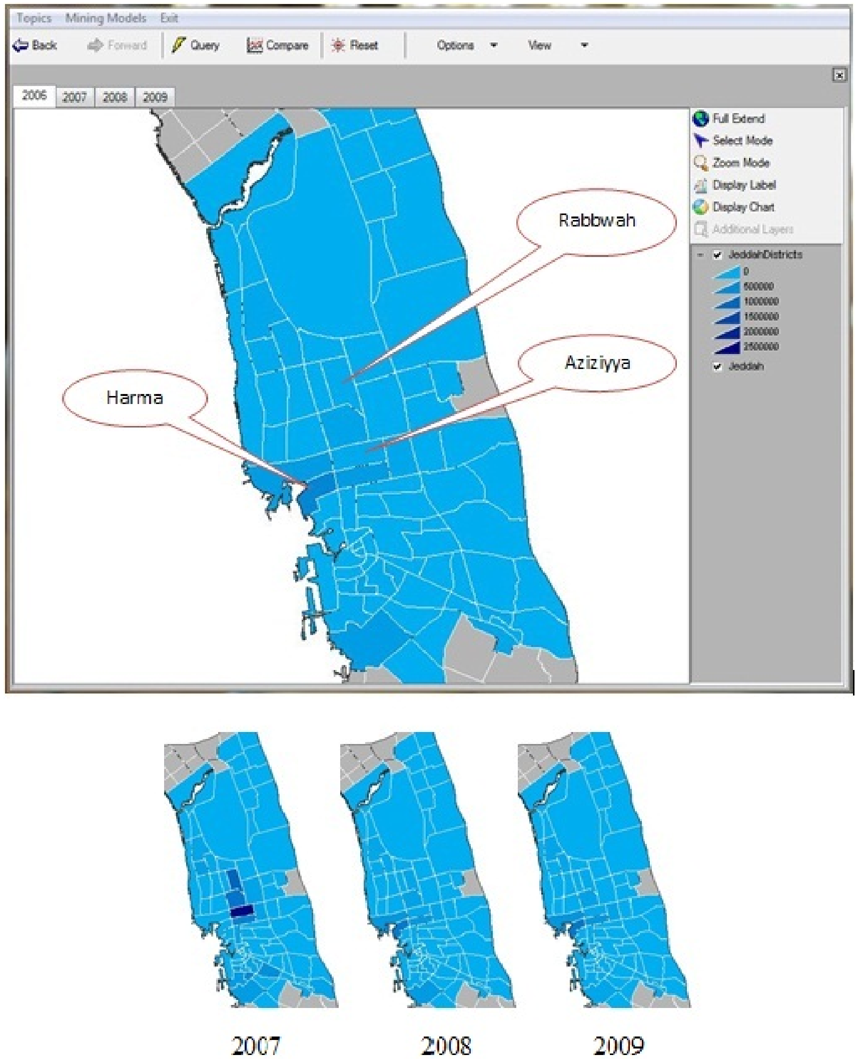

Figure 17. Health Professionals / 1000 dengue fever cases (2006 – 2009)

The maps in figure 11 depict the ratio of total health professionals per 1000 dengue fever cases in each census tract. It appears that changes across the years of 2006 to 2009 have been limited. Hamra has always maintained the highest ratio except for the year 2007. In 2007 there were increases in the ratio in 3 census tracts in the middle of the city. Specifically, Aziziyyah, Faysaliyya, and Rabbwah have increased and Aziziyyah was the highest. However, there is no overall decrease in the ratio that can be detected from the map. Additionally, the ratios of professional per dengue cases tend to be high, especially in census tracts that are with the catchment areas of hospitals.

2. Based on the dengue fever data, rank the top 10 census tracts that are in greater need for more health professionals?

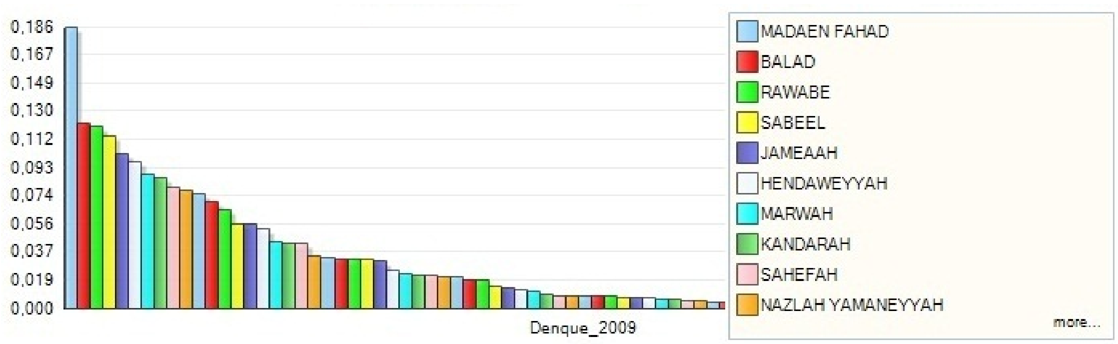

Figure 18. Top 10 census tracts with Dengue Fever cases

The graph in figure 12 depicts the ranks the top 10 census tracts that contain dengue fever cases and need an increase in their numbers of health professionals. These census tracts are located in many parts of the city with a concentration in the southern part followed by the middle part. In fact, most of the top 10 census tracts are located closer to the southern part except for Marwah census tract. Thus, based on the dengue fever cases, the southern part of the city is in greater need for more health professionals.

3. What is the ratio of primary clinics' and hospitals' health professionals / 1000 diabetes cases in every census tract for years from 2006-2010?

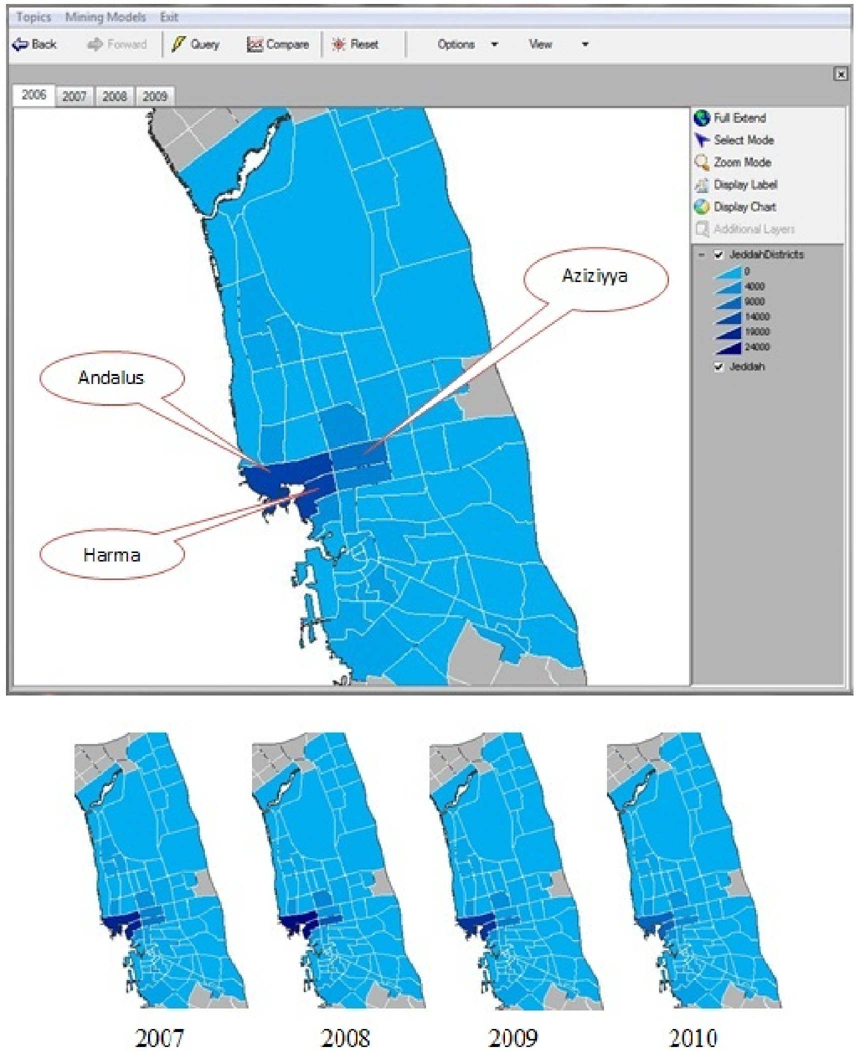

Figure 19. Health Professionals / 1000 Diabetes cases (2006 – 2010)

The maps in figure 13 depict the ratio of total health professionals per 1000 diabetes cases in each census tracts. It appears that changes across the years of 2006 to 2009 have been limited. Andalus and Hamra census tracts have always maintained the highest ratios followed by Meshrefa census tract. In 2009 and 2010 they started to show a decrease in their ratios however. Also Azizeyyah is one of the census tracts that have had a large ratio but showed a drop in the ratio in 2008. The rest of the census tracts appear to maintain steady ratios throughout the years. Unfortunately, reading the detailed results from the charting area reveals that there is an overall decrease in the ratio that can be detected from the chart. However, there are some exceptions. Qryat and Thaalbah have showed an increase in the ratio.

4. Based on the diabetes data, rank the top 10 census tracts that are in greater need for more health professionals?

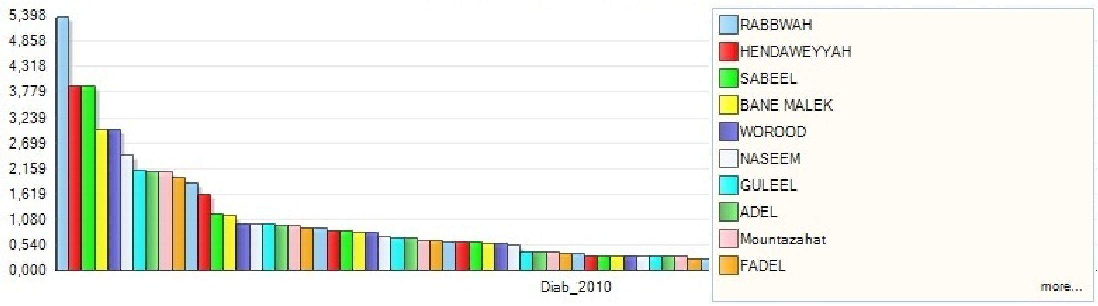

Figure 20. Top 10 census tracts with Diabetes cases

The graph in figure 14 depicts the ranks the top 10 census tracts that contain diabetes cases and need an increase in their numbers of health professionals. These census tracts are located in many parts of the city with a concentration in the southern part followed by the middle part. However, the census tract with largest number of diabetes cases, Rabbwah, is located in the northern part of the city. And the last census tract in the top 10 list is located closer to the southern part of the city. Thus, based on the diabetes cases, the southern part of the city is in greater need for more health professionals followed by the middle part.

5. What is the ratio of primary clinics' and hospitals' health professionals / 1000 hypertension cases in every census tract for years from 2006-2010?

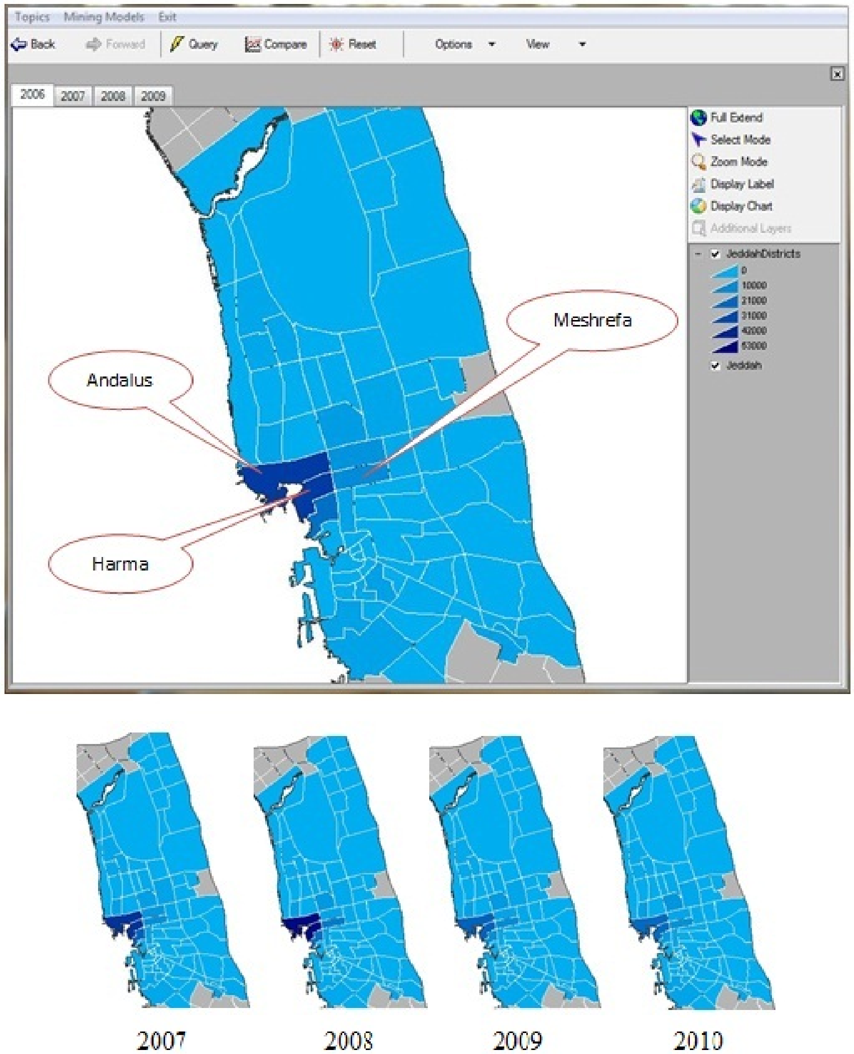

Figure 21. Health Professionals / 1000 Hypertension cases (2006 – 2010)

The maps in figure 15 depict the ratio of total health professionals per 1000 hypertension cases in each census tracts. It appears that the changes across the years of 2006 to 2009 have been limited. It can be detected, however, that Andalus and Hamra have always maintained the highest ratios followed by Meshrefah. While their peak ratios were in 2008, they have been witnessing decreases since then. Unfortunately, reading the detailed results from the charting area reveal that there is an overall decrease in the ratio of professional per HTN cases. However, there are some exceptions as Faysaliyya has had an increase in its ratio.

6. Based on the hypertension data, rank the top 10 census tracts that are in greater need for more health professionals?

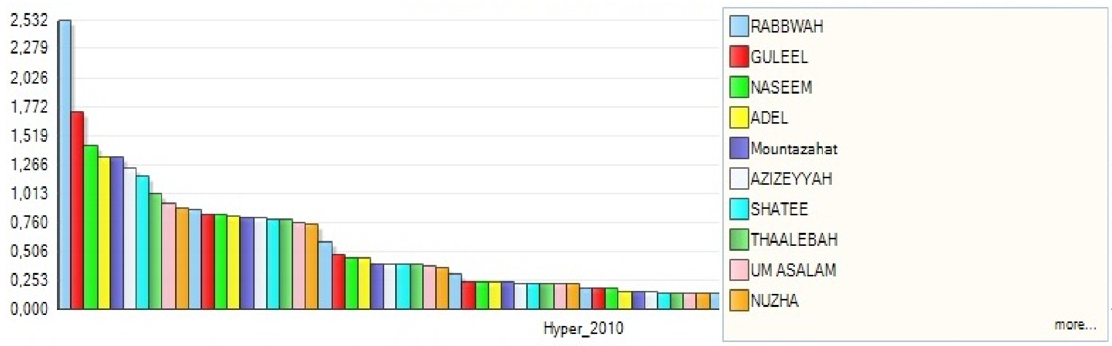

Figure 22. Top 10 census tracts with Hypertension cases

The graph in figure 16 depicts the ranks the top 10 census tracts that contain hyper tension cases and need an increase in their numbers of health professionals. These census tracts are located in all parts of the city with a concentration in the southern part. The census tract with largest number of diabetes cases, Rabbwah, is located in the northern part of the city. Likewise, the last census tract in the top 10 is also located in the northern part of the city. Thus, based in the hypertension cases, it appears that there is a need for more professionals all over the city.

7. What is the ratio of primary clinics' and hospitals' health professionals / 1000 Asthma cases in every census tract for years from 2006-2010?

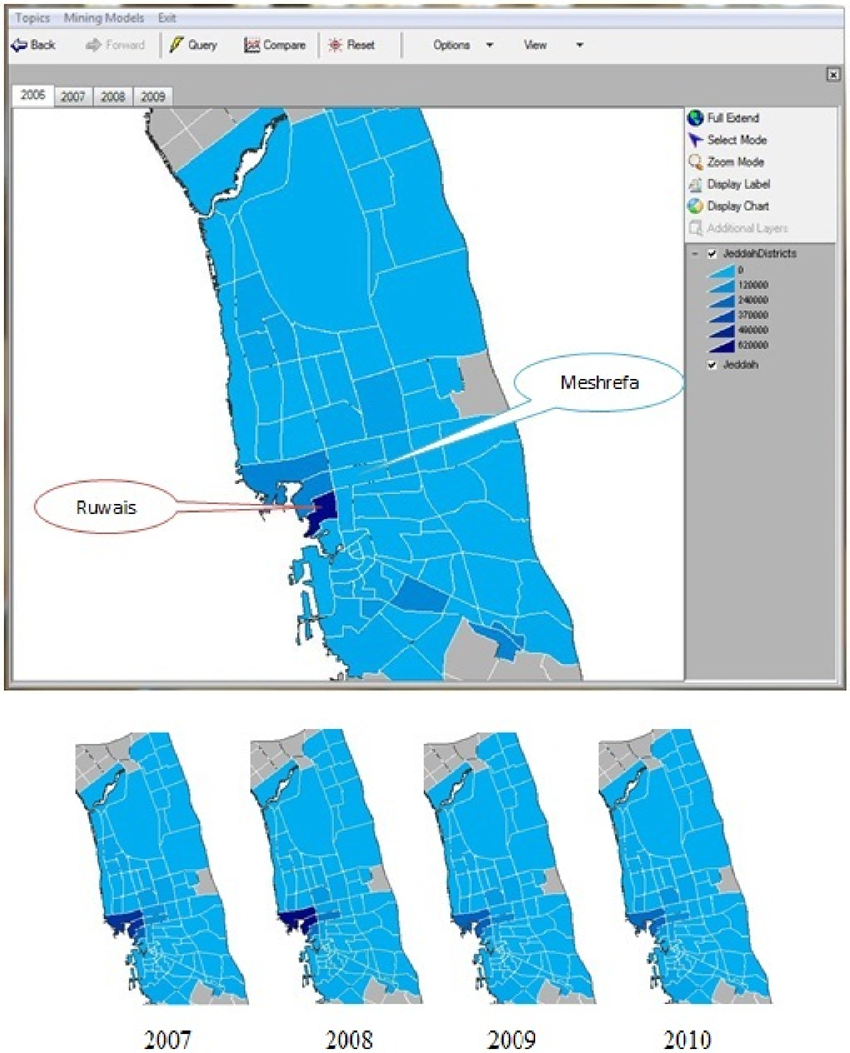

Figure 23. Health Professionals / 1000 Asthma cases (2006 – 2010)

The maps in figure 17 depict the ratio of total health professionals per 1000 Asthma cases in each census tracts. It appears that the changes across the years of 2006 to 2009 have been limited. As can be detected from the maps, Ruwais had the highest ratio in 2006. Other census tracts have had high ratios throughout the years. Still, it can be detected that the ratios tend to decrease over the years reaching 2010 where almost all census tracts had decreased ratios except for Meshrefa census tracts. Unfortunately, reading the detailed results from the charting area reveals that there is an overall decrease in the number of health professionals per asthma cases.

However, there are some exceptions. For example, Betrumeen and Thaalbah have maintained steady ratios.

8. Based on the Asthma data, rank the top 10 census tracts that are in greater need for more health professionals?

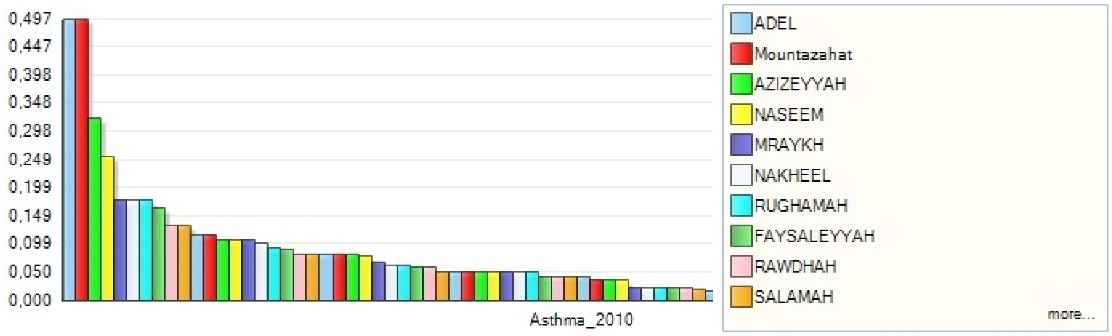

Figure 24. Top 10 census tracts with Asthma cases

The graph in figure 1 depicts the ranks the top 10 census tracts that contain Asthma cases and need an increase in their numbers of health professionals. These census tracts are mostly located in the middle and southern parts of the city. The census tract with largest number of diabetes cases, Adel, is located in the southern part of the city. And the last census tract in the top 10, Salamah, is located closer to the northern part of the city. Thus, based on the asthma cases, the middle part of the city is in greater need for more health professionals followed by the northern part.

5.0 ANALYSIS AND DISCUSSION

5.1 SOVAT

Using SOVAT for this study proved to be more efficient and fast than using a traditional GIS tool. The design of SOVAT interface allows user to explore the data rapidly and in a multidimensional approach. The left side of the interface contains the data dimensions and their member. User can simply pick the desired dimension and select a member and query it. Results are shown instantaneously on the map which is located in the visual component of the interface. In fact, SOVAT is perceived as more satisfactory and faster than GIS tool (Scotch, et al., 2008). Additionally, analytical features in SOVAT allows for more detailed results. With such capabilities and features, it allowed the researcher to perform the research queries in a rapid and efficient manner. Despite having a number of complex queries that consists of multi dimensions and multi-epoch, results of this study were achieved within seconds. Conversely, performing the same queries with a traditional GIS tool would take endless effort as they are not efficient with ad-hoc, multi-dimensional, and multi-epoch queries (Bernier, et al., 2009).

5.2 POPULATIONS' ACCESSIBILITY

Using SOVAT:

In this dimension Exploration the goal was to determine whether the primary clinics are allocated in accordance with the populations' densities. Two questions have been formulated to get an answer to this dimension Exploration. These questions are as follows:

3. *Rank census tracts by their population density.*

4. *Rank the accessibility of population densities.*

Higgs (2004) stated that a techniques of measuring accessibility by measuring the distance from the population demand point to the provider. Demand is commonly summarized as a centroid depending on the available data. In fact, Guagliardo (2004) named this measure amongst the most published measures of spatial accessibility to health care. The researcher used this technique with SOVAT.

In question 1 the first step was establishing a population's density for each census tract. This is to give the researcher an idea of how congested the census tract is as opposed to the populations' sizes in general. Second step was to rank the accessibility of these census tracts according to the distances to their designated primary clinics. In other words, to indicate which census tract is closer to its designated primary clinic. Despite the fact that this query is not being complex, performing it in SOVAT is more efficient. Population density is represented on the map with colors. The darker the color the higher population density the census tract has. This makes it very easy to recognize by the researcher. On the other hand, the results were ranked according to the density using the SOVAT analytical feature of Sort Descending. Results are shown sorted in the chart and spreadsheet. This query can be performed in a GIS tools, nevertheless, much more effort will be needed to reach the final results. For example, researcher will need to perform additional steps (classifications and symbology) to color-code the density on the map. While in SOVAT this is achieved automatically. In the second question, census tract accessibilities to their primary clinics are represented by color. The darker the color of a census tract the far away it is from the designated primary clinic. Thus, user can determine the most or least accessible census tracts with a quick glance. In addition, these accessibilities are ranked using the Sort Descending feature in SOVAT.

Results:

The queries of this dimension Exploration were performed using SOVAT tool. It can be quickly detected that most census tracts are located very close to the primary clinics. According to the Saudi Planning Standards, each primary clinic should cover an area from 2 – 4 Km. Fortunately; all of the large density census tracts are classified as very close to their primary clinics. Only 2 census tracts, Marjan and Basateen, are classified without accessibility to their designated primary clinics. Unfortunately, some census tracts have no classifications as they are not located within a catchment area of any primary clinic. In other words, these census tracts are not provided with primary clinics services at all. This could lead to additional problems as Parchman and Culler (1999) found an association between primary care shortage and a preventable hospitalization.

5.3 PROFESSIONALS AVAILABILITY

Using SOVAT:

In this dimension Exploration the goal was to determine if there is an increase in the number of health professionals in each primary clinic over the past five years (2006 - 2010). Three questions have been formulated and all of them were considered complex questions as they require complex queries to answer since they all have many dimensions. The questions were:

1. *For each primary clinic, compare the number of health professionals / 100,000 populations in their catchment areas for the years from 2006 – 2010.*

2. *For each primary clinic, compare the number of family medicine / 100,000 female population in their catchment areas from 2006 – 2010*

3. *For each primary clinic, compare the total number of visits in their catchment areas from 2006 – 2010.*

Amongst the most published accessibility measure is the provider to population ratio (Guagliardo, 2004). This measure has been used with SOVAT. The dimension Exploration's first question contains the dimensions: Facilities (primary clinics as sub-dimension), Populations, Geography (census tracts as sub-dimension), Years, and Measures dimension. Using SOVAT, all of these five dimensions were accessed at once with few clicks of the mouse and the query was performed very rapidly. Professionals' ratio is represented by color that ranges from blue to dark blue. The bigger the professionals' ratio the darker it is represented on the map. Furthermore, SOVAT analytical features that help giving more detailed answers for each query. For example, Charts, sorting, and top 5 features were used in this research. The current question used the map and the chart for detailed results. On the other hand, answering these questions with a GIS tool would require an extensive amount of work to finish each single question. It will be required from the researcher a complete familiarity with the database structure and to perform a number of SQL queries. In the later questions, performing such a query with a GIS tool (using SQL) would require the researcher to repeat the query at least five time to acquire the results for the five-year period (2006-2010). GIS tools are good for simple queries but fall short when performing ad-hoc multidimensional queries (Bernier, et al., 2009).

Same facts apply to the second and third questions. Each of these questions consists of a number of dimensions that need to be accessed when performing a query. For example, the second question contains the following dimensions: Facilities (primary clinics as sub-dimension), Professionals (family medicine as sub-dimension, Populations (female as sub-dimension), Geography (census tracts as sub-dimension), Years and Measures. SOVAT will enable the access of all the dimensions and measures at once and perform the query rapidly and getting instantaneous results.

Results:

Looking at the generated map in SOVAT, we can detect from figure 4 that health professionals per populations have been increasing over the five-year period for the primary clinics. However, the increase is limited to some of the primary clinics like Ubhor Shamaliyya, Mahjar, and Bani Malik. Additionally, it also can be detected that most primary clinics had lower numbers of professionals. The same fact is true regarding the number of family medicine per female populations. There was a serious deficiency in the numbers of family medicines. However, their numbers have increased in 2008 as Mahjar and Ubhor Shamaliyya showed a large increase. These findings agrees with Mansour & Al-Osimy (1996) and Banakhar, et al (2006) as the authors have found that there is a shortage in the number of physicians in primary clinics. Finally, there is an overall increase in the number of visits detected. However, primary clinics with the biggest increase, like Safa, are not showing an increase in the number of professionals. This indicates that such clinics deserve more attention when staffing decisions are made.

However, according to Saudi Planning Standers, there should be 1 physician per 2,000 populations (50 physicians per 100,000 populations). This construct a serious problem as Gulliford (2002) and Shi and Starfield (2001) found a negative association between primary care doctors and mortality rates. It can be quickly detected from the maps that there is no census tract has reached the number required by the planning standards except Ubhur Shamaliyya. The rest of census tracts' number of professionals which include physicians and nurses didn't comply with the Planning Standards. Family medicine ratio, however, was high in two census tracts only. The rest falls short according to the Planning Standards.

Finally, there is an overall increase in the number of visits to the primary clinics. This is attributed to the fact that primary clinics are serving more populations than their capacities. According to the Planning Standards, each primary clinic is to serve a population between 7,000 and 25,000. There are only 3 primary clinics providing medical care to populations under 25,000. The rest of the primary clinics are serving much more populations than the standards require. Not to mention, primary clinics are not adequately staffed with health professionals as mentioned previously. Murad (2008b) has suggested the reduction of the primary clinics catchment areas in order to provide better care to fewer populations.

5.4 FACILITIES AVAILABILITY

In this dimension Exploration the goal was to determine whether there is a need to increase the number of hospitals or primary clinics. Four questions have been formulated to acquire an answer to this dimension Exploration. None of these questions is considered complex as only 2 dimensions needed to be accessed at once to get the results. The questions are:

1. *For every census tract, compare between the number of hospitals, primary clinics, and health professionals/100,000 pop?*

2. *For every census tract, compare between the overall Hospital beds/1000 pop?*

3. *Compare the number of population reside outside the catchment areas of hospitals and primary clinic?*

4. *Compare the numbers of visits / physician for hospitals and primary clinic?*

Using SOVAT:

The use of SOVAT analytical features helped performing the queries for questions 1, 2, and 4 and gives the desired results instantaneously. Despite the fact that the queries in this dimension Exploration are not considered complex, they were performed very rapidly with few mouse clicks. Results were shown on the map with color ranging from blue to dark blue depending on the results. In addition, detailed results were shown on the charting area. On the other hand, performing these same queries using a GIS tool would require much more amount of work. It will also require complete familiarity with the database structure and SQL queries. In addition, more work will be required to get the desired color coding and charts of the results.

Results:

The queries of this dimension Exploration were performed using SOVAT tools. It can be quickly detected from figure 7 that there is a big part of the city that doesn't have any hospital services with only 31 census tract located within hospitals' catchment areas. This finding agrees with Murad (2005) as the researcher found that %25 of the city falls outside the hospital catchment areas. Goodman, et al (1997) found a negative association between the proximity to hospital and the hospitalization rate. Consequently, populations living farther from hospital do not have the same chance of access. On the other hand, primary clinics tend to cover a bigger part of the city as 68 census tracts are located within the catchment areas primary clinics. This can be shown in the maps in figure 7. Thus, population resides outside the catchment areas of hospitals (1,257,823 populations) is far larger than those who reside outside the catchment areas of primary clinics (57,112 populations). In other words, primary clinics are much better distributed compared to hospitals.

As expected, It is clearly shown in the third map in figure 7 that census tract that are with catchment areas of both hospital and primary clinic tend to have the highest numbers of health professional. Nevertheless, as shown on the first map in figure 7, the locations of the hospitals are not properly chosen. The largest two hospitals, KFGH and Musaadiyya are located in the same census tract. Thus, there are big discrepancies in the hospital beds (as shown in figure 8) per populations' ratios between census tracts. Not to mention that census tracts located off the hospital catchment areas have no hospital beds resource.

5.5 DISEASE PROFESSIONALS AVAILABILITY

In this dimension Exploration the goal was to determine if there is an increase in the number of health professionals per some selected diseases (Diabetes, Hypertension, Asthma, and Dengue fever) over the a five years (2006 - 2010). Eight questions have been asked and four of them were considered complex questions as they require complex queries to answer since they all have many dimensions. The questions were:

1. *What is the ratio of primary clinics' and hospitals' health professionals / dengue fever cases in every census tract for years from 2006-2009?*

2. *Based on the dengue fever data, rank the top 10 census tracts that are in greater need for more health professionals?*

3. *What is the ratio of primary clinics' and hospitals' health professionals / diabetes cases in every census tract for years from 2005-2009?*

4. *Based on the diabetes data, rank the top 10 census tracts that are in greater need for more health professionals?*

5. *What is the ratio of primary clinics' and hospitals' health professionals / hypertension cases in every census tract for years from 2005-2009?*

6. *Based on the hypertension data, rank the top 10 census tracts that are in greater need for more health professionals?*

7. *What is the ratio of primary clinics' and hospitals' health professionals / Asthma cases in every census tract for years from 2005-2009?*

8. *Based on the Asthma data, rank the top 10 census tracts that are in greater need for more health professionals?*

Using SOVAT:

Questions 1, 3, 5, and 7 are considered complex queries as each one of them consists of a number of dimensions that need to be accessed in order to perform the query and get the desired results. These dimensions are: Facilities (hospitals and primary clinics as sub-dimensions), Professionals (physicians, nurses as sub-dimensions), Disease (diabetes, hypertension, asthma, and dengue fever as sub-dimensions), Geography (census tracts as sub-dimension), Year, and Measures. All of these dimensions were accessed at once and the query was performed very rapidly using SOVAT. On the other hand, performing such queries using a GIS tool would cause a tremendous amount of frustration as it will take endless steps and queries to finish. As previously mentioned, the researcher might need to spend a lot of time and effort on each single query as repetition will be needed in order to get the results.

Analytical features of SOVAT are extremely helpful when performing the queries for questions 2, 4, 6, and 8. Despite the fact that these queries are not considered complex as only two dimensions are needed to be accessed in each query. Performing them with SOVAT is better than using a GIS tool. The spreadsheet and charts enable for getting detailed answers of the queries instantaneously. For example, ranking the top 10 census tracts in greater need for health professionals, the spreadsheet shows the exact desired results after sorting the results in a descending order.

Results:

The complex queries of this dimension Exploration were performed with SOVAT and maps were generated showing the results. It is vital for a person with illness to live within a close proximity to a treatment center. There is an association between increased travel distance and decrease utilization of treatment (Athas, et al., 2000) and (Nattinger, et al., 2001). As previously mentioned, there is a negative association between the availability of primary physicians and mortality rates (Shi and Starfield, 2001). It can be quickly detected by looking at the maps that health professionals per diabetes and hypertension cases are more concentrated in the Andalus and Hamra census tracts which are located north of the city. This is expected as these census tracts are located within the catchment areas of the largest 2 hospitals in the city. On the other hand, census tracts with diabetes cases which need most attention tend to be located in the middle and southern part of the city, while the whole city needs additional professionals in terms of hypertension cases. This finding agrees with the finding of Murad (2008a). While for asthma cases, the ratio tend to be concentrated in Ruwais and Meshrefah census tracts which are located in the middle part of the city. Census tracts that need most attention are located in the middle and southern parts of the city. Finally, for the dengue fever cases, it appears that Hamra census tracts had maintained the highest ratio of professionals per cases except in 2007 when Azeziyya and Rabbwah showed the highest ratios. It also appears that census tracts that need the most attention are mainly located in the middle and southern parts of the city. However, dengue fever cases are confronted with a surveillance program to monitor and control the cases (Alharthy, 2007).

5.6 PATTERNS AND TRENDS DISCOVERED

Going beyond the predefined dimension Explorations and questions, one of the significance of this study is the possibility of discovering hidden patterns and trends within the data by the use of the multidimensionality feature in SOVAT. The strength of the spatial and multidimensional approach used in SOVAT is that user can explore the complex data thoroughly and discover hidden patterns and trends that cannot be detected otherwise (Parmanto, et al., 2008). This can be achieved by the possibility of picking any combination of sub-dimensions and then query them at once. The use of SOVAT for a thorough exploration of the data in this study allowed for discovering of some patterns that could be still hidden if a traditional GIS tool had been used. Most of these patterns are counterintuitive as the researcher expects their opposites when trying to predict them. There patterns are as follows:

1- Primary clinics with highly increasing numbers of visits are having little or no increase in their ratios of professionals per 100,000 populations.

This pattern suggests that the increase in the number of health professionals is not proportional to the increase in numbers of visits (the reader is referred to the figures 10 and 12 in the results). This is an indication that even if there is some increase in the numbers of professionals in some of the primary clinics, this increase is not taking place for primary clinics with most need. This fact explains the findings of (Banakhar, et al., 2006) as most of the respondents reported that number of physicians is insufficient. And a smaller percentage of the respondents reported that number of nurses is insufficient. It also lead to the fact that waiting times being long (El-Shabrawy and Mahmoud, 1993). On the other hand, there are some primary clinics with larger number of visitor and professionals. Nevertheless, their numbers of health professionals is still insufficient according to the Saudi planning standards (Murad, 2004) as discussed previously.

The random browsing of the dimension and maps' comparisons in SOVAT allowed for the detection of this hidden pattern. Two queries were involved in this pattern. First query was about the primary clinics' numbers of visits, and consisted of the following dimensions; Facilities (primary clinics as sub-dimension), Geography (census tracts as sub-dimension), Years, and Visits from the Measures dimension. Second query was about primary clinics' number of professionals, and consisted of the following dimensions; Facilities (primary clinics as sub-dimension), Geography (census tracts as sub-dimension), Years, and Professionals per 100,000 Populations from the Measures dimension. As can be seen from the figures, charting area facilitated the detection of this pattern by giving detailed results. It shows that with largely increasing numbers of visits tend to have small or no increase in their ratios of professionals per populations.

2- *Top 10 census tracts with diseases tend to have smaller numbers of primary clinics health professionals ratios.*

This pattern suggests that the distribution of health professionals is not in accordance with the distribution of the disease cases (the reader is referred to the figure 4 and dimension Exploration 4 figures in the results). This fact points out an improper utilization of the current health resources. Not to mention the deficiency of the health resources in the first place. This means that larger numbers of diseases cases are sharing the services of same limited health professionals, while fewer diseases cases are benefiting from more health professionals. There must be a redistribution take place to allocate the larger numbers of professionals in accordance with the larger numbers of diseases cases.

This pattern was a result of comparing maps and charts of diseases queries with the health professionals' query. The diseases' queries consisted of the following dimensions; diseases (diabetes, dengue fever, hypertension, and asthma as sub-dimensions), Geography (census tracts as sub-dimension), Years, and Measures dimension. The professionals' query consists of the following dimension; Facilities (primary clinics as sub-dimension), Geography (census tracts as sub-dimension), Years, and Professionals per 100,000 Populations from the

Measures dimension. As can be seen in the figure, it can easily detected from the charting area that the top ten census tracts with disease cases tend to have lower numbers of primary clinics' professionals.

3- *The ratio of health professionals / 100,000 pop tend to be smaller in census tracts with high population and/or pop density*.

This pattern is counterintuitive as the ratio should be larger in census tracts with larger populations or populations' densities to meet the demand (the reader is referred to the figures 8 and 10 in the results). It means that fewer health professionals are available to larger populations and vice versa. Such a trend causes more demand pressure on the professionals which could lead to providing medical care with lesser quality. Census tracts with larger populations and larger densities need more attention from the decision makers in terms of recruiting health professionals. The Saudi planning standards clearly indicate that there should be one physician serving 2000 population (50 physicians per 100,000 populations). In some census tracts with high density the ratio of professionals is smaller. On the other hand, in census tracts with lower densities like Hamra, the ratio is large.

This pattern was a result of 2 comparisons between three queries. The first comparison was between the number of health professional and populations of each census tract. The second comparison was between the number of health professionals and the populations' densities in each census tract. Health professionals' query consisted of the following dimensions; Geography (census tracts as sub-dimension), Years, and Total Professionals per 100,000 Populations from the Measures dimension. The populations' query consisted of the following dimensions; Populations, Geography (census tracts as sub-dimension), Years. And the populations' densities query consisted of the following dimensions; Geography (census tracts as sub-dimension), Years, and Populations Density from the Measures dimension. It can be easily detected from the charting area that census tracts with large populations of populations' densities tend to have lesser numbers of professionals.

4- *The ratio of female medicine / 100,000 female populations tend to be smaller in census tracts with large female populations.*

This pattern suggests that the ratio of family medicine per female populations tend to be smaller in census tracts with larger female populations (the reader is referred to figure 25). In other words, the larger the female population the smaller the number of family medicine serving them is. For example, Safa census tract has the largest female population with a small ratio of family medicine. On the other hand, Ubhur census tract has a small female population with a large family medicine ratio. This adds more challenge to the current situation as there is already a serious deficiency in the numbers of family medicine. In addition, the available family medicine professionals are improperly distributed across the city. Some parts of the city, like in the middle part, have never had any family medicine in their primary clinics during the years 2006 – 2010.

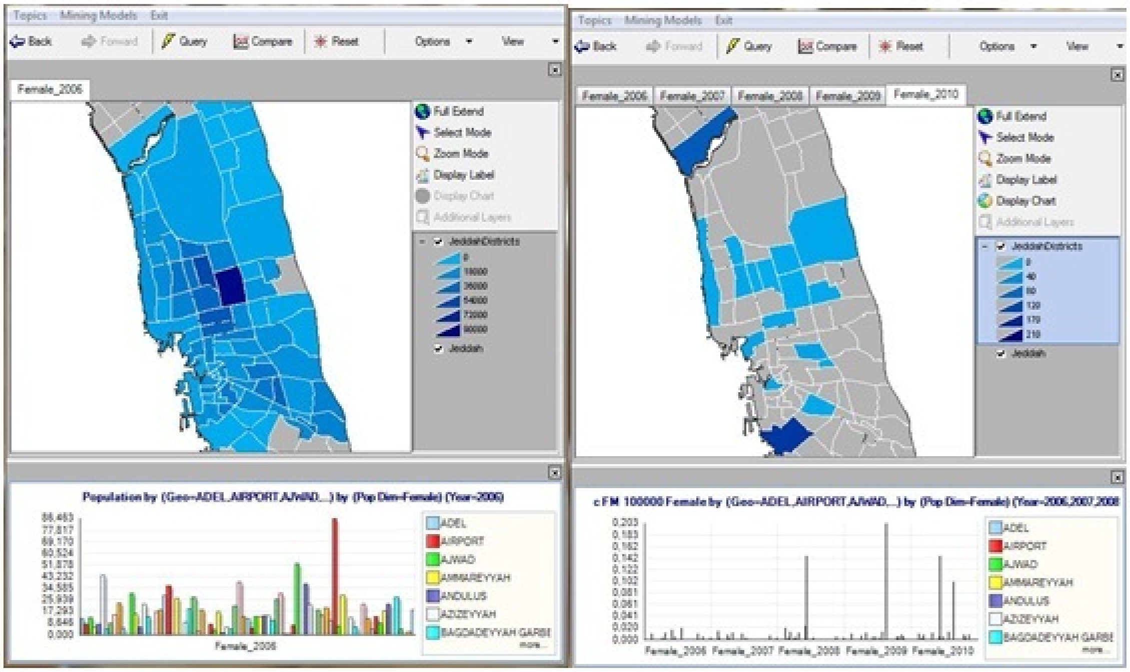

Figure 25. Female Population (Right) and Family Medicine Ratio (Left)

This pattern resulted from comparing numbers of family medicine with the female populations in each census tract. Two queries have been performed. First query consisted of the following dimensions; Facilities (primary clinics as sub-dimension), Professionals (family medicine as sub-dimension, Populations (female as sub-dimension), Geography (census tracts as sub-dimension), Years and Measures. Second query consisted of the following dimension; Populations (female as sub-dimension), Geography (census tracts as sub-dimension), Years and Measures. It can be detected from the maps and charting area that ratio of family medicine per females tend to be smaller in census tracts with larger female populations.

5- *The ratio of beds / 1000 pop tend to be little or zero in census tracts with high population density.*

This pattern suggests that the ratio of hospital beds per 1000 populations tend to be small or zero in census tracts with most populations concentrations (the reader is referred to the figures 13 and

8 in the results). This means that beds are not allocated in accordance with the populations' density. In fact, only 4 out of the top 10 high density census tracts have hospital beds services. On the other hand, none of the bottom 10 census tracts have hospital beds services. This fact poses a huge improper beds' distribution problem. The distribution should be according to Saudi planning standards which specify 2.5 beds per 1000 populations. Nevertheless, the largest two hospitals, KFGH and Musaadiyya are located in the same census tract, which explains the beds distribution challenge. The most benefiting census tracts have an extremely high ratio while other census tracts are completely excluded.

This pattern resulted from comparing the maps of 2 queries, hospital beds per populations' ratio and populations' densities. First query consisted of the following dimensions; Geography (census tracts as sub-dimension), Years and beds per populations' ratio from the Measures dimension. The second query consisted of the following dimensions; Geography (census tracts as sub-dimension), Years, and Populations Density from the Measures dimension. It can be detected from the charts that most of the high populations' densities census tracts tend to have low or zero beds available.

5.7 IMPLEMENTING SOVAT REQUIREMENTS

Utilizing SOVAT as a research tool would yield for benefits due to its ease of use and multidimensional capabilities. However, there are some requirements that need to be met in order to successfully apply the SOVAT tool by Jeddah Health Affairs. Some of these requirements are technical as they are related to the utilization of the tool itself and others are organizational as they are related to the official health system in Saudi Arabia, Jeddah city. They complement each other in preparing the environment for the seamless utilization of SOVAT. These requirements include Training, Updated Data, and Official Approval.

Starting with the training part, there are two aspects when applying SOVAT, data preparations and actual use in numerical-spatial problem solving. It has been found by Alshehri and Drew (2010) that lack of qualified personnel is one of the major barriers in adopting technology in Saudi Arabia. In addition, Reffat (2006) stated that technical skills are required for implementing technology. Data preparation is a demanding task as it requires experience and sufficient background in some technologies in order to prepare the date and integrate it with SOVAT. Such a task involves preparing the data (in a multidimensional OLAP cube), preparing the maps, and connecting the data cube to the map. These technologies include the necessary tool to build an OLAP cube such as Microsoft SQL Server so the data could be stored in a multidimensional approach as aforementioned (Microsoft, 2008a). Furthermore, GIS tool like ArcGIS may also be needed to prepare the maps prior to integration with SOVAT. Finally, connecting the OLAP cube with the map is achieved using XML language.

On the other hand, the training required for the actual use of SOVAT is limited as SOVAT is designed to be a user friendly tool (Scotch, et al., 2008). This aspect of the training part should be accomplished with minimum effort and time. However, it is recommended to combine access with training when adopting new technology (Reffat, 2006). This will lead to the reduction of resistance to change as it was found to be one of the barriers of adopting new technologies (Alshehri and Drew, 2010).

The second requirement is ensuring the availability of updated data from official sources. It is critical to ensure the availability of updated data from their original sources to get the optimum benefit of SOVAT. These data will be from the MOH Directorate of Information and

Statistics in addition to many other sources. For example, populations' data are extremely important as it provides a populations' dimension, and are acquired from the Central Department of Statistics and Information. Unfortunately, one of the barriers of adopting new technologies is the lack of partnership and collaboration between different governmental agencies (Alshehri and Drew, 2010). Such agencies tend to be strict when asked for their data to be shared. Fortunately, "Yesser" is a program designed to establish channels of collaboration and communications among various governmental agencies (YESSER, 2009). Such a program could facilitate and regulate the data exchange process. Thus, communications' channel could be established with other official data sources in order to insure the availability of updated data. Otherwise, results of SOVAT will be based on outdated data which is a limitation that weakens the decision-making process.

Finally, the third requirement is getting the official approval from the MOH as regional health directorates (like Jeddah Health Affairs) don't have complete autonomy as they have to adhere to top officials at the MOH. In fact, getting the official's in charge support is key to successfully adopting new technologies (Alshehri and Drew, 2010). Akbulut (2003) describes top management support as the commitment from the top management to providing a positive environment which encourages electronic information sharing with other agencies. Thus, it will facilitate data requisitions from other sources. In addition, MOH statistics and computer department is under the authority of the assisted deputy minister (WHO, 2006b). Applying the tool at Jeddah Health Affairs requires authorization from the assisted deputy minister. This will ensure applying SOVAT with the updated data available. In fact, without the official approval it is completely impossible to adopt SOVAT as a research tool.

5.8 BENEFITS OF SOVAT

There are some benefits associated with using SOVAT as a research tool that are previously mentioned. However, these benefits have been projected when SOVAT were applied to a case like Jeddah city. Large population, large geographical area, and many diseases are all factors that make Jeddah a unique case. Such characteristics stress the benefit of using a tool as SOVAT when researching as it provide the following benefits:

- Speed and ease of use:
- Numerical-spatial problem solving:
- Better understanding:
- Different possibilities for queries:

The speed and ease of use are features of SOVAT. Tools like SOVAT go beyond GIS applications in terms of speed and easiness (Bernier, et al., 2009). Thus, little training is required for researchers or potential users to enable them to use SOVAT is problem solving as found by Scotch, et al (2007). Many of the top officials the researcher have had met during the data collection phase have medical backgrounds. Those officials are the decision makers at Jeddah Health Affairs. Using SOVAT will make it easier for them to conduct their queries easily and very rapidly instead of having to request assistant from their IT department.

Similarly, performing numerical-spatial queries requires some technical background. Specifically, the spatial part which involves handling maps requires certain skills in dealing with GIS tools like ArcGIS. SOVAT allows for performing such queries with no skills required. Thus, researchers and decision-making officials with no technical background in Jeddah Health Affairs will be able to get answers to their numerical-spatial problem.

The ability of integrating different types of data from different sources into SOVAT gives better understanding of the city. Having different types of data like, populations, diseases, and geographical would be hard to comprehend as they are scattered. However, combining them into one screen and browsing them as themes (dimensions) gives better way to understand them(Rivest, et al., 2005). This leads to better decisions as these decision are built on better-understood situation at hand.

Finally, the ability to view the data in different dimension increases the chances to answer more numerical-spatial problem by allowing researcher to pick any combination of dimensions and query them at once. This will enable researching many different topics and solving various complex questions as long as the updated data are available. In fact, hidden patterns that were discovered during this study resulted from combining different dimensions and observing the resulting maps. Such patterns could not have been revealed without using a tool such as SOVAT.

6.0 CONCLUSION

This study has been conducted as a community health assessment of Jeddah city (public) health resources using a novel numerical-spatial problem solving tool which is SOVAT. This tool has proven to be a fast and efficient method for deeply exploring the data and discovering hard-to-detect relationships between these data elements. Thus, Jeddah health data was explored extensively and results were revealed with minimum steps required to achieve them. Furthermore, additional patterns were discovered that gave to the researcher more in-depth understanding beyond the pre-formulated study dimension Explorations about the health resources situation in Jeddah city. Such a method makes it feasible to answer or formulate any question within the boundaries of the available data. It also facilitates the integration of scattered data and transforms them into coherent scenarios. In fact, endless possibilities of health research could be conducted more efficiently with the proper data available.

In addition, the tool offered a new perspective as it helped interpret the interactive nature of “Access as fit” framework dimensions. Such findings which required statistical analysis were reached by the use of the multidimensionality feature of SOVAT. That was achieved by dividing the explorations of this study according to the framework’s dimensions. Thus, the interaction between those explorations demonstrates the interaction between the framework’s dimensions. For example, in census tracts where there is no primary clinics availability, there was no accessibility as well. Thus, expanding the exploration with additional data allow SOVAT to further interpret the interaction between the Access dimensions.

However, there is another perspective of using SOVAT tool. Despite the speed and ease of use, preparing the data for the purpose of integrating it with SOVAT requires extensive effort and knowledge of other technologies. Researcher needs to be familiar with designing an OLAP cube and querying it. This process requires knowledge of SQL server and MDX language. In addition, researcher might need to use other GIS tool such as ArcGIS should the map needed any necessary modifications prior to the integration with SOVAT. Besides, SOVAT by design doesn't grant the researcher complete control over the map. Specifically, researcher is not able to control the classifications and customizations of the results that appear on the map. For example, when comparing a number of maps, it is more helpful to be able to control the range of classifications of the values. This is done automatically in SOVAT.

Finally, despite some minor disadvantages in the design of SOVAT, It conveys its purpose seamlessly as this study has proven. Scattered data from various sources were explored in an easy and efficient manner. In fact, research data were more sensible when explored with SOVAT. Despite being designed to investigate the public health field, is there any field that such a tool couldn't investigate with the sufficient data available?

From the public health perspective, this is an exploratory study to assess the public health resources of Jeddah city in order to gain a better understanding of the resources and its availability to the public. However, the strength of this study is that it utilizes a novel technology to achieve its purpose. Evidently, such technology has never been utilized in any study in the area of interest.

Conducting this study required large amount of data to be collected from various sources. This process has taken tremendous amount of effort and time as the data are not readily available for research purposes. Unfortunately, the publically available data are generic as they pertain to the city as a whole. Data required for this study are all detailed to the census tract level. Researcher had to go through official channel in order to get approval to acquire the necessary data. This makes the tool a candidate for implementation at Jeddah health affairs as they can meet the entire previously mentioned requirement to employ it. They have the health data and they can establish data channels through the top official to acquire data from other sources. As for individual researchers, it is better to focus on a specific topic rather on the whole city when conducting future work. This allows researchers to deal with specific official source to obtain the required data.

A more comprehensive understanding of the health resources has been gained from this study. Each hospital and primary clinic's capacities have been assessed with scrutiny for a five-year period in order to understand their progression. This gave a clearer picture of how each facility has been providing medical services to the public. Consequently, exact needs of each census tract have been identified. Officials will be able to make decisions on more concrete results rather than depending on scattered and complex data that are uneasy to comprehend.

Going beyond the predefined dimension Explorations in this study, new previously unknown patterns in the health resources have been revealed. This was possible due to the ability to pick any combination of the sub-dimension in the query. It led to the discovery of some hidden patterns or trends in the data that researcher would be unaware about otherwise. Such new discovered patterns could be problems that officials need to give more attention to. In fact, additional information learned about the health resources leads to even better understanding of current status of the resources.

7.0 LIMITATIONS

There are a number of limitations to this study that need to be discussed within the context of the spatial tool of this study and the data elements acquired and used for this study.

Limitation 1: the census data (populations) used in this study was published in 2004. Unfortunately, the next detailed census for Jeddah was not available during the study process. With the continuing populations' growth this is considered a limitation to our study.

Limitation 2: the health data were representative of only five year period. Exploring the data to gain a better understanding would require data for more years in order to better detect any patterns of changes through the years. However, five-year period is sufficient to get a clear idea of changing happening to the public health sector.

Limitation 3: only 4 diseases have been considered when assessing the available medical resources for them. Adding more disease diseases would give a better understanding. There might be some diseases cases that are far less medically served. Thus, it is better to include all the available diseases data. However, the selected disease cases gave a good understanding as their cases in continuous need for medical resources. In addition, the fact that they are spread among the populations' make them better representative of the populations' medical needs.

Limitation 4: Populations' locations are not pin pointed. Rather, they were specified as values to each census tracts. This makes it impossible to calculate the distance between each member of the populations and their primary clinic. Instead, distance between the primary clinics and census tracts' centroids were calculated as a workaround.

8.0 FUTURE STUDIES

It has been proven that SOVAT makes an extremely useful numerical-spatial problem solving tool. The ability to integrate scattered data from various sources and use them in answering different complex queries in an easy approach is strength of this tool. Thus, I believe that this tool could be even more helpful for the MOH in conducting the following:

- *Expanding and advancing the exploration*:

  There are many datasets exist that could be used with such an advance exploration tool like SOVAT. This is due to the fact that the tool itself is novel and yet to be utilized by MOH. Data sets, like mortality data, would highly benefit the MOH in discovering connection between mortality rates and other dimensions of the data. MOH has a wealth of detailed data that could be integrated with SOVAT, thus makes it easier for decision maker to get answers for any complex query. The more data integrated with SOVAT, the more benefits the researcher gets. Unexpected patterns and trends could be discovered that give butter understanding than with using a traditional GIS tool.

- *Focus on specific prominent diseases and assess the spread patterns*:

  Jeddah suffer from some health related problem, like very high rates of some communicable diseases than the rest of the country (MOH, 2009b). SOVAT could be used to investigate diseases such as hepatitis and try to discover the pattern of spread through the years. Also try to establish connection between such a disease and other data dimension that might help facing and understanding the spread causes.

- *Private sector can use SOVAT to determine the best place with high demand*:

  One of the roles of MOH to coordinate and encourage the private sector to take part in providing health services (WHO, 2006a). SOVAT could be adopted by the private sector to conduct their own queries when expansion decisions were to be made. In such cases, they must have access to MOH data as the latter supervise and manage the countries official health data. This will lead to better coordination with the public sector in establishing and distributing health resources across the city efficiently.

APPENDIX A: Sample Data of Manpower in 5 Primary Clinics

Table 5: Sample Data of Manpower in 5 Primary Clinics

Primary Clinic	**General Practitioner**	**Family Medicine**	**Dentist**	**Nurse**	**Midwife**	**Pharmacist**	**Lab Tech**	**Radiology Tech**	**Health Inspector**	**Total**
Marwah	4	1	0	19	0	3	2	0	1	30
Sharq Khat Saree	5	1	3	22	0	4	3	2	3	43
Safa	5	2	3	16	0	3	3	2	4	38
Aziziyyah	4	2	2	15	0	2	3	0	1	29
Faysaliyya	2	0	2	12	0	2	2	1	1	22

APPENDIX B: Sample Data of Visits in 5 Primary Clinics

Table 6: Sample Data of Visits in 5 Primary Clinics

PHC	**Chronicles Clinic**	**Dental Clinic**	**Antenatal Clinic**	**Well-Baby Clinic**	**Emergency**	**Lab**	**Radiology**	**Total**
Marwah	1687	0	173	6800	1494	2741	0	12895
Sharq Khat Saree	862	4842	523	12082	2570	5614	484	26977
Safa	2301	8779	1008	13773	2380	7190	612	36043
Aziziyyah	3173	3000	301	9555	1080	6473	0	23582
Faysaliyya	1330	1417	86	4960	359	2451	0	10603

APPENDIX C: Official Letter from Advisor to Request Data

University of Pittsburgh

School of Health and Rehabilitation Sciences
Department of Health Information Management

Bambang Parmanto, PhD
Associate Professor

6026 Forbes Tower
Pittsburgh, Pennsylvania 15260
412-383-6649
Fax: 412-383-6655
HIM: http://www.him.pitt.edu
SHRS: http://www.shrs.pitt.edu

October 20, 2009

To whom it may concern

As the academic advisor to Faisal Jamalallail, I would like to confirm that Faisal is a doctoral student at the School of Health and Rehabilitation Science, University of Pittsburgh. He is currently writing a dissertation on Spatial and Multidimensional Visualization of Jeddah City Health Resources. His work requires collecting data on the health resources of Jeddah city and integrating these data into SOVAT, a decision support system. I would like to confirm the need for health data of Jeddah city in order to complete the dissertation work.

Please contact me at (412)383-6649 or by email at parmanto@pitt.edu if further information is needed.

Sincerely,

Bambang Parmanto, Ph.D.
Associate Professor
Health Information Management &
Biomedical Informatics

APPENDIX D: Official Letter from Sponsor to Request Data

بسم الله الرحمن الرحيم

سفارة المملكة العربية السعودية
الملحقية الثقافية بالولايات المتحدة الأمريكية

Royal Embassy of Saudi Arabia
Cultural Mission To The U.S.A.

الرقم: ١٩٥١٧ /٣ التاريخ: ٢٠/١٢/١٤٣٠هـ المرفقات: ____

رسالة هاتفيه عاجله

سعادة مدير عام الشؤون الصحية في محافظة جده المحترم

السلام عليكم و رحمة الله و بركاته

افيدكم ان الطالب فيصل جمل الليل احد المبتعثين لتحضير درجة الدكتوراه في مجال ادارة النظم الصحية في الولايات المتحدة الامريكية في جامعة بتسبيرج. و نظرا لحاجته لجمع بعض المعلومات الضرورية المتعلقه في المديريه العامه للشئون الصحيه في محافظة جده والتي هي في مجال تخصصه.

امل من سعادتكم التكرم بالموافقه له على ذلك والايعاز لمن يلزم بتسهيل مهمته و تمكينه من الحصول على المعلومات المطلوبه حسب القائمة المرفقة.

و لسعادتكم خالص تحياتي

مساعد الملحق الثقافي السعودي
في الولايات المتحدة الامريكية للشئون الدراسيه
د. محمد بن عبدالرحمن العمر
12/7/09

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