LUMA-GIS Thesis nr 18

Best Living Neighborhood in the City

A GIS based Multi criteria evaluation of ArRivadh Citv

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Best Living Neighborhoods in the City.

A GIS based Multi-Criteria Evaluation of ArRiyadh City.

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Dedicated to those who have knowledge and Spread it to others

and to my cute Sons, Haroon Nadeem & Salaar Nadeem

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i. Acknowledgments

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iv. Acronyms

Abbreviation	Description
ACSM	American Congress on Surveying and Mapping
ADA	ArRiyadh Development Authority
AHP	Analytical Hierarchy Process
ANGS	Accessible Natural Green space Standards
CAD	Computer-Aided Design
CPR	Cardiopulmonary Resuscitation
DEM	Digital Elevation Model
DSS	Decision Support System
DTM	Digital Terrain Model
EIA	Environmental Impact Analysis
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
GML	Geography Markup Language
HSEB	Higher Secondary Education Board
IT	Information Technology
KML	Keyhole Markup Language
KSA	Kingdom of Saudi Arabia.
MCE	Multi-Criteria Evaluation.
MoH	Ministry of Health.
NSDI	National Spatial Data Infrastructure.
OGC	Open Geospatial Consortium.
POI	Points of Interest.
UN	United Nations.
UTM	Universal Transverse Mercator.
VDC	Village Development Committee.
ATM	Automated Teller Machine

Abstract

ArRiyadh city is one of the fastest growing cities in the world. It hosts almost five million people from different parts of the world and different parts of the country. The city is facing heavy migration pressure therefore the living conditions in the different parts of the city are different. The inhabitants are concerned about their mobility and accessibility to different civic services. Therefore living area selection in the city becomes an important subject because living area affects a person physically, economically and emotionally.

This study illustrates the use of Geographic Information System to assess the accessibility to six basic civic services including health care, educational, emergency response in the form of firefighting & ambulance, public parks and shopping centers from different parts of the city and Multi-Criteria Evaluation framework to aggregate the accessibility of these services to find the best area(s) for living in the city. The study defines the "Best" areas as the areas that have easiest accessibility to all these services.

Service areas for each service have been calculated using road network and these service areas are converted to raster to aggregate them into a single dataset using weighted linear addition method. The single raster is classified into five classes including, best, good, acceptable, bad and worst using the natural breaks classification scheme.

It has been found that this approach of using network based analysis with Multi-Criteria Evaluation is very useful for selecting a neighborhood for living for the residents and for planners this approach provides an opportunity to find the planning gaps and evaluation of the availability of civic services to the citizens.

Key words: Accessibility, Network Analysis, MCE, ArRiyadh, Riyadh

1. Introduction

The developing world is experiencing a rapid urbanization process. For the last few decades the urbanized population of the developing countries has increased from 27 % to 40 %. The United Nations (UN) projects that by 2030 almost 56 % population of the developing world will be urban. Urban areas have become the economic growth engines, and therefore attract people to migrate from the rural areas (Hinrichsen et al, 2002). Cities attract people because they are considered a place where community and social life is possible, and in the words of Thomas Hobbes, without which the life is “nasty, poor and short. Beginning in the 19th century, associated with the Industrial Revolution, streams of people migrated into cities, drawn by jobs and wealth, theoretically leaving poverty behind” (GIS Techniques in physical planning, 2008).

The urbanization process affects the urban environment, puts pressure on infrastructure and civic services. Fortunately, there are many examples of cities which function well and which provide their inhabitants with a satisfactory quality and way of life; where a balance is struck between economic development and retention of a high quality environment; where high levels of participation, neighborhood and community development, a sense of belonging and pride exists (GIS Techniques in Physical planning, 2008).

However there are many cities that are not very well off and they suffer a lot of urban problem such as inner city decay, engendering, deterioration of historic centers, traffic jams, noise and air pollution. Furthermore the cities internally have different quality of living which means that one area of a city may be well off and other could be deprived of better living conditions. Inhabitants normally are concerned about their mobility, their accessibility to the civic services and clean environment. Therefore living areas selection in the city becomes an important subject because it affects a person physically as well as emotionally because one of the biggest commitments anybody makes in his life, both financially and economically is building a house (Raghavendran, 2001). Accessibility has been defined in many ways in the literature. It has been said that accessibility

represents the ease with which activities may be reached from a given location by means of a particular transportation system (Zhu et al, 2005). Penchansky and Thomas (1981) defined the accessibility as “a concept representing the degree of ‘fit’ between the clients and the system”. They proceed to break down access into a series of dimensions-availability, accessibility, accommodation, affordability and acceptability.

Geographic Information System (GIS) has a history of use in urban planning and particularly in evaluation of the accessibility since mid of the last century. Several models of GIS have been developed and used by the researchers in the course of history to model the physical/geographical accessibility of human beings to different facilities. Several researchers have used Euclidean distance, Thiessen polygons and areal distance. Although these methods claim objectivity however these methods just provide a crude measure of accessibility because they do not take into consideration the topographic variations of land or the use of networks of paths or roads (Brabyn et al, 2002). In an urban environment, road network is a fundamental factor that affects the accessibility. The proximity analyses based on Euclidean distance can be used more efficiently in a situation where sufficient information about the topography and land surface is not available. However in urban environment whole transportation is dependent on the road network, traffic density and road conditions. Therefore accessibility measured in terms of proximity does not give true results. Because It might be possible that a service is located just on few meters from a location but to access this service, a long route may be required due to the existence of a highway or another impassable obstacle in-between.

Cost path analyses, calculated from a road network results into real accessibility. This method is less frequently used as compared to Euclidean distance and Thiessen polygons techniques. The most probable reason might by, it involves complex computation and requires sophisticated computing infrastructure. Recent improvements in the IT resources and availability of data make it easier to implement this technique. In cost path analyses a road network which is

referred as a flow network, characterized by its topology and flow characteristics (such as capacity constraints, path choice and link cost functions) is used. Several computation algorithms and software are available for such analysis. Environmental Systems Research Institute's (ESRI) ArcGIS Network Analyst is a powerful extension of ArcGIS family of products that provides network based spatial analyses including routing, travel directions, closest facility and service area analyses. ArcGIS Network Analyst enables users to dynamically model realistic network conditions, speed limits, height restrictions, and traffic conditions at different times of the day (Zamorano et al, 2009). In ArcGIS Network Analyst, accessibility is measured in terms of travel time, distance, or any other impedance on the network. Networks used by ArcGIS Network Analyst are stored as network datasets. A network dataset is created from the feature source or sources that participate in the network. It incorporates an advanced connectivity model that can represent complex scenarios, such as multimodal transportation networks. It also possesses a rich network attribute model that helps to model impedances, restrictions, and hierarchy for the network (ESRI, 2006).

Figure 1.1: A Network Dataset & Analysis Result in ArcGIS

Current study is a manifestation of the use of GIS, cost path analyses, and Multi-Criteria Evaluation (MCE) to evaluate the accessibility to the health care facilities, educational facilities, public parks, shopping malls and emergency response services and then these accessibility results are aggregated to find the best area (s) in the city. The word “best” although does not convey scientific meaning however it refers to the area(s) those have easy access to different services in the city. There could be a number of services that affect the living conditions of human being and their importance varies from person to person therefore it is difficult to incorporate living preferences of each person. However different studies conducted in the field of human geography highlight the importance of these six services more prominently therefore these services are selected in this study as analysis parameters. The main characteristic of this study is that it lays down the foundations to evaluate the planning and living conditions in any city which means that any number of parameters can be included in the analysis depending upon the objectives of the evaluation.

1.1. Study Objectives

The overall aim of this research work is to study the accessibility of the residents of the city to several civic services and availability of basic infrastructures in the neighborhood. Specific objectives of the study include;

- To study spatial distribution and provision of civic services in the capital city.
- To identify the planning gaps in the city based on the availability and unavailability of services.
- To assess the living easiness in the different parts of the city.

2. Literature Review

Efficient planning for the civic services in a community is always a desire of city planners. With the growth of population, rising expectations of the people are increasing this challenge of effective urban planning (Zhu et al, 2005). Many studies have been undertaken all around the globe to assess the spatial distribution of a public services and their accessibility to the people. Most of the previous studies have discussed only a particular factor such as, the accessibility to a hospital, or to a public school. However they are related to this study in the context that this study has taken all such civic services in the analyses and evaluated their accessibility from different neighborhoods of the city. The referred studies can be grouped together according to their relevance of subject.

2.1. Multi-Criteria Analyses

The inspiration of this study has been taken from the work of Raghavendran, (2001). He used a multi-criteria analyses (MCA) approach to prepare a Decision Support System for promotion of residential apartments in a city of India. He used ten factors and ranked them on a scale of ten points. These factors include accessibility to, city center, education, railway, bus terminals and health care services. The analyses also took into consideration the availability of several services such as ground water, metro and sewerage system. The outcome of Raghavendran's work is a DSS which enables the buyers and the sellers to make a quick and optimum decision in selection of a site for home. The DSS is a very important tool because one of the biggest commitments anybody will make in one's life, both financially and emotionally is buying a house (Raghavendran, 2001).

A similar approach has been adopted by Zhu et al, (2005). They used MCA approach to analyze the accessibility to different factors for housing development. They interviewed around five hundred residents and summarized their response to create average score of each factor and its rank. Based on the resulted list of housing accessibility criteria, a decision model was built using a

multi-criteria analysis tool JavaAHP. The research resulted into a methodology for using a GIS framework to determine the overall attractiveness of an area for housing development from a demand-side perspective (Zhu et al, 2005).

2.2. Health Care Services

A considerable literature is available to assess the availability of health care services in different part of the world. The literature on service provision is grouped into two broader groups, the mapping and modeling of the service accessibility and its utilization (Kalogirou et al, 2006). An unlimited number of research works can be found related to these two areas of service provision in the health care facilities however this literature review will focus only on some recent studies that have utilized GIS to model the accessibility and not the utilization of the services.

Kalogirou et al, (2006) modeled accessibility to the Irish acute hospitals in a GIS framework. They performed this study in response to “Hanly” report that was prepared by the Irish government to reclassify the major, general and local hospitals. They applied a weighted approach to produce a measure of accessibility based on travel time, hospital size and population. They applied this measure to produce different scenarios to understand the impact of “Hanly” report. The study identified that the population in the central and western parts of the country are most vulnerable, while the impacts of a full roll-out of “Hanly” suggests additional potential impacts on some suburban hospitals in the Greater Dublin area.

Integration of geographically referenced data from different agencies concerned with the health care enables researchers to visualize the trends over time and space. The recent development in web based GIS systems enables the integration of spatial data in real time (Higgs, 2004). These web based technologies have also been used in health sector in the Kingdom of Saudi Arabia. King Abdul Aziz university hospital and King Faisal Specialist hospital has developed Saudi national diabetes registry. The registry is designed with the

goal to provide information on the extent and diabetes types, complication and treatment in the Kingdom (Subhani, 2009). The registry is a web based GIS system that provides information about the patients and their geographic location.

Together with cancer and myocardial infarction, Stroke is among the three greatest causes of death in Japan (Ohta et. al, 2007). These researchers used the Analytical Hierarchy Process (AHP) and GIS to improve the geographical accessibility to the neurosurgical hospitals in Japan for the elderly people. They developed several alternative site plans for a new neurosurgical hospital in city of Sapporo. GIS was inputted with hospitals, population data, routes, and the numerical information for AHP. Pair wise comparison was conducted for finding alternatives which resulted weights for four criteria: 0.674 for availability of hospital beds; 0.169 for the maximum road distance of the shortest routes; 0.101 for the elderly population within a 3-km radius; and 0.056 for the median road distance of the shortest routes. A pair wise comparison is a mathematical method of comparing alternatives with each other. In this method each candidate (alternative) is compared head-to-head (one-on-one) with each other and a score is assigned to each candidate based on number of wining matchups. The number of possible matchups depends on the number of candidates and is calculated by the formula *"N (N-1) / 2"* where N is the number of alternatives (Bowen, 1998). This research concluded that the integration of GIS with AHP is a powerful method for analyzing the accessibility and road traffic conditions for better service provisions.

Lin. and Allan (2002) found that overall hospitalization in British Columbia Canada is inversely related to the distance to the hospital. This research was focused to identify the effect of travel distance on total and on avoidable hospitalization in three regions in British Columbia, Canada. The distance to hospital is conceptualized in geographic and socioeconomic context from the care seeker's perspective. The researchers geocoded the hospital locations and patient locations to determine travel distance for each hospitalization. They

generated several geographic barriers such as steep slope, mountain crossing and linked the patient locations to the socioeconomic variables. The research has been motivated by the facts reported by Health Canada (2000) and the work of Aday and Anderson (1974) which showed different dimensions and barriers in accessibility of health care services and the travel distance or physical barrier is the one of them.

Geographical accessibility is but one of many dimensions in the accessibility of healthcare (Other dimensions of accessibility, identified by the World Health Organization are financial, cultural and functional. To evaluate the geographic accessibility using GIS several models are used including Euclidian distance, Thiessen polygons and cost path Analyses (Brabyn et al, 2002). These researchers used cost path analyses to determine the minimum travel time and distance to the closest hospital via a road network. The analysis was applied to 38,000 census enumeration district centers in New Zealand allowing geographical access to be linked to local populations. They calculated average time and distance statistics for local populations by modeling the total travel of a population. The study revealed that the northern and southern parts of New Zealand have high average travel times to hospital services.

2.3. Education Services

GIS has also been used very effectively in the education sectors. A lot of research work is available related to the education services, planning, mapping, utilizations and accessibly analyses. Higher Secondary Education Board (HSEB) Nepal takes GIS as a tool for Educational Decision Support System to meet a challenge of information management of around half million students and around two thousands schools in Nepal. The digital mapping of educational institutions along with the village development committee (VDC) boundary, road access, river and major settlement provides the ground reality in terms of spatial and social coverage (Banskota, 2009). HSEB Nepal used GIS to map the location of higher secondary school and analyze the accessibility of feeder schools in the periphery of these higher secondary schools. Because cycling continues to be a

transportation option for many students, assessing existing bikeway networks can be an important first step towards making schools more accessible (Inouye et al, 2008). This is the motive of this research work. The researchers evaluated factors relating to bike way infrastructure around schools for a case study of three middle schools in Washoe County, Nevada using GIS framework. In addition to the absolute length of bikeways, other factors for bicycle use included connections of bikeways to the schools and ratios between roadways, bikeways, and student capacity of a school. The research concluded that an accessible school balances all forms of transportation with the community's demographics, geography, and built environment. Such studies help to understand one chapter of the complex story about how students are transported to school. In Riyadh city most of the students travel in the private cars, and majority of expatriates students travel in the school vans and buses.

2.4. Other Services

Besides the above described research works that emphasize on one or other specific service, I have also gone through some other research works that have direct or indirect relation with this research work. One of such works is carried out by, Alexis et al, 2008 in UK. They used GIS to evaluate the accessibility to the green spaces in Leicester city to different ethnic and religious groups. They used the network analyses to compare the green space access by different religious groups with bench mark standards for provision of green spaces in United Kingdom.

3. Study Area

3.1. History

ArRiyadh, the capital of Kingdom of Saudi Arabia is the plural of the Arabic word 'Rawdah', which means 'Garden' or 'Meadow'. The name has been derived from the nature of the low location where flood water collects, and green grasses cover the soil with fragrance of roses. The city name comes from here. The city has risen on the ruins of Hajar Al Yamamah ancient City (ArRiyadh City Website, March, 2010).

3.2. Geography

The city is in the interior of the Kingdom of Saudi Arabia, 900 Km from Jeddah city on the Red Sea and 400 Km from Dammam city on the Arabian Gulf. Along the road to Jeddah towards west of the city at about 100 miles lies the impressive Tuwaiq escarpment- brittle sandstone cliffs rising 60 to 150 meters for about 50 Km. In the south of the city at about 50 miles lies an extensive irrigated area. From east, the city is surrounded by greatest desert of the Middle East Rub Al Khali (the Empty Quarter) (The Saudi Network, 2010).

The city lies between 24° to 25° North and 46° to 47° east on the globe. The environmental protection area that is administered by the ArRiyadh Development Authority (ADA) consists of 5000 square kilometers with almost 600,000 land parcels. The city contains more than 100 administrative neighborhoods (districts), which are called “Hara” or “Hayy” in Arabic. These districts are planned to have their civic centers with all basic services such as medical clinic, school and post office etc.

From north to south along the west side of the city, Wadi Hanifa flows. This is a natural valley which is a great source of natural landscape of the city.

Figure 3.1: Study Area Location on the globe

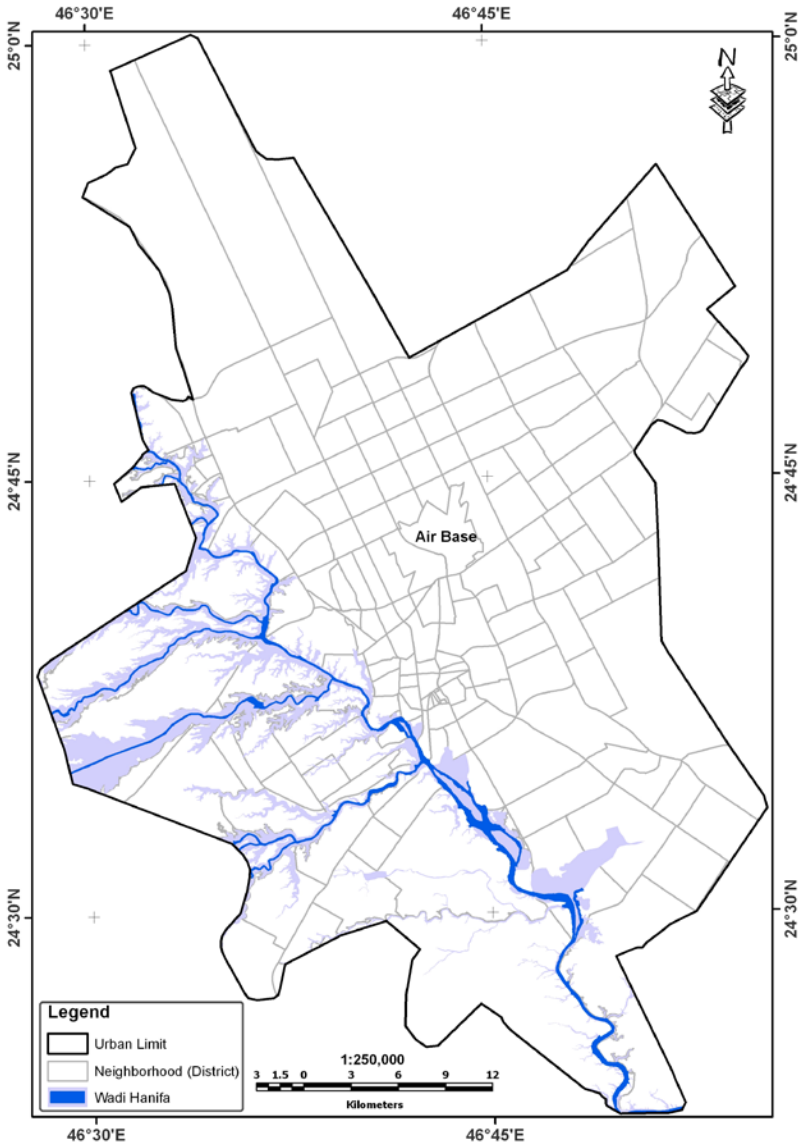

Figure 3.1a: ArRiyadh City (Study Area)

3.3. City Growth

The city is not only a fastest growing city of the Kingdom of Saudi Arabia but is also an economical and cultural hub in the Middle East region. There are several points of interest (Land Marks) in the city which have historical or cultural value. Some of the major land marks are Kingdom Tower that is the tallest building in the kingdom, Faisalia Tower, Muraba Palace which is the Royal palace of founder of Saudi Arabia King Abdul Aziz, Masmak Palace, Salam Park and Historical Dareaya.

The city is expanding its boundaries in such a rapid speed that it is considered one of the fastest growing cities in the world, distributed over a large geographic area equal to the size of greater London (ADA, 2005). There are several reasons for city's expansion, including cultural, planning and financial. Culturally people like to live in villas and isolated, and this behaviors is supported by the low transportation cost having very cheap oil availability. From planning point of view, the city has been planned in a grid design and a lot of empty land has been designated for public services in each neighborhood. ADA monitors the city's physical boundary every ten years. Figure 3.2 shows the city's growth from the year 1910 to the year 2000, which is based on the real historical data available in the ADA data repository. For the year 2010, the results have not been yet published.

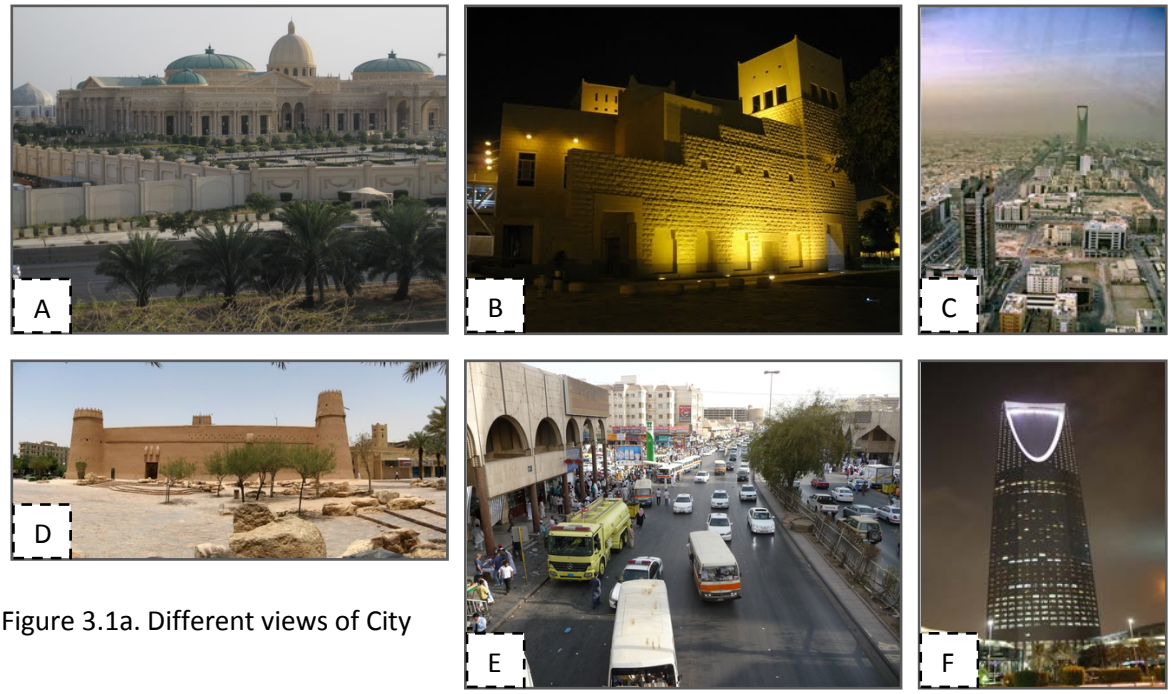

Figure 3.1a. Different views of City

A. Al-Yamama Palace (King's Office)
B. Murab'a Palace (Royal Palace of the founder of KSA)
C. A view of city's central area. View from South towards North.
D. Masmak fortress (Historical fortress, office of governor before current ruling family).
E. Downtown area of the city (Batha Market).
F. Kingdom Tower (tallest building in Saudi Arabia, 2011).

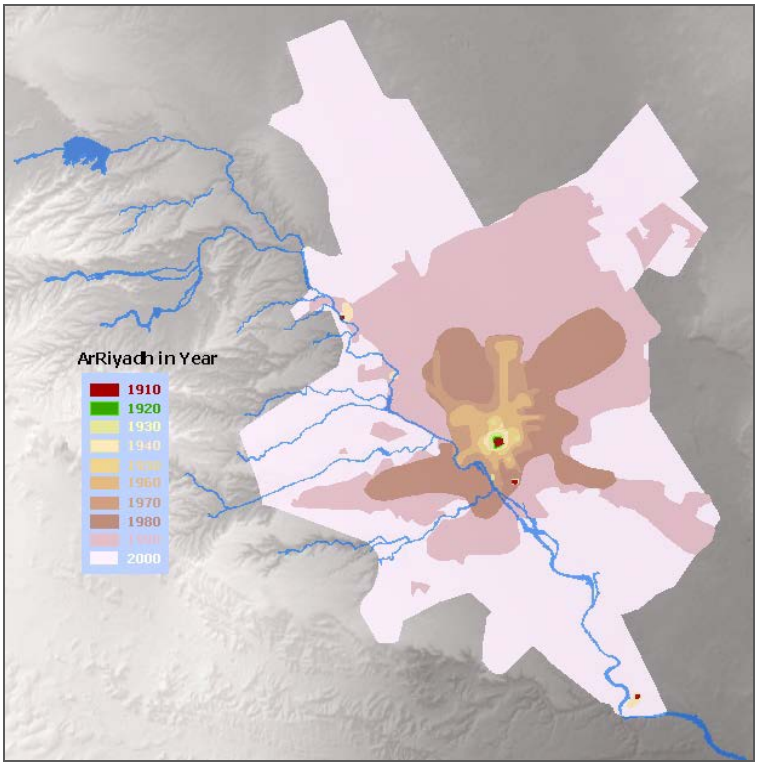

Figure 3.2: Riyadh Growth from year 1910 - 2000

3.4. Population

Population of the city has risen steadily at a rate of 4.2% per year, during the period 1990 to 2004. In the early 1950s the population of the City was not more than 100,000, mostly of common heritage and following a pattern of life characterized by unified activities, but it now accommodates over 4.6 million people from more than 50 different cultures, languages and countries (ADA, 2004). The increase in population has been responsible for the growth of other sectors that seek to meet people's needs. From an annual increase of 8% in the mid-20th century, since the 1980s the growth has doubled to 16%, with a consequent change to the way of life. According to a population survey in year 2007, the population of ArRiyadh City stood at 4.6 million compared with only 3.1 million in 2006. The migration rate towards the city has been reported 120% as compared to previous years. (ArRiyadh Urban Indicators, 2010). Young people make up the majority of the ArRiyadh City population. Those below 15 years of age constitutes about 34% of the total, as shown in figure 3.3, thus the base of the pyramid is wide due to the growing number of youth.

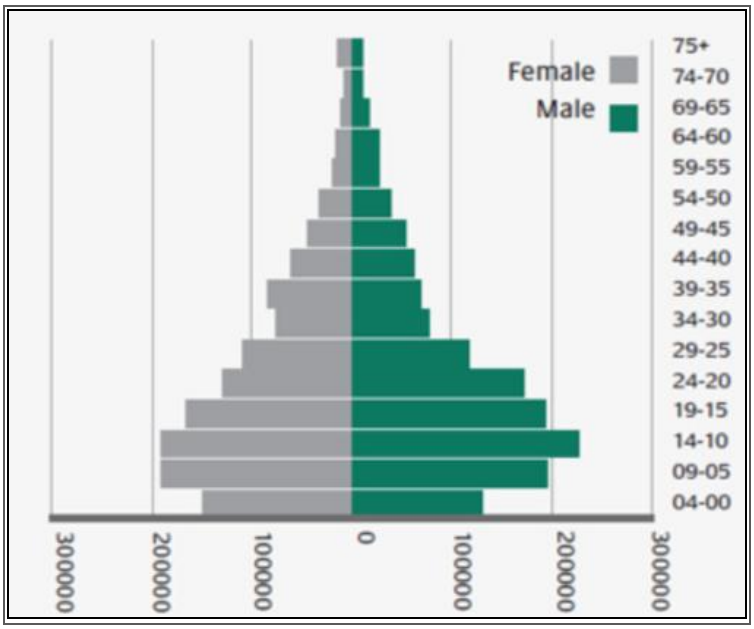

Figure 3.3: Population pyramid in the city of Riyadh (Census 2007)

3.5. Climate

The climate of the city is marked by extremes of temperature with low humidity throughout the year, particularly in the summer season. In summer, highest average temperature ranges between 40°C - 45°C. Humidity ranges from 10% to 13%. In winter it is cold, with the highest temperature ranging between 20°C and 28°C, and the lowest between 8°C and 14°C (ArRiyadh city Website, March 2010)

4. Methodology

The methodology of this research work is based on the accessibility analyses of different services and then the aggregation of these accessibility results to find the best area (s) in the city. Although the term “best” does not convey scientific meaning being a qualitative term that varies from person to person, however in this research the "best" is used for the areas of the city that have better living conditions than others in the context of accessibility/availability of certain civic services. There could be a number of services that affect the living conditions of human being and their importance varies from person to person. However the availability of some services such as health care, quick emergency responses and educational services are more important for every one. Therefore only services that are most commonly important to everyone in daily life are included in this research work. Another reason for keeping the number of services limited is the non-availability of primary data about people's choices about the services. The other factors that also affect a person's choice to select an area for living in a multi-cultural metropolitan city may include ethnic distribution, air quality, noise and traffic density. A point should be noted that this study may provide a methodology to the urban planners and to the researchers for evaluating the living conditions in different neighborhoods of the city. The planners and researchers can make the analysis more complex by including as many parameters as they want, however this study has a limited time and limited scope. Therefore this research work will highlights the neighborhoods in the Riyadh city that have better accessibility to the following services and those areas are referred as the "best" areas in the city.

a) Health Care Services
b) Educational Services
c) Emergency Response Services (includes fire fighting & ambulance)
d) Shopping Malls
e) Public Parks

4.1. Data Preparation

All dataset used in this research work is a courtesy of ArRiyadh Development Authority (ADA). ADA is responsible for the development of the city therefore it maintains the most accurate and up-to-date base map for the city. ADA base map consists of several data layers related to the city cadastral, environmental and physical settings. The base map also includes the land use, land parcels and the land marks of the city. Recently (end of 2009) ADA has updated the land use and land marks (point of interests) datasets. The land use data has been updated through field surveys, satellite images and Riyadh municipality's permit database. All the land marks have been collected through a field survey. In the

survey not only the locations of a feature is collected but some other related information has also been collected, for example if a collected feature is an ATM then its type such as drive trough, in room or inside a bank branch has also been recorded. Field collected data then has been converted to Geodatabase feature class. A land use description table has been created. Table 4.1 represents a subset of these land use codes.

Table 4.1: A subset of land use codes.

ID	Land use Code	Land use Description
1	1110	RESIDENCE
2	1160	IMAM/MOATHEN QUARTERS IN MOSQUES
3	1190	OTHER TYPES OF RESIDENTIAL DWELLINGS
4	1231	NURSES DORMITORIES
5	1232	COLLEGE DORMITORIES – MEN
6	1233	COLLEGE DORMITORIES – WOMEN
7	1234	POLICE DORMITORIES
8	1235	MILITARY DORMITORIES
9	1239	OTHER DORMITORIES
10	1241	ORPHANAGES, MALE
11	1242	ORPHANAGES, FEMALE
12	1290	OTHER GROUP LIVING QUARTERS
13	1300	RESIDENTIAL HOTELS
14	6722	FIRE STATIONS
15	1412	TRAILERS
16	6852	FEMALE COLLEGE AND UNIVERSITY SITES
17	6832	FEMALE INTERMEDIATE GOVERNMENT SCHOOLS
18	6834	FEMALE INTERMEDIATE PRIVATE SCHOOLS
19	6822	FEMALE PRIMARY GOVERNMENT SCHOOLS
20	6824	FEMALE PRIMARY PRIVATE SCHOOLS

Using the land use codes given in table 4.1, all the services that are used in this study have been extracted from Points of Interest (POIs) feature class as point locations and are verified with land use dataset. An ArcGIS personal Geodatabase has been created.

The study evaluates the living condition in a neighborhood; therefore neighborhood boundaries feature class has also been extracted into personal Geodatabase from ADA's enterprise Geodatabase. This layer has population statistics for each neighborhood and it also includes the neighborhoods those are not yet populated, they only exist as planned, therefore such neighborhood where the human population is zero have been excluded from the feature class.

ADA's enterprise Geodatabase contains another layer that defines the urban areas of the city. This layer has also been used to filter the unwanted neighborhoods, which means that all the neighborhoods inside this boundary have been considered in the research work.

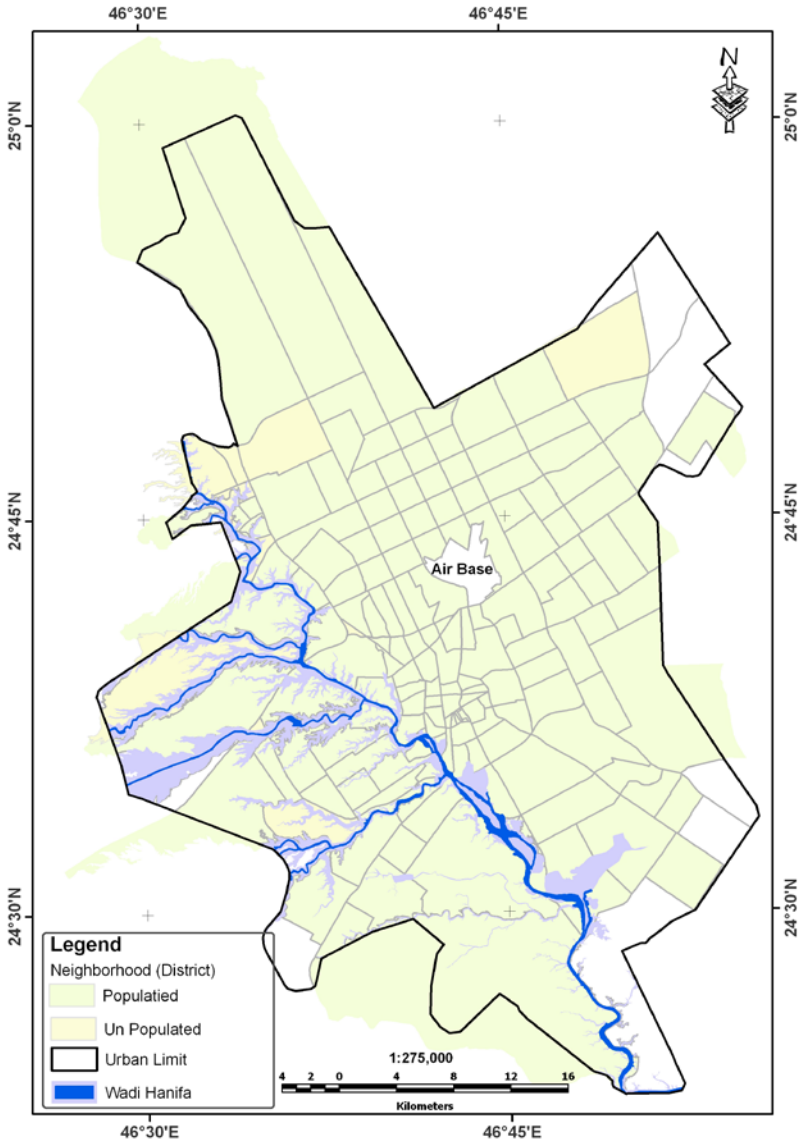

Figure 4.1: Neighborhood boundaries in Riyadh City

4.1.1. Road Network

In GIS environment linear features such as roads and streets are stored as line features. In arc-node topology data models, a node is created at every point where two lines intersect each other. This data model is not smart enough to take into consideration traffic flow parameters and other restrictions such as under passes and flyovers.

ESRI has created another data model (Zeiler, 2005) that is called Network data model. In this data model, road network is represented as a network data set. A network dataset is created from the feature source or sources that participate in the network. There are three types of network sources that participate in the creation of a network dataset: edge, junction, and turn feature sources. A line feature class represents the edge feature sources. Point feature class creates the junction features in the network dataset and Turn feature classes participate as turn feature sources in a network. A turn feature source explicitly models a subset of possible transitions between edge elements during navigation (ArcGIS desktop help, v9.3). The network data model incorporates advanced connectivity model that can represent complex scenarios, such as multimodal transportation networks. It also possesses a rich network attribute model that helps model impedances, restrictions, and hierarchy for the network (ESRI, 2006). Each street line segment between intersections contains attribute information such as road type, distance and travel speeds that are used to perform the network based analyses.

ArRiyadh development Authority has created a navigable map for the city. On screen digitization of high resolution satellite images was used to digitize the streets. Street center line data which was derived from aerial photos was used as reference. The street network data set contains navigable information as well as the name of the streets in English and Arabic. ADA's transportation department contributed in this navigable data development by providing roads design speeds and traffic statistics. The transportation department records the statistics of the traffic volume on main roads of the city on different location and on different times of the day and on different days of the week. Such information is utilized by the traffic planners and road designers to understand the traffic dynamics in the city to cope with the increasing demands for the infrastructure. This data has been incorporated in calculating an average speed on major roads as the traffic planning department has simulations regarding traffic count and average speed with that number of vehicles on roads.

Network data set that is a pre-requisite of network analyst has been created using Arc Catalog wizard. In this wizard all network parameters such as one-way field, speed field and name fields are identified and analyses rules are described. Figure 4.2 represents a subset of road network in the Riyadh city and table 4.2 shows the attributes of the network dataset.

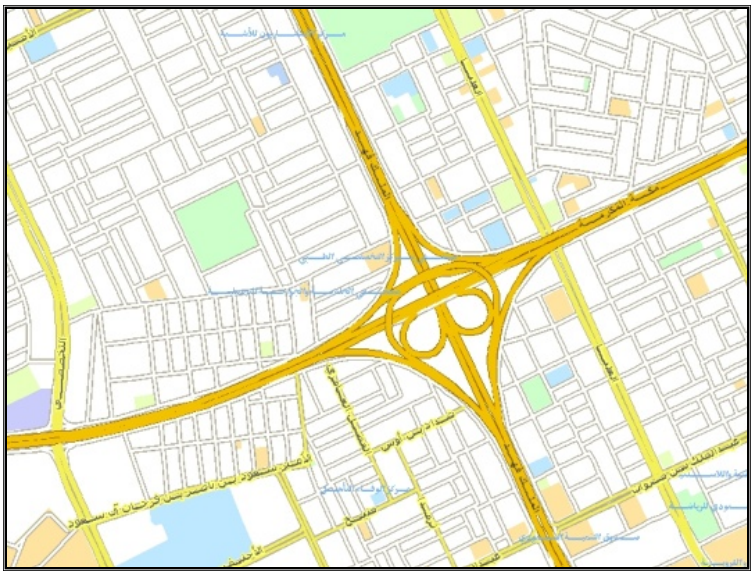

Figure 4.2: A subset of Road Network.

There are some fields that are pre-requisite for creating a network dataset. Although it is possible to create a network dataset without these fields however the results obtained from such network dataset will not be accurate, for example if there is no information about “one-way” then for the network solver algorithm all roads will be traversable in both direction which off course is not possible in reality. Table 4.2 provides the details of mandatory fields and their role in creation of the network dataset.

Table 4.2: Important fields for Network dataset

Filed Name	Explanation
One-way	This field provides the information about the flow direction of traffic. The common values for this field are FT, TF and B. FT means from-to that is digitize direction of the street segment and TF means To-From and B means the road is traversable in both lanes.
Meters	This field represents the length of the road segment in meters. This information is used as impedance (cost) in the length based route analyses such as shortest path between two locations.
SPEED	Represents the drive speed on the segment in kilometers per hour. It is used as cost impedance in time based analyses such as fastest route between two points.
SECONDS	Represents the number of seconds required to travel a line segment. In some cases the time on both side of a road is not equal then two extra fields FT_SECONDS and TF_SECONDS are used.

4.1.2. Hospitals / Clinics

Riyadh city, being the capital enjoys a well distributed network of health care services. Like educational services hospitals are also categorized as

government, private and armed forces hospitals which include army, air force navy and paramilitary forces. Due to their sector specification, these hospitals are not included in this research because these hospitals only entertain patients from their own agency's employees and their families. However in life threatening emergencies such as heart attack these hospitals also provide the services to the civil citizens. Dental hospitals and diagnostic centers (medical laboratories) have also been excluded from the analyses. Table 4.4 provides the land use codes list that has been used to separate the health care services from main feature dataset in ADA enterprise Geodatabase. The city hosts big hospitals with all the modern operation facilities and small clinics for normal disease. There are some specialized hospitals working on certain diseases such as diabetes, cancer and tuberculoses and they have not been included in the analyses.

Some of the main government hospitals in the city include King Fahd Medical City, ArRiyadh Medical Center, the Prince Salman Hospital, Al-Yamamah Hospital, Al-Imam Hospital, the Pediatrics Hospital, the Psychology Health Hospital, Al-Amal Hospital, the TB and Pulmonary Diseases Hospital and the Convalescence Hospital. There are also sixty three (63) Primary Health Care Centers spread throughout the City. These basic health care centers provide free treatment, diagnosis and surgery for citizens. Additionally, there are other medical facilities affiliated with other government agencies (ArRiyadh website, March 2010). Including all governmental, private clinics and hospitals, three hundred and twenty six (326) facilities have been included in this research.

Table 4.3: Medical services land use codes.

ID	Land use code	Description
384	6513	PRIVATE HOSPITALS
388	6517	PRIVATE MEDICAL CLINICS
392	6763	GOVERNMENT HOSPITAL
395	6767	GOVERNMENT MEDICAL AND DENTAL CLINICS

4.1.3. Educational Services

In Saudi Arabia there are separate educational facilities for boys and girls. However recently a new university has been inaugurated by His Royal Highness the King Abdullah bin Abdul-Aziz, which has co-education and is the first ever university of its kind in the country. Furthermore the schools and colleges are grouped as private schools and govt. schools. Almost all nationalities residing in the city of Riyadh has a community school that is administered by the respective embassy and governed by the Saudi Arabian education ministry. In this research work all the schools have been used regardless of their category such as private or government, and gender specification. However certain educational institutes such as poly-technique and special education schools / colleges have been

excluded due to incomplete information about such institutions. Table 4.5 lists the land use codes for the educational services. A total number of two thousands, one hundred and fifty seven (2157) educational facilities are included in the analyses.

Table 4.4: Educational services land use codes.

ID	Land use code	Description
398	6810	PRESCHOOLS AND KINDERGARTENS
399	6821	MALE PRIMARY GOVERNMENT SCHOOLS
400	6822	FEMALE PRIMARY GOVERNMENT SCHOOLS
402	6824	FEMALE PRIMARY PRIVATE SCHOOLS
404	6831	MALE INTERMEDIATE GOVERNMENT SCHOOLS
405	6832	FEMALE INTERMEDIATE GOVERNMENT SCHOOLS
406	6833	MALE INTERMEDIATE PRIVATE SCHOOLS
407	6834	FEMALE INTERMEDIATE PRIVATE SCHOOLS
409	6841	MALE SECONDARY GOVERNMENT SCHOOLS
410	6842	FEMALE SECONDARY GOVERNMENT SCHOOLS
411	6843	MALE SECONDARY PRIVATE SCHOOLS
412	6844	FEMALE SECONDARY PRIVATE SCHOOLS
414	6851	MALE COLLEGE AND UNIVERSITY SITES
415	6852	FEMALE COLLEGE AND UNIVERSITY SITES
416	6853	CO-EDUCATIONAL COLLEGE AND UNIVERSITY SITES
417	6860	RELIGIOUS SCHOOLS

4.1.4. Emergency Response Services

There are two most important emergency services that a person may need any time. These include fire fighting services and ambulance services for a health emergency. The basic mission of these services is to protect life, property and natural resources, therefore these services are very time critical (ESRI , 2007). An as early as possible response of such services may save a lot of human lives and financial loss.

The city of ArRiyadh has two departments that provide these services. The fire protection is carried out by Civil Defense and the ambulance services are provided by Red Crescent Authority. They have their presence in all parts of the city. The city is divided into different response zones based on the time. Almost every hospital and clinic has its own ambulance however they do not take patients from homes or from the accident locations; normally they are used to transport patients from one hospital to another if required, and back home from the hospital. In land use database the emergency services are collected into three categories as civil defense, fire stations and Red Crescent. Table 4.5 lists the land use codes for these services. Twenty (20) Red Crescent facilities and

thirty four (34) fire stations and civil defense location have been included in the analyses.

Table 4.5 emergency services land use codes.

ID	Land use code	Description
366	6723	CIVIL DEFENCE
365	6722	FIRE STATIONS
396	6768	RED CRESCENT

4.1.5. Shopping Malls

A number of departmental stores have been opened in the city during the last few years. These departmental stores are not only a place for people's daily grocery needs but also have become a place for leisure. The big chains include food courts, play lands and cafes under the same roof. The rationale behind using this service as a parameter is that people spend a reasonable time for their daily use shopping, therefore an easy access to such services may save time and hassle which results into an easy livings. Although a number of departmental and mega shopping malls are present in the city, only the shopping malls and mini markets which have grocery and food items including vegetables & fruits are included in this study. The rationale behind this decision is that people spend a reasonable amount of time on groceries as compared to other shopping activities such as house hold appliances or cloths etc. Table 4.6 lists the land use codes for shopping malls. A total number of one hundred and seventy three (173) facilities have been included in the analyses.

Table 4.6: Shopping services land use codes.

ID	Land use code	Description
226	5412	MINI MARKETS
227	5413	SUPERMARKETS

4.1.6. Public Parks

Another public place which plays an important role in the daily life of residents of the city is the public park. Contact with and access to nature is beneficial to the people's quality of life (Alexis et al, 2008).It has been said that if you want to see how healthy a living is in a city, see how much its parks are crowded. Public parks are important environmental facilities: they are a highly valued contact with nature (Kahn, 1999) and offers health benefits (Frumkin, 2001).

The importance of public parks in the city has not been ignored by the planning authorities of Riyadh city. In the modern city, each neighborhood has its own park and green space. The city also hosts few main public parks, one of which

has the biggest artificial lake in the kingdom. A total number of four hundred and forty two (442) parks including neighborhood parks, regional parks and other recreational services have been included in the analyses. Table 4.7 lists the land use codes that have been used to extract the parks from enterprise Geodatabase of ADA.

Table 4.7 Recreational services land use codes.

ID	Land use code	Description
474	7611	REGIONAL PARKS
475	7612	CITY AND DISTRICT PARKS
476	7613	NEIGHBORHOOD PARKS
478	7619	OTHER GENERAL RECREATION PARKS
479	7690	OTHER MISCELLANEOUS PARKS
473	7491	OTHER RECREATIONAL FACILITIES

Table 4.8 summaries the dataset used in the research work.

Dataset Name	Description	Type	Feature
Road Network	Geodatabase feature class	Vector	Polyline, represents streets
Hospitals / Clinics	Geodatabase feature class	Vector	Point, represents hospitals location
Schools	Geodatabase feature class	Vector	Point, represents schools location
Red Crescent / civil Defense stations	Geodatabase feature class	Vector	Point, represents ambulance and fire engine stations location.
Shopping malls	Geodatabase feature class	Vector	Point, represents major shopping malls location
Public parks	Geodatabase feature class	Vector	Point, represents location of public parks
Urban Limit	Geodatabase feature class	Vector	Polygon represents the city limit.
Districts	Geodatabase feature class	Vector	Polygon represents the neighborhood boundaries.

4.2. Criterion Identification

Every person has its own choices and priorities for selecting a place for living. It has therefore become very important to get the first hand information about the people's choice for defining a best place for living. Due to some legal and cultural restrictions, it was not possible for this research to conduct a public survey and

build the real choices of the people living in ArRiyadh city. However a small personal questionnaire was used to collect information from the colleagues in ArRiyadh development Authority office but current study mainly takes reference from the work done by other researchers and scientists in other parts of the world to set the priority ranking of the parameters used.

Raghavendran (2001) conducted a field survey in India to get the choices of people for selecting a place for housing. A ten point scale was used to prioritize different services. The field survey resulted into an equal score for health care and educational services that means that for people a proximity to both of these services is of same importance. The value for these parameters was distance in kilometers from a housing location to the hospitals and schools.

Zhu et al (2005) conducted similar study in Singapore. They interviewed five hundred people and got their priorities for selecting a housing location. They used a questionnaire that was distributed in local shopping centers, to identify the relative importance of accessibility to these services. The interview resulted into a list of eight services that people consider more important for selecting a place for living. These services included public transport, shopping centers, health care banks, schools, community centers, post offices and parks.

Analytical hierarchy Process (AHP) provides a methodology for a multi-criteria analyses and decision making. JavaAHP is a web based software tool that implements AHP to evaluate relative desirability of alternatives (Zhu et al, 2001). The researchers used JavaAHP to build the decision model and they weighted all these services using SMARTER (Edwards et al, 1994) weighting method available in JavaAHP.

Work of Raghavendran (2001) and of Zhu.et al (2005) has been used as a reference to assign the ranking to the services that are used in this study. Furthermore information collected from the colleagues has also been used in ranking process. A five point scale has been created on which one represents the most important and five represents least important.

1= Most important 5 = Least important.

Table 4.9: Priority ranking of the services

No	Facility	Priority Ranking
1	Hospitals & Clinics	1
2	Schools	3
3	Emergency Response Ambulance	2
	Fire Fighting	2
4	Shopping Mall	4
5	Public Parks	5

4.2.1. Parameter Values

The main criterion for the research is the “Travel Time”. Different time intervals have been used to analyze that which areas of city have an easy and closer to the world’s standards (that are discussed in previous and following paragraphs) accessibility to a service. Time is a very critical element in emergency situation and this research work is based on this element. In case of fire emergency for example, the fire growth can expand at a rate of many times its volume per minute. It is very critical to rescue the people and extinguish the fire to minimize the financial and human loss. Regardless of the speed or length of burn time, all fires go through the same stages of growth. There is a stage that makes critical changes in the condition, which is called flashover. It depends on many factors such as type of fuels in the burning area, size of burning area /room and so on. These factors vary; therefore it is not possible to predict when the flashover will occur. The flashover occurs when the room temperature reaches the vicinity of 600° F to 700°F (Kennedy et al, 2004).Normally it may occur less than 4 minutes (Fire knowledge101, August 2010) and beyond 10 minutes of free burning as shown in figure 4.3. A post flashover fire burns much hotter and expands faster. Fire growth occurs exponentially which means that it doubles itself every second of free burn that is allowed resulting into a difficult rescue operation (ESRI, 2007).

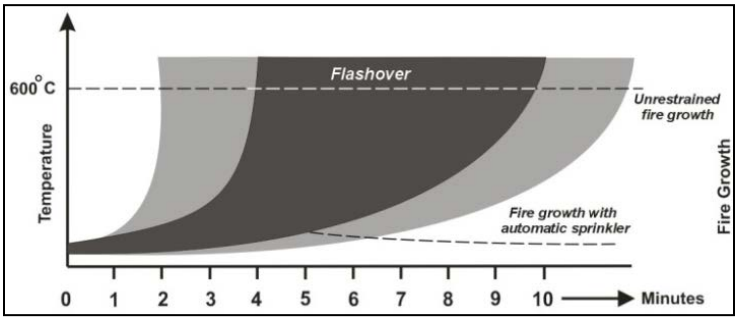

Figure 4.3: Fire growth over Time. (Source: ESRI, 2007)

Therefore a location at which a fire engine can reach before a flashover occurs would be a preferable for a safety point of view for a resident. On the other hand the availability of fire engine within four minutes at every location of the city would be a pre-cautionary measure for the city planners. Howerton (2006) used three time intervals of one minute, three minutes and five minutes for fire stations planning in Dallas, Texas. The current study considers three time intervals for fire emergencies at 3 minutes, 6 minutes and 8 minutes.

The delivery of medical emergency services is also time critical, survival rates for some types of medical emergencies are dependent on rapid response of trained emergency attendant. For example if a person has a heart attack and Cardiopulmonary Resuscitation (CPR) is started within four minutes , the survival chances of the patient are four times greater than a person who did not get CPR until after four minutes (ESRI, 2007). Figure 4.4 shows the survival rate of heart attack victim when CPR is available and figure 4.5 shows the heart attack stages over time when CPR is provided.

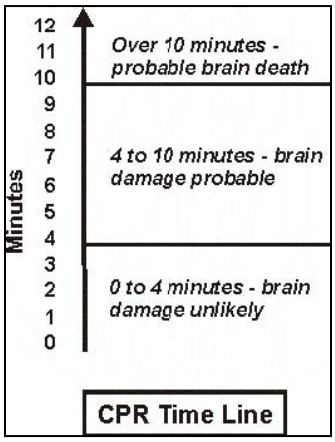

Figure 4.4: Outcomes of heart attack victims Source: ESRI, 2007

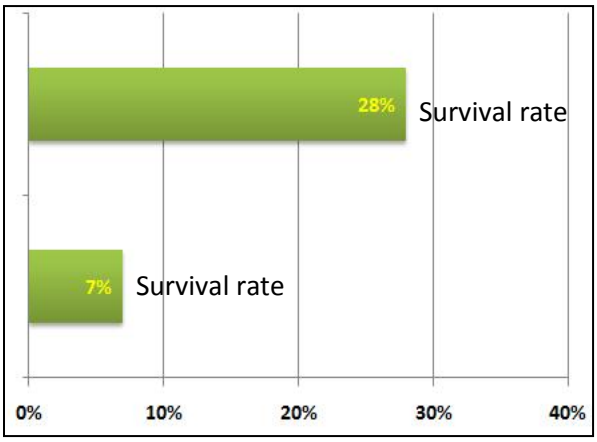

Figure 2.5: Survival rate of heart attack victims. Source: ESRI, 2007

The time between the beginning of the heart attacks and administration of the definitive care proved to have a pronounced effect on survival. If the travel time exceeds 12 minutes, 17 percent of the victims lived long enough to be admitted in the hospital and 6 percent survived to be discharge. With a travel time of 6 minutes or less to the definitive care, 52 percent survival rate has been observed (Mayer, 1979). this study takes travel time intervals of 4 minutes, 8 minutes and 12 minutes to reach a medical facility into consideration.

“Natural England” which is a public body in England and plays a role of government’s advisor on the natural environment

(http://www.naturalengland.org.uk/about_us/default.aspx) provides a set of standards for evaluating the provision of and access to natural places, Accessible Natural Green space Standards (ANGSt) (Alexis et al, 2008). According to these standards “No person should live more than 300m from their nearest area of natural green space of at least 2ha in size”. However for the city of ArRiyadh, there is only one natural feature that can serve as a natural green Space which is “Wadi Hanifa”. This is a natural valley that runs along the city from north to south. Recently ADA has rehabilitated Wadi Hanifa and has created several picnic spots in the valley. It has become a good recreation place for the city’s residents. It is also observed that a notable community goes and sits out in the public parks available in each neighborhood.

In reference to ANGSt standards this study has used a value of 400 meters to have a park regard less of the size. Which means every home in the city must have a public park at 400 meters distance. The rationale behind this distance is that a human being can easily walk this distance within 5 to 10 minutes. Other intervals are 1000 meters and 1500 meters.

Travel time to a school and from school to home is not as critical as the life threatening medical emergencies. It is only the matter of easiness for the children traveling to the school and a person going to pick and drop them. Therefore in most cases a 10 minutes drives is considered an easy access by many people as discussed with colleagues at ADA In the current study travel times of 3 minutes, 5 minutes and 10 minutes have been used. Another rationale for selecting these time intervals is to minimize the computation overheads. There are more than 2000 educational locations and to perform the analyses for longer time intervals could be very difficult for normal computers.

Similarly the accessibility to a shopping mall is also not very critical. In recent years with more opportunities of enjoyments and leisure inside the malls, going for shopping has become fun. Secondly people do not travel to shopping malls daily, it may happen weekly and so on. Therefore the travel time intervals used in the study are 5 minutes, 10 minutes and 15 minutes. Another point that makes the difference in the results of study is lack of complete data set for shopping malls. With the rapid growth of ArRiyadh city, the number of shopping malls in the city is also increasing exponentially. To minimize the bias, that may be created due to incomplete dataset a low ranking has been assigned to this service. Table 4.10 summarizes the parameters and their values.

Table 4.10: Parameter values and weight

No.	Parameter Name	Evaluation Criteria	Intervals			Weight			
			1st	2nd	3rd	1st	2nd	3rd	Total
1	Hospitals	Time (Minutes)	3	6	10	0.1	0.06	0.04	0.20
2	Schools	Time (Minutes)	3	5	10	0.075	0.045	0.03	0.15
3	Ambulance	Time (Minutes)	3	6	8	0.125	0.075	0.05	0.25
4	Fire Fighting	Time (Minutes)	3	6	8	0.125	0.075	0.05	0.25
5	Shopping Malls	Time (Minutes)	5	10	15	0.025	0.015	0.01	0.05
6	Public Parks	Distance (Meters)	400	1000	1500	0.05	0.03	0.02	0.10

4.3. Accessibility Analyses

Accessibility analyses have been performed using ArcGIS desktop network analyst extension. It is a powerful extension that provides network- based spatial analyses including routing, travel directions, closest facility and service area calculation.

In this study service areas calculation analyses has been used. A network service area is a region that encompasses all accessible streets, that is the streets that lie within a specified impedance. Network service area is a polygon (closed area) representing the distance that can be reached from a facility or to the facility in all direction within a given amount of time or length or any other cost value (ArcGIS desktop help, v. 9.3). These polygons can be calculated on different intervals such as one minute, two minutes and so on; in this case ArcGIS network Analyst creates multiple concentric polygons as shown in figure 4.6. In this research work service area have been calculated, based on the parameters and values described in the previous section.

Figure 4.6: Multi-impedance service areas.

After having created network dataset and all facilities have been extracted to a geodatabase, ArcMap (the mapping application in ArcGIS desktop products family) has been used to calculate multi-impendence (the impendence values are described in previous section) service areas for each service separately. The software requires several analyses environment settings to perform the analyses, the important settings that are used in this study have been presented in table 4.11.

Table 4.11: Network analysis settings for services

Facility	Impedance	Default Breaks	Direction	Allow U-Turn	Restriction
Health care	Seconds	180, 360,600	To the Facility	Everywhere	Oneway
Education	Seconds	180,300,600	To the Facility	Everywhere	Oneway
Emergency	Seconds	180,360,480	From the Facility	Everywhere	Oneway
Shopping Malls	Seconds	300,600,900	To the Facility	Everywhere	Oneway
Parks	Meters	400,1000,1500	To the Facility	Everywhere	Oneway

As the output of the network service area is a polygon layer, sometimes polygons around one service overlap with the polygons of the other service, the service area layer properties dialog box allows to define the rules for these overlapping areas as shown in figure 4.7. There are three options available for polygon generations, which are overlapping, non-overlapping and merge by break values.

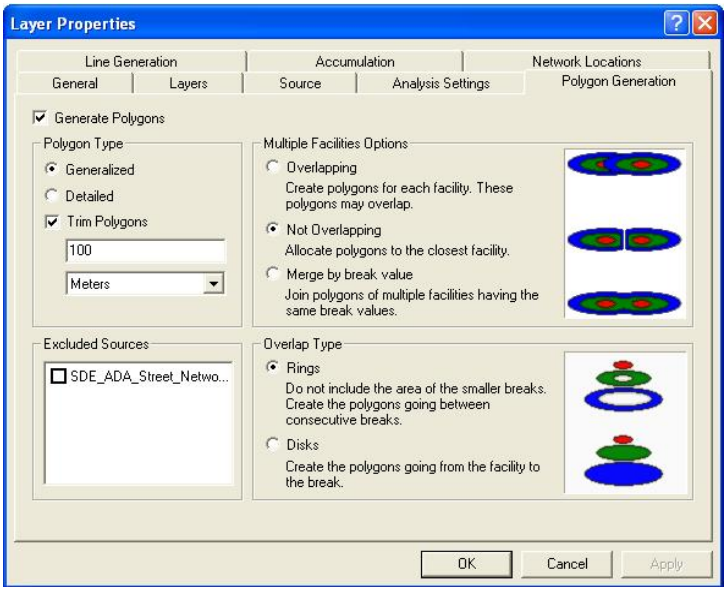

Figure 4.7: polygon generation settings

Overlapping option creates individual polygon per facility per break (ArcGIS help v9.3), which means that the polygons overlap each other. This option is very useful to evaluate the performance of a facility because in this case the output polygons represent the full areas that can be served from facility therefore by combining other factors such as demographic data, the service availability can be estimated.

Non overlapping option creates separate polygon for each facility, instead of having overlapping polygons, the polygons encompass only the area that can be reached from the closest facility. The third option is to merge the polygons based on break values. This option creates one polygon per break. Where ever the polygons from different facilities overlap each other having the same break values they will be merged together. This option is useful for identifying the areas that can be served in a certain break value regardless of the facility for example facility "A" or facility "B".

The third option has been used in this study because the objective of this study is only to identify the areas that can be served in a certain time and it is not necessary that they are served by facility "A" or by facility "B". After displaying the network data set in ArcMap, and having adjusted the analyses environment settings, all services were loaded from the database in the facilities layer of service area, one by one. When facilities are loaded the network analyst searches the network edge within a given tolerance, if a network edge is found then the location is marked as located if not then it displays these locations as not located. Each service has been analyzed and corrected as described in the

following section separately and service areas have been calculated. The distribution of each service has been shown in figure 4.10.

HealthCare Services.

There were total 326 health care locations in this study out of which only 4 were marked as “unlocated”. By overlaying them with urban limit polygon, it was found that all of these 4 locations are located outside the urban limit therefore were excluded from the analysis

Educational Services

There were 2157 locations in the city for education. When these locations loaded to the service area analyses layer, 10 were found as “unlocated” and they were out of the urban limit boundary, these “unlocated” and other locations that were out of the urban limit were excluded from the analysis.

Ambulance Services

There were 20 locations in the city for ambulance services. All these location were located on the network data set. However there was only 1 location that were found out of the urban limit and hence excluded from the analysis.

Fire Fighting Services

There were 34 fire stations and all located on the network dataset and were all inside the urban limit therefore all locations have been included in the analysis.

Shopping Malls

Out of 173 locations only 1 was fond as “unlocated” and 1 was found outside the urban limit, both of these have been excluded from the analysis.

Public Parks

There were 442 public parks locations out of which 3 were “unlocated” and 7 were out of urban limit, therefore 432 parks used in the analysis.

When the analysis was run 2 locations were fund on non-traversable network, which means that they were located on the network however the nearby roads were not allowed to traverse. By visually inspection 1 was found inside the premises of an airbase.

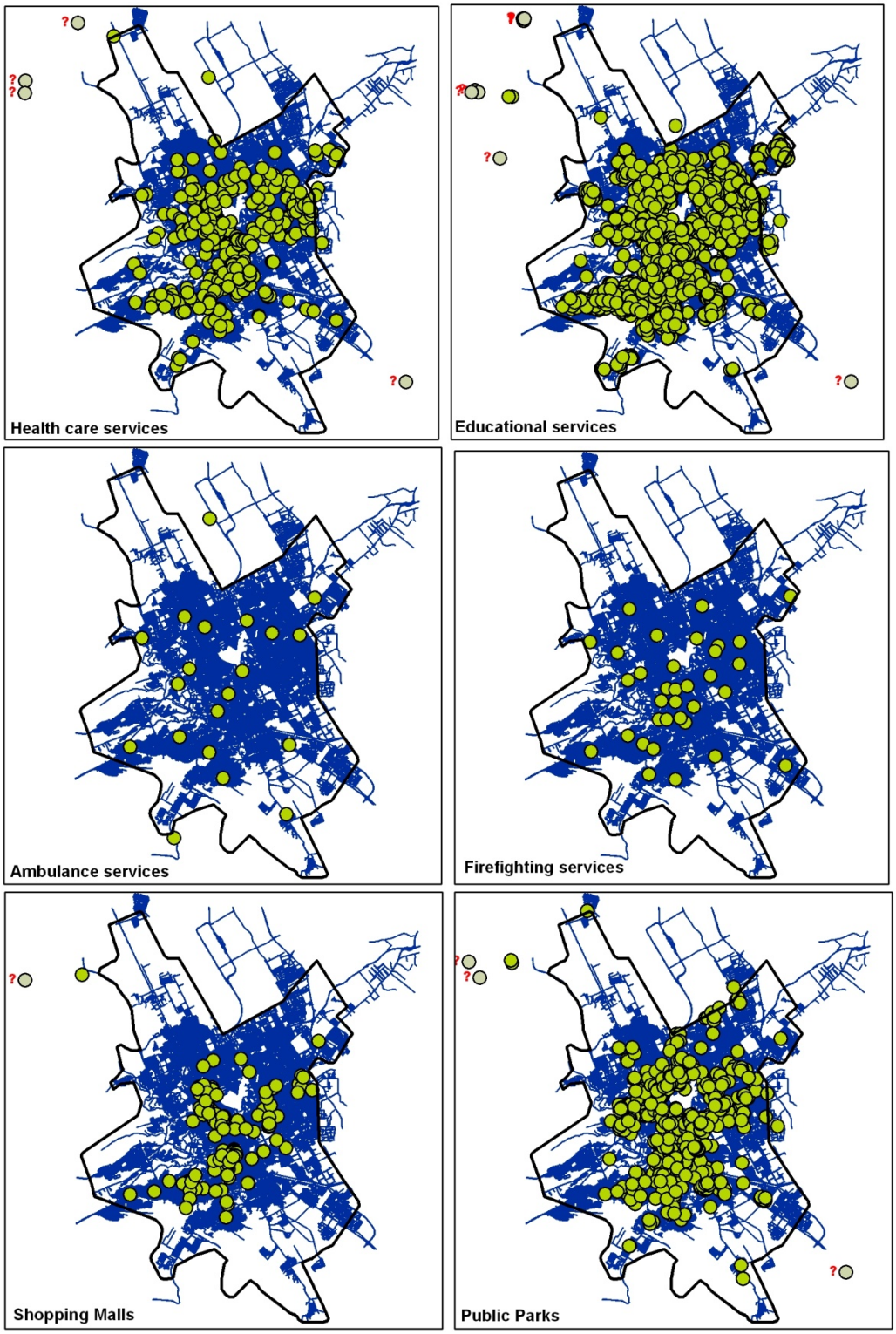

Figure 4.8: Distribution of services.

4.4. Aggregation of Accessibility (Results)

The accessibility map for each service has been created and shown in section 5, using the three time intervals. These maps highlight the quality of each service in the different parts of the city. These maps are useful for the evaluation of each service and the planners can use such maps for re-arrangements of the services in the city so that a maximum number of people can be served.

However current study was focused on to evaluate the neighborhoods of the city in context of all these services therefore all the six services were combined together using multi-criteria evaluation (MCE) method. MCE is a methodology consisting of a body of techniques for evaluating options on individual, often conflicting criteria and combining the separate evaluations into one overall evaluation (Zhu et al, 2005). The combination of several criteria in MCE is done either through Boolean overlay or Weighted Linear Combination (GIS Techniques in physical planning, 2008). In the Boolean overlay, the criterion are converted to logical statements of suitability, which are then combined by means of one or more logical operations such as “AND” and “OR”. In the weighted linear combination each standardized factor is multiplied with a factor weight and then summed. The weight of any factor represents the importance of the factors. This weight can be set either by the interviews of the stakeholders or from the experiences of the other related researches. There are different methods that are used to assign the importance of weight to a factor. The simplest method is to rank every criterion to be included in order of the decision makers’ preference. A scale of rank is normally established for example the most important factor is rank as 1 and the least important rank as 5. The numerical weights are generated by using different mathematical formulae. Another method is called the rating method. In this method the importance of different factors is rated on a scale for example from 1 to 10. Then the overall score of the decision is calculated by the formula;

$$\text{Score} = \sum_{i=1}^{k} Wi * Sij \qquad \text{(Zhu et al, 2005)}$$

Where “k” is the number of criteria

“j” represents the alternative j under consideration

“Wi” is the weight representing the relative importance of criterion i

“Sij” is the score representing the relative attainment of alternative j on criterion I. MCE works on a raster dataset which means a single pixel is assigned a value and then that values are multiplied by a weight and then added to the other

rasters. The output of the network analyst was a vector layer consisting of a polygon for each evaluation interval. All these polygons were converted to raster using ArcGIS Spatial Analyst's "Feature to Raster" function. The output of this step was 18 (6 services and 3 intervals) grids datasets. Weights of each service were identified and then further they were divided for each interval as given in table 4.11. Following formula was used to combine all the 18 raster grids to get the overall accessibility of the services.

0.125 * [ambulance_180] + 0.075 * [ambulance_360] + 0.05 * [ambulance_480] + 0.075 * [education_180] + 0.045 * [education_300] + 0.03 * [education_600] + 0.125 * [fire_180] + 0.075 * [fire_360] + 0.05 * [fire_480] + 0.1 * [health_180] + 0.06 * [health_360] + 0.04 * [health_600] + 0.05 * [parks_400] + 0.03 * [parks_1000] + 0.02 * [parks_1500] + 0.025 * [shopping_300] + 0.015 * [shopping_600] + 0.01 * [shopping_900]

Output of this formula was a raster layer having the values from 0 to 0.5. where the 0 value means that these areas does not have any access to any service within the given intervals for each service and 0.5 value means that these areas can be served by all services within their shortest intervals and these are the areas that the current study denote as the "best" areas.

"Natural breaks (Jenks)" method of data classification in ArcGIS was used to classify this raster into 5 classes. "Natural breaks" is a data classification method that is also called as "Jenks optimization method". It is designed to determine the best arrangements of values into classes. It is achieved by seeking to minimize the each class's average deviation from the class mean, while maximize each class's deviation from the means of other groups. This method was developed by an American cartographer George Jenks in 20th century (Wikipedia, 09/2010). These values are given in table 4.12 and figure 5.7 represents these values as map which is the final output of this study.

Table 4.12: Classification of accessibility raster.

Natural Breaks (Jenks)		Equal Intervals	Accessibility Class
From	To		
0	0.058823529	0.1	Worst
0.058823529	0.170588235	0.2	Bad
0.170588235	0.284313726	0.3	Acceptable
0.284313726	0.38627451	0.4	Good
0.38627451	0.5	0.5	Best

4.5. Zonal statistics

The best areas map that was created by aggregation of all services shows areas by color shades representing different living conditions; however the name and living condition statistics for an individual neighborhood are not available through this map. To get this information “zonal stats” function available in spatial analyst of ArcGIS desktop has been used. The neighborhood boundaries were used as the zone boundary and the raster’s values are analyzed for each neighborhood. The output of this process is a table that has the name (or unique ID) of each zone (neighborhood) and the statistics calculated from the raster.

5. Results & Discussion

The service areas for each service have been calculated using the intervals identified and described in table 4.12. Network based analyses are very resource hungry and require heavy computation and if there is a large number of locations that need to be processed on multiple intervals it becomes very difficult for the normal computers to complete the task. It was the case in this study, therefore in some services the locations were separated into different parts based on geographic locations (such as municipality boundaries) or land use codes (if the service comprise of several land use codes) and in other case such as educational services the time intervals were kept smaller, and then the results were merged together to form a single analysis layer for each service

Service areas for each service are shown and discussed in the following section.

HealthCare Services.

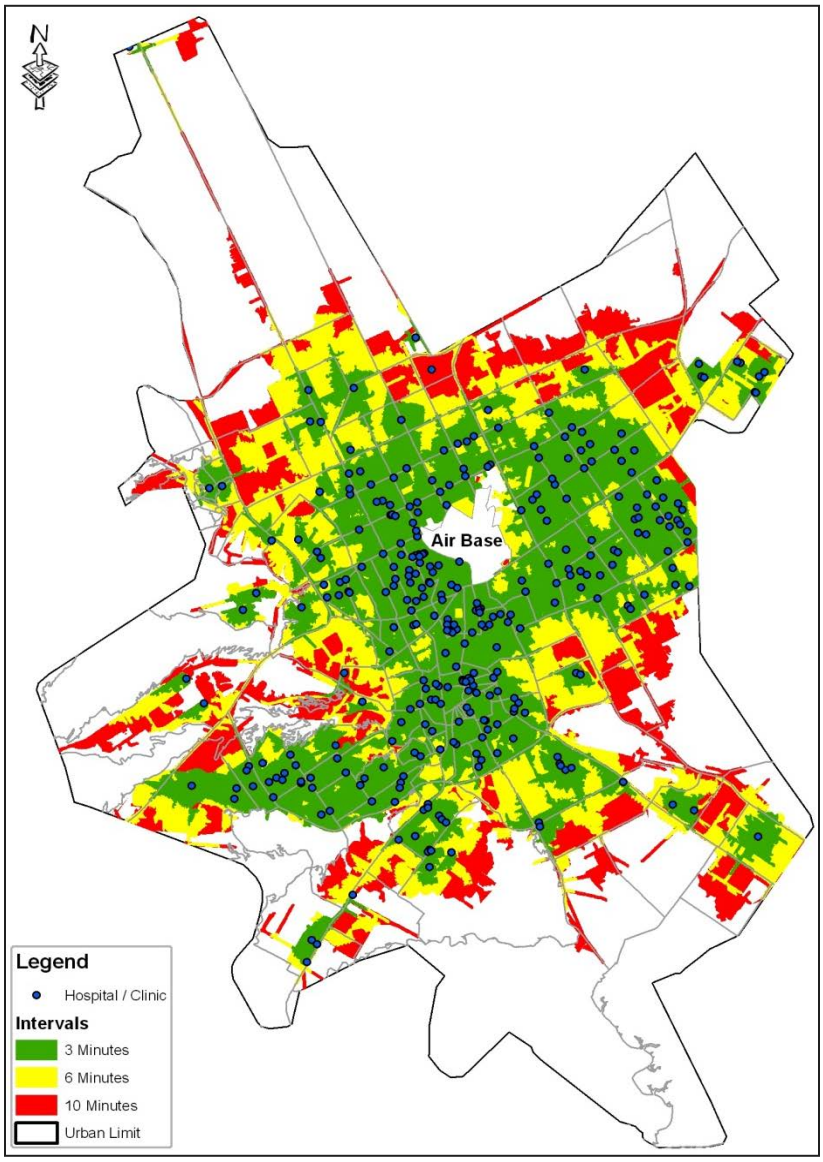

Figure 5.1: Service areas for health care services.

Figure 5.1 shows that health care services are concentrated in the central part of the city and mostly inside the ring road. It looks like that most of the city residents has the accessibility to the hospitals and clinics however there are 18 neighborhoods that do not have either completely or partly access to the medical facilities even in 10 minutes. Such neighborhoods are situated on the out skirt of the city and some of them are even not residential neighborhoods such as industrial city etc.

Educational Services

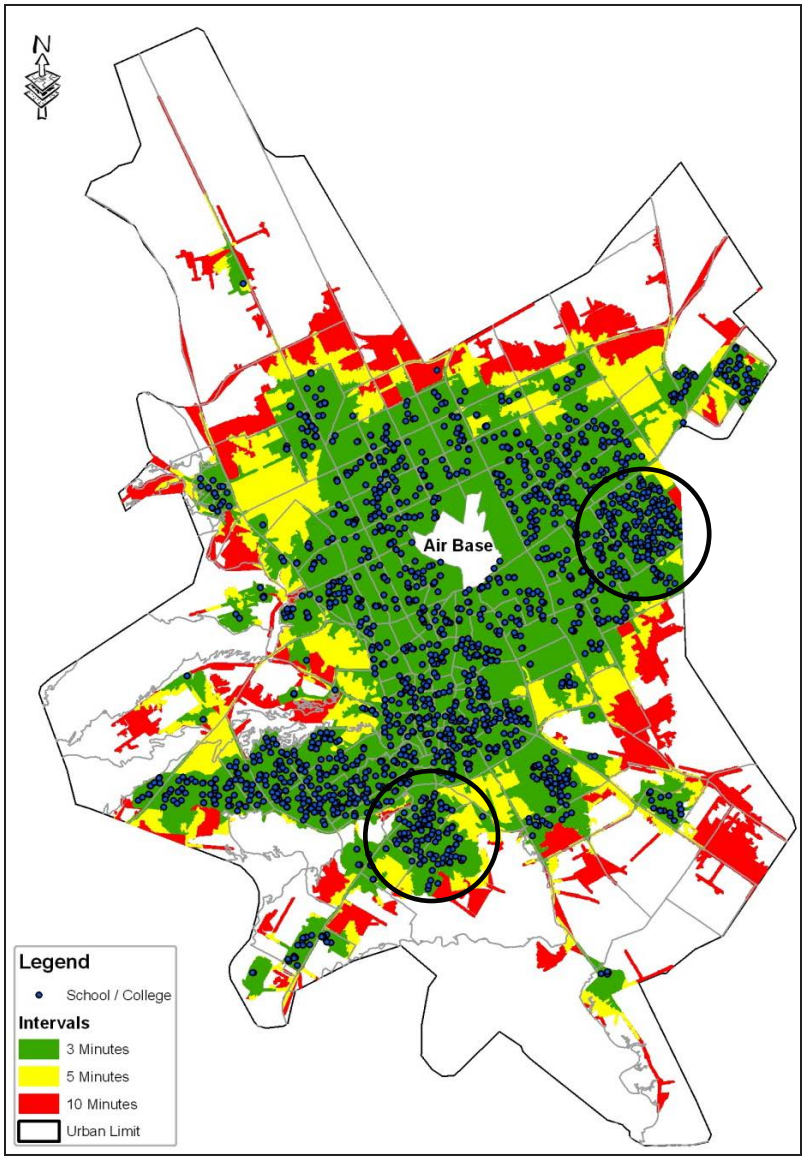

Figure 5.2: Service areas for educational services.

A pattern similar to health care services has been observed in educational services where the out skirt neighborhoods have poor / less accessibility to these services.

It has been observed that education services are available in every part of the city however some concentrated groups can also be observed in different parts of the city, mainly in the central, south west and eastern part of the city. This pattern reveals the fact that city planners have been focusing on city's education

services since long time as these concentrated areas had been the city centers in the past.

The other reason for such pattern is the data structure of schools location. In Saudi Arabia, each school has its own separate building according to its grade, such as primary, intermediate etc, however these buildings are located next to each other. The Point of Interest data set has been collected by adding a separate location for each school even if they are located in the same compound. Due to this fact schools appear as concentrated into groups and look like the distance between the schools is very short.

These locations could be separated and a single location for each compound could be created, however it would required some field verification that was not possible during the study, also the study takes in account all schools regardless of their grade and gender.

Ambulance Services

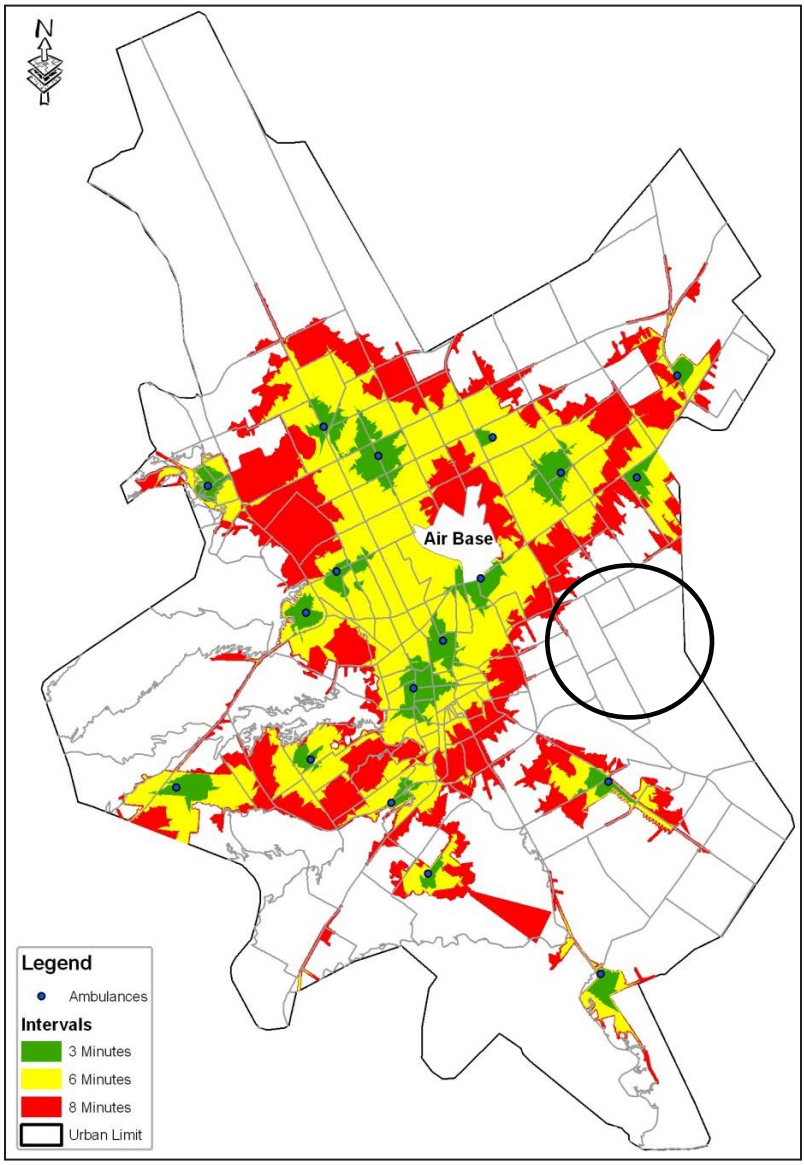

Figure 5.3: Service areas for ambulance services.

Service areas for ambulances show a very interesting pattern. It has been observed that most of the city cannot be reached by an ambulance in 3 minutes. Only the central part trending towards north can be reached by the ambulances in 6 minutes and 8 minutes. There are 8 neighborhoods (circled in fig. 5.3) in the south east parts of the city that are not reachable by any ambulance station in 8 minutes. These neighborhoods are listed in table 5.1.

Table 5.1: Neighborhoods not reachable by ambulance services.

No.	Name	Population
1	West Naseem	1,56,573
2	Salam	47,389
3	Jazerah	59,068
4	Fayha	33,864
5	Saadah	40,786
6	Manakh	10,483
7	Farooq	3,785
8	Faysaleah	16,216

There are some other neighborhoods in other parts of the city with low cover from the available ambulance services, however the listed (8) neighborhoods have a population and are near the city center. These neighborhoods are also the center of industrial and commercial activities and therefore are very vulnerable for any emergency situation. It is very important to have ambulance centers in the vicinity of these neighborhoods.

The table 5.1 shows a very important aspect of planning gap, as it is quite clear that a reasonable number of people lives outside the service areas of a specific time intervals. The planning gaps in the context of population can be evaluated for each service in the similar way.

Fire Fighting Services

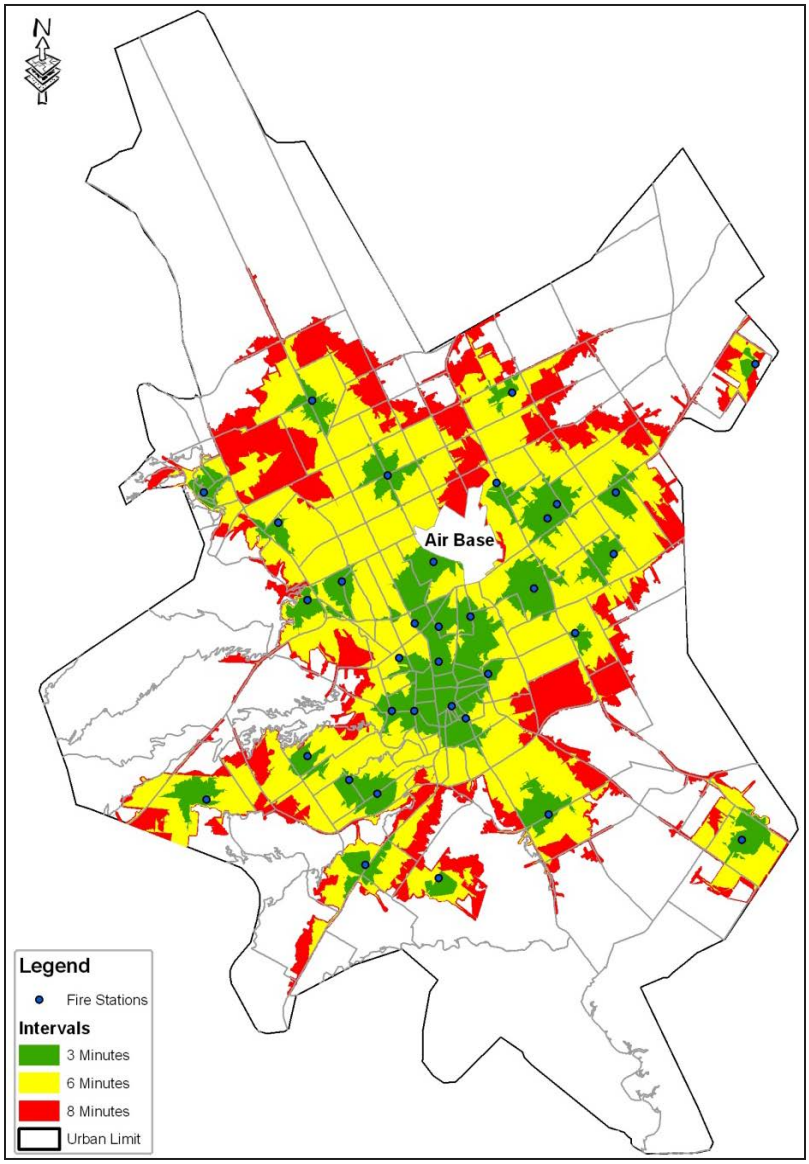

Figure 5.4: Service areas for firefighting services.

Firefighting services have been observed to be well distributed in the whole city. A reasonable part of the city mainly the down town areas are reachable by firefighting service in 3 minutes and the rest of the city is reachable in 6 minutes. There are 4 neighborhoods in the north east part of the city that are not reachable by fire engines within the given time intervals. These include Nada, Muaneseah and Yarmook. The total population in these neighborhoods is around 14611. Although the accessibility of fire stations is much better in the city however it is also obvious that the southern parts of the city is more vulnerable and therefore require even better response against any fire or emergency incident.

Shopping Malls

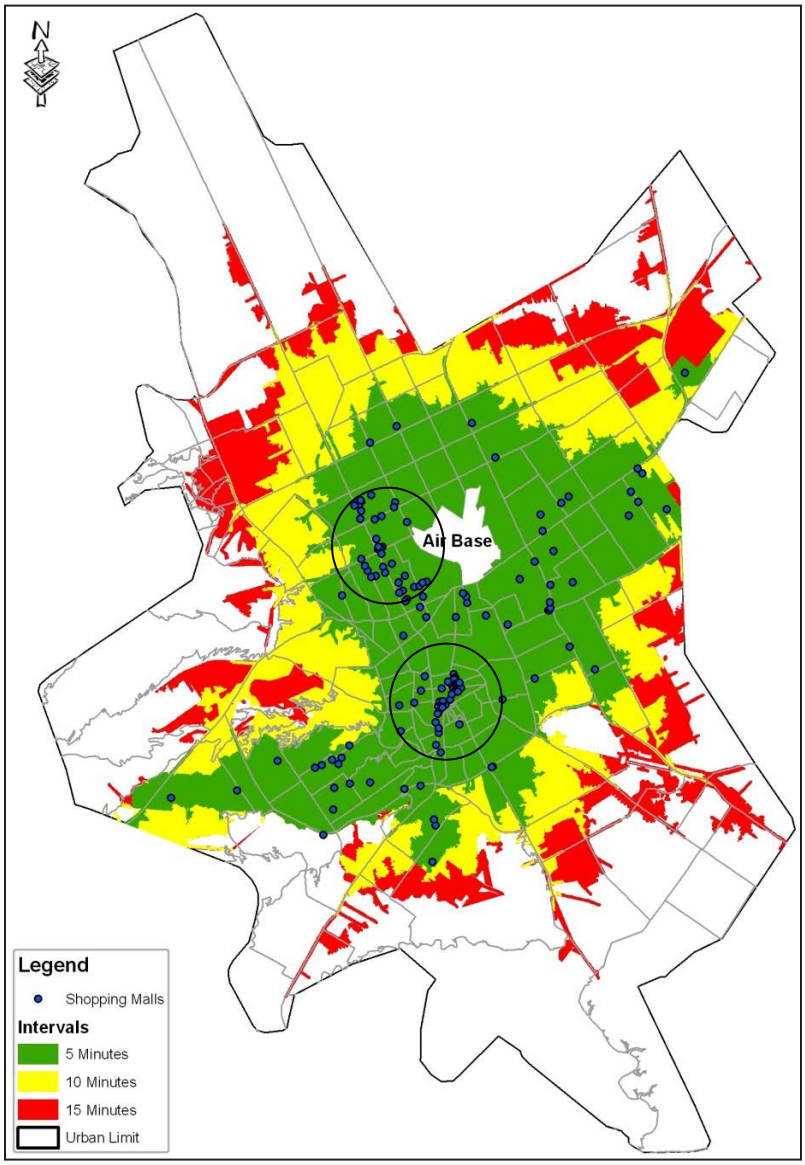

Figure 5.5: Service areas for shopping malls.

Shopping centers are spread in the whole city with two major concentrated groups. One group that is located in the middle of the city represents the down town area. This area has been the business hub and is the oldest part of the city. The distribution of shopping centers also reveals the fact that city center is moving towards the North. From the beginning of Saudi Arabian development era in 1970s, the city started to grow towards north and it is quite evident from the shopping services.

Public Parks

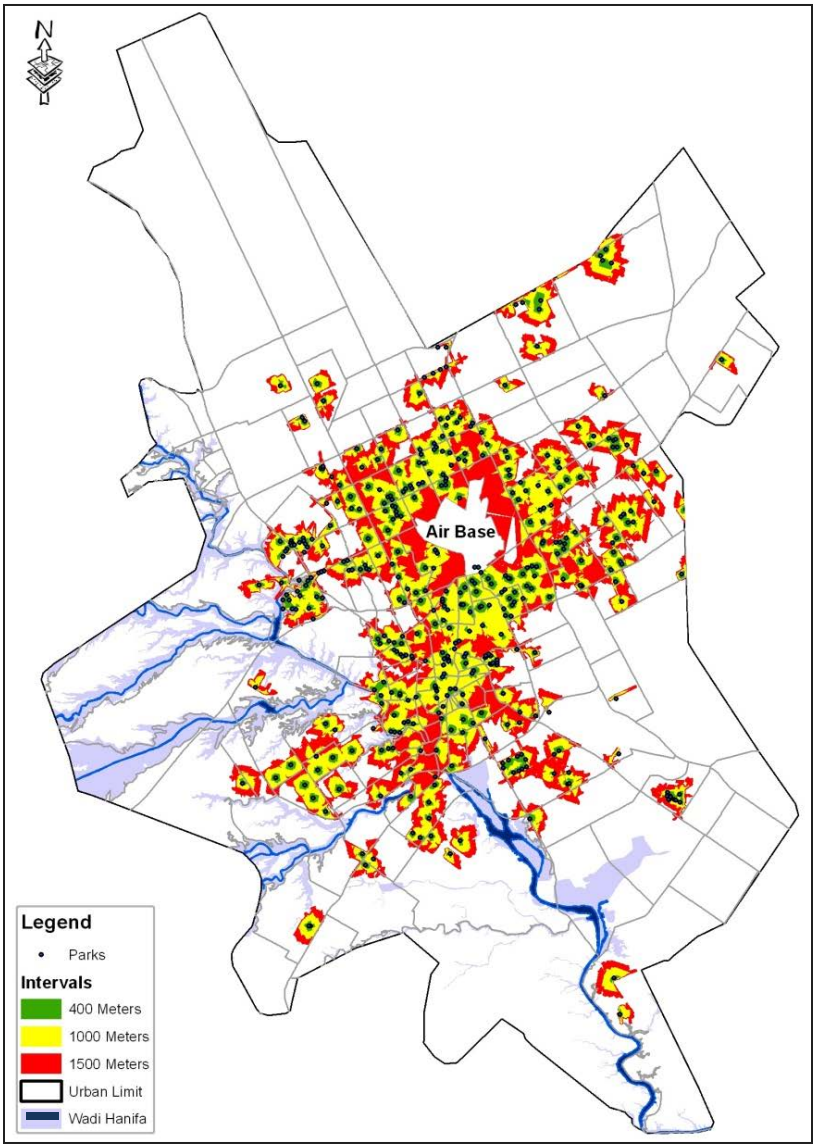

Figure 5.6: Service areas for public parks.

Parks service areas are distributed in the central part of the city. This pattern of public parks reflects that the city is growing and in the out skirt of the city where there is less population, such public services are not yet got matured. It is also obvious that the city planners from the beginning are well aware of the importance of the green spaces in the city.

Wadi Hanifa (Hanifa Valley) that have won Agha Khan Architect award in year 2010 has also become a good point of green space in the city. In the words of ADA's president "the Wadi restoration project will not only attract visitors but is also good for the environment". The value of Wadi has been restored that was diminished due to great urbanization process that has taken place in the Kingdom's capital city during the latter part of the last century.

The Wadi has become an activity center for those who love nature and it is a great green space in the heart of desert.

Views from Wadi Hanifa

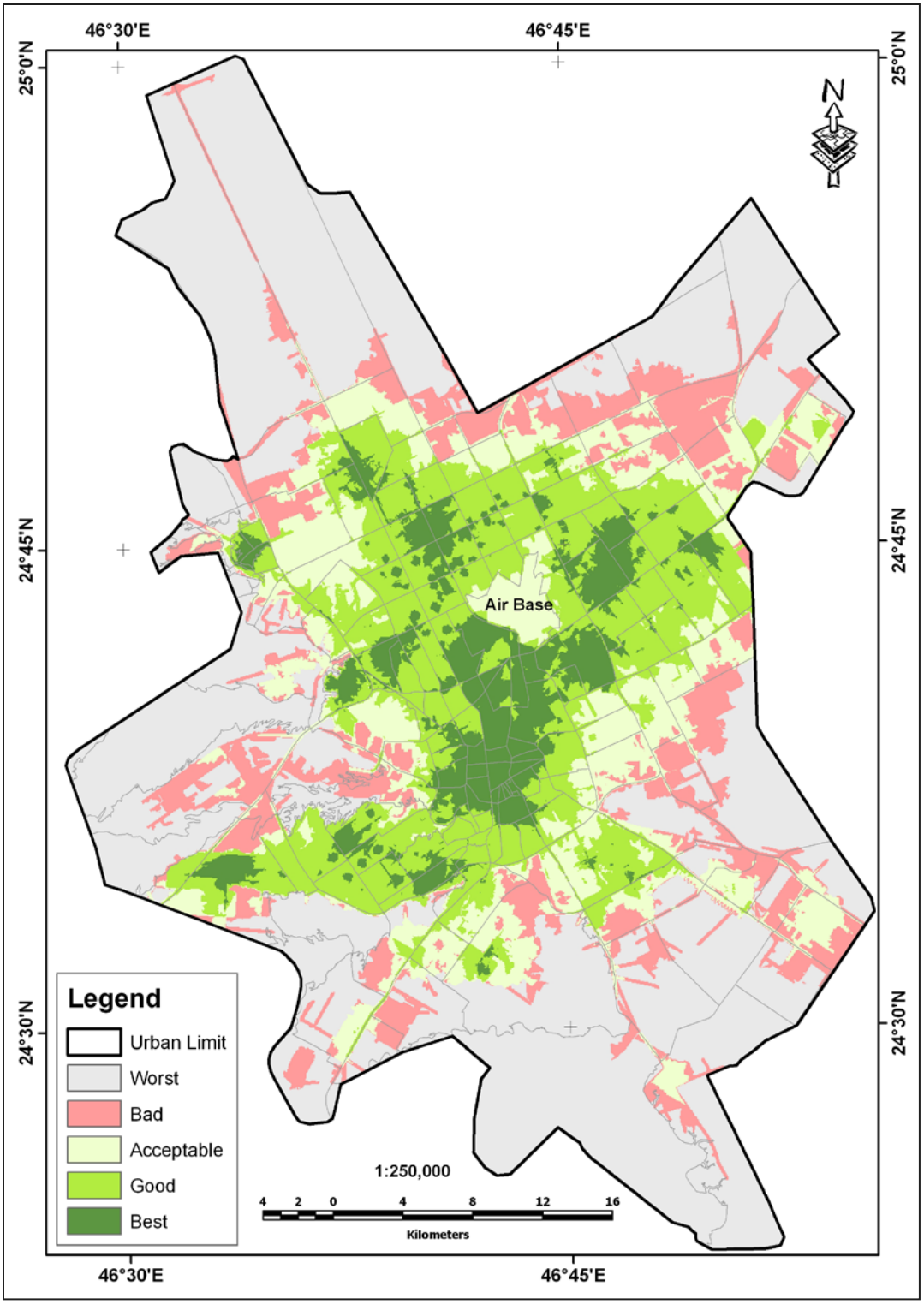

Figure 5.7: Living conditions in different neighborhoods.

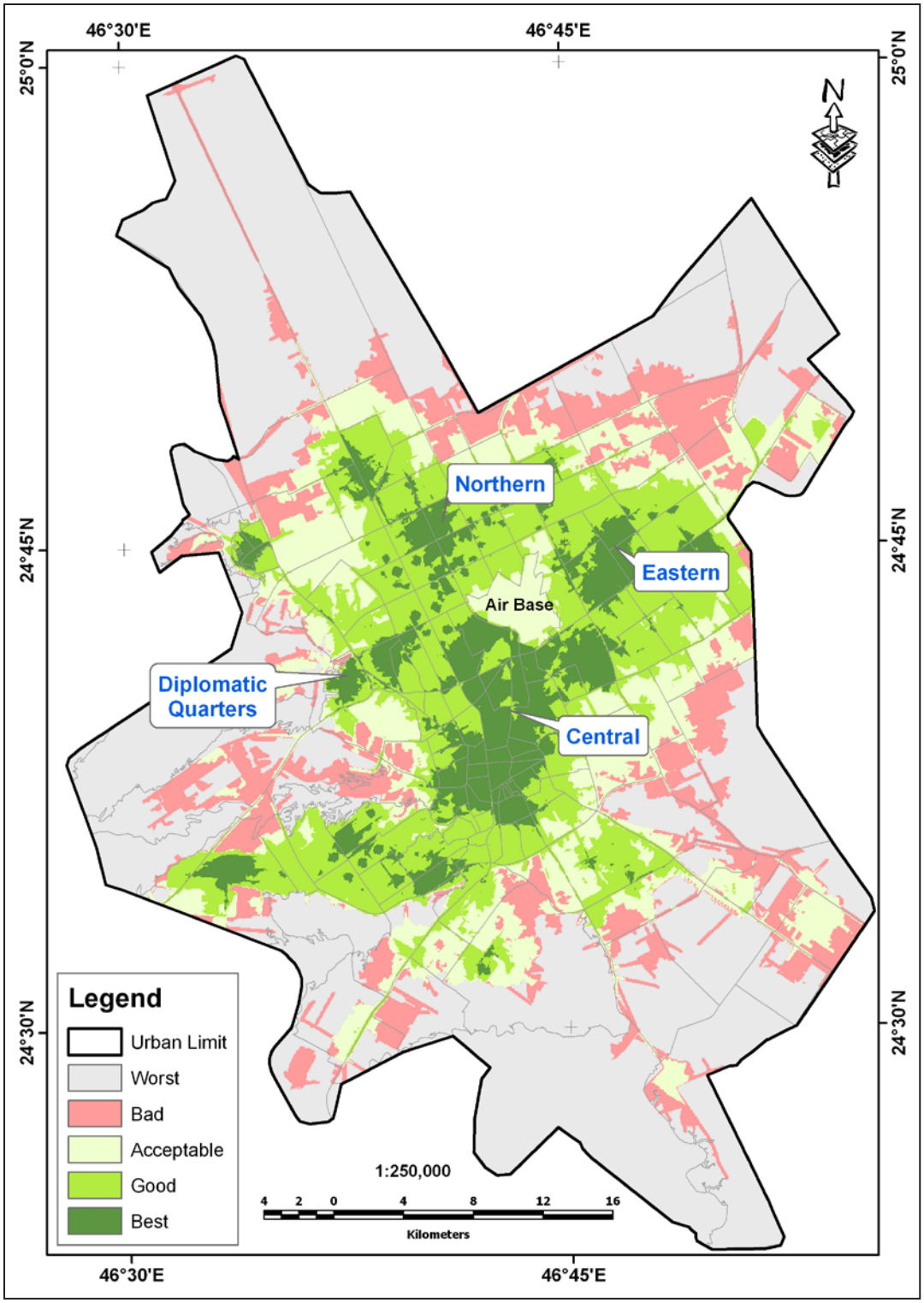

Figure 5.8Best Living Neighborhoods /Areas

5.1. Description of best areas

There are several neighborhoods in the city that have been highlighted as “Best Areas” based on the parameters in this study. Some of these neighborhoods / areas are discussed here. These areas are labeled on figure 5.8.

Diplomatic Quarters (DQ)

Diplomatic quarters as the name describes, is a habitat of the diplomatic missions in the Kingdom of Saudi Arabia. This study has highlighted this neighborhood as the “Best” area for living because all the services that have been used in this study exists in side this district.

Taking into consideration the objectives of this study, one of the objectives of the study is to assess the easiness in a neighborhood and this neighborhood can be marked as a neighborhood of easy living. Being the area of diplomatic missions, this is also less crowded and secure area.

This area can really be selected as best area for living esthetically as there is a lot of greenery and all basic facilities such as parks, sports center and shopping areas exist inside this fenced neighborhood. However land price is very high in this area and too much security may create some time a hassle rather than blessing.

Figure 5.9: Different views for Diplomatic quarters. (Photos: Google Earth)

North

For the last few years, city center has been observed to move towards north, which means that most of the development has been happening in the north part of the city and people are moving from down town areas to the north of the city. In chapter 3, city growth map (figure3.2) shows this fact and it is the real situation in the city. There are two new major projects that will accelerate this trend in future as well. One of them is the development of King Abdullah Economic City and the second project is the mono-rail station that is planned to be situated in the north of the city.

Being newly developed, these areas are very beautiful, neat and well planned. The social environment in these areas is very peaceful because the most of the inhabitant are well-off population of the city those are migrated from different parts of the city and even the country as well. Ethnically mostly the native and Arabic speaking communities are found in such areas.

Figure 5.10: Different views for north areas. (Photos: Google Earth)

East

Eastern part of the city is another fast developing area of the city however these areas are not as new as the north part of the city. They could be considered in middle of the development age of the city. These areas are good and well planned and had been enjoyed the title of posh areas of the city in the past.

Figure 5.11: A view for east areas. (Photo: Google Earth)

Central

Central areas are consist of the city down town and are the oldest part of the city. They are the most congested neighborhoods of the city and planning in these neighborhoods is very poor as they have been developed without any planning. These areas were the only areas that can be seen on an aerial photo taken in1950. Until now mud houses can found in these areas. ArRiyadh Development Authority is trying to preserve many mud houses as cultural heritage of the city.

Ethnically these areas are the habitat of the native poor communities, African and Sub-continental communities. However these areas are still commercial hub of the city as most of the whole sales distributors have their outlets in these areas.

Figure 5.12: A view of central areas (left picture: royal palace of the founder of KSA. (Photo: Google Earth)

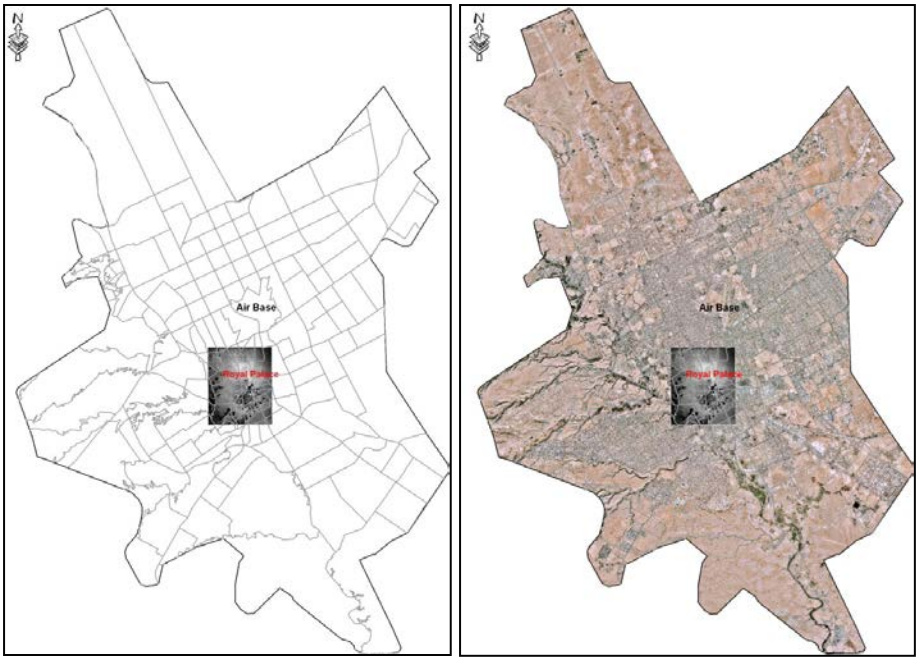

Figure 5.13: A comparison of city growth, left image 1950 and right 2005.

Zonal statistics

The result of zonal statistics calculation has been shown in the table 5.3; (only the top 15 are shown here and complete list has been presented in the appendix) it includes the minimum, maximum, mean , standard deviation values and the neighborhood name.

Table 5.2: living condition values for neighborhoods

Neighborhood Name	Min	Max	Mean	STD
Um Sulaem	0.470	0.500	0.482	0.009
Futah	0.430	0.500	0.464	0.025
Alamal	0.430	0.500	0.442	0.019
Derah	0.430	0.500	0.456	0.026
Dubeah	0.430	0.430	0.430	0.000
Meekal	0.430	0.430	0.430	0.000
Wesata	0.430	0.450	0.435	0.008
Qrai	0.430	0.450	0.431	0.005
Butaha	0.430	0.450	0.449	0.004
Wesham	0.430	0.500	0.472	0.011
Margab	0.420	0.480	0.432	0.007
Jubrah	0.405	0.450	0.433	0.008
Zahraa	0.380	0.500	0.438	0.020

5.2. Livability map

The best areas map can be displayed as livability map. Using the natural breaks the data is classified into three major groups. The group having the highest values has been denoted as the first options areas for living and then second option and the third group have been classified as not livable. Figure 5.13 shows these results.

Table 5.3: Livability classification for neighborhoods

Natural Breaks (Jenks)		Accessibility Class
From	To	
0.28	0.5	First Choice
0.17	0.28	Second Choice
0	0.17	Not Livable

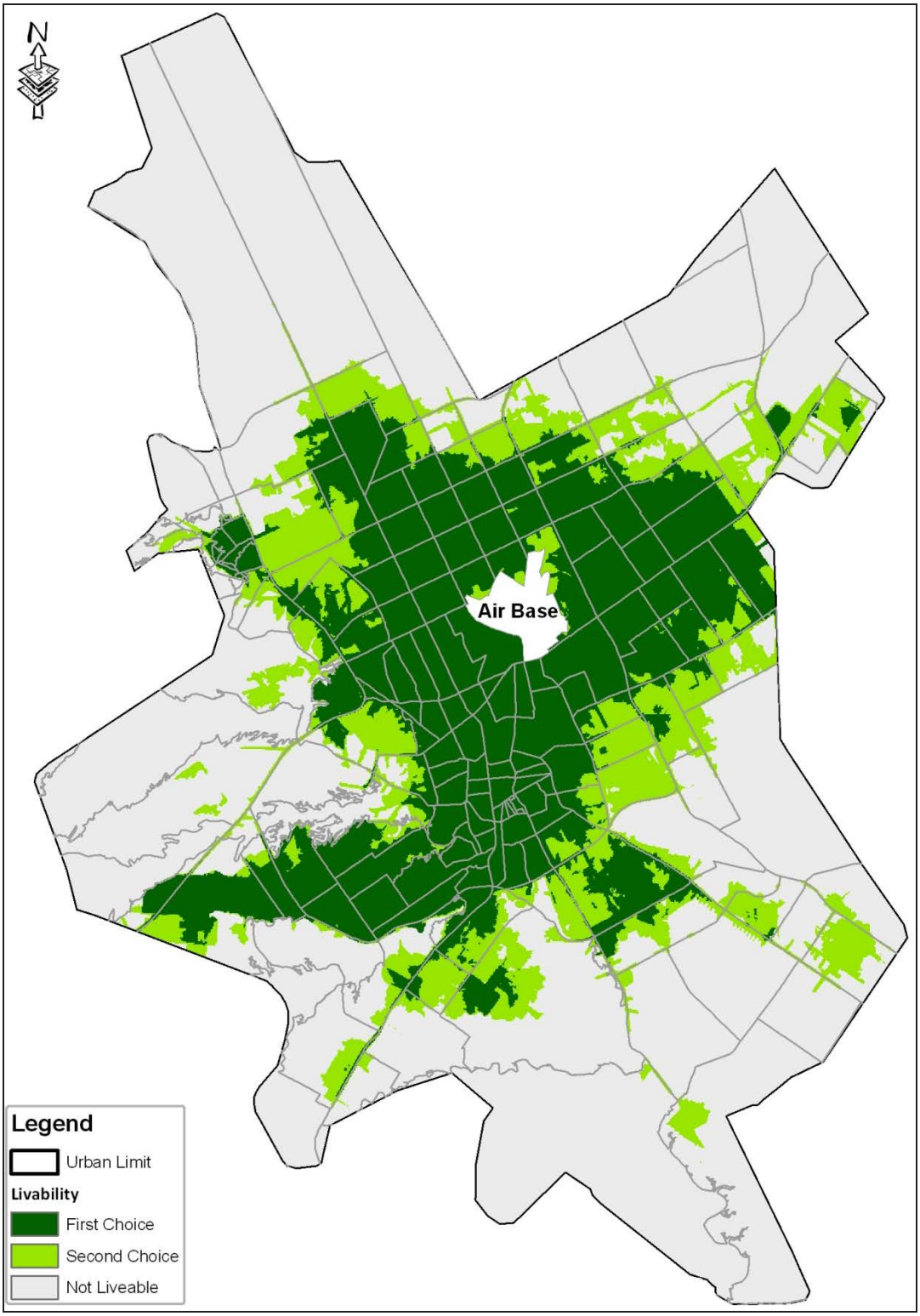

Figure 5.14: Livability in the city of ArRiyadh.

6. Conclusions

Planners and decision makers find it difficult to come to a conclusion on site selection for the civic services in the city (Aina et al, 2006). Their main concern is that a wrong location of a facility may lead to be neglected by the community. From the community point of view, selection of a place for home is also very critical and involves emotional feelings of someone as making a home in one's life is a biggest commitment.

Geographic Information System has emerged as a helping and decision support system in the recent age. Several methods have been developed in this field to assist the planners to make their decision more efficient. The approach presented in this study is one of such methods.

Current study has presented a GIS based multi-criteria evaluation of the ArRiyadh city. Although the study has analyzed the accessibility of certain services from the user point of view for selecting a best location for housing however the planners can use these results to plan /re-locate these services for better usability and accessibility.

The study found that the services under consideration are well distributed in the city and most of the areas of the city have accessibility to these services in the specified threshold values. However it is has also been found that some services such as ambulance and public parks need some re-arrangements (or add new locations) to cover more areas of the city. Particularly the south eastern part of the city requires more attention for emergency response and health care services. This part of the city mainly consist of commercial and industrial businesses and therefore are more vulnerable, however the current study found that the fire fighting, ambulance and health care accessibility is very poor in these areas.

The quality of the planning can be more efficiently evaluated by combining the population data in each neighborhood, so that it can be known that how many people are served or not served by a particular service. However it was not the objective of the study therefore population data has not been evaluated with all the services except public parks to demonstrate that how the current study can be used for identifying the planning gaps.

It has been observed that the ArRiyadh city is growing towards the North and this study has also revealed this fact. Therefore in future more services will be required in the north part of the city and this study can provide the planners a foundation to analyze future needs.

This work has successfully evaluated the accessibility to several public services and has shown the living conditions in the city, however it will be worth not to ignore the fact that the study had some limitations. It only evaluated limited number of services and their spatial accessibility has only been evaluated. The study has not taken into account the non-spatial factors that also influence the decision for home site selection. These non-spatial factors may include population density, ethnicity of the residents, environmental pollution including noise and air quality.

The study has also highlighted down towns areas as the best areas and this result highlights the need to add more factors related to urban environment and urban design. By the experience, it is a known fact that majority of people do not want to live in the down town areas of the city and as soon as they get opportunity (financially) they move to the new neighborhoods, because in the down town areas the planning was poor and some streets are so narrow that it is impossible to drive through these streets. Adding factors as open areas and neighborhood built areas can exclude such congested and poorly planned neighborhoods from the best areas.

Furthermore up-to-date and complete data may also change the results. The data set that has been used in this study has been collected by ArRiyadh Development Authority from different sources on different times, Therefore there are possibilities of errors in the data, in terms of location, and attributes.

Another question that can be made about the study is the time intervals used for the analyses as there were no first hand preliminary data about the public opinion was available, however the time intervals were selected with the reference of other scientific researches therefore it can be claimed that they are closer to the reality if not exactly representing the reality. Another argument that can be made in favor of these time intervals is that this study is not a planning project that a wrong time interval may create wrong urban plans rather this study has presented a methodological approach that how GIS can be used by urban planners for city planning activities and of course time intervals are adjustable based on real public opinion data.

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Appendix I: Best Areas Statistics.

Name	MIN	MAX	STD
Um sulaem	0.47	0.50	0.01
Futah	0.43	0.50	0.02
Alamal	0.43	0.50	0.02
Derah	0.43	0.50	0.03
Dubeah	0.43	0.43	0.00
Meekal	0.43	0.43	0.00
Wesata	0.43	0.45	0.01
Qrai	0.43	0.45	0.00
Butaha	0.43	0.45	0.00
Wesham	0.43	0.50	0.01
Margab	0.42	0.48	0.01
Jubrah	0.41	0.45	0.01
Zahraa	0.38	0.50	0.02
King Fahad	0.37	0.48	0.03
Worood	0.37	0.43	0.01
Ulaya - Ulaya	0.37	0.45	0.03
Sulaimaneah	0.37	0.47	0.03
Wazarat	0.37	0.50	0.04
Dubat	0.37	0.50	0.02
Murabaa	0.37	0.50	0.03
Saleheah	0.37	0.43	0.03
Jaradeah	0.37	0.50	0.03
Shemase	0.37	0.50	0.03
Thulaem	0.36	0.48	0.01
Manfuha	0.36	0.45	0.01
Rawdah	0.35	0.50	0.03
Maseef	0.35	0.50	0.04
Malaz	0.35	0.45	0.02
Ulaya - Maathar	0.35	0.45	0.02
Jareer	0.35	0.45	0.03
Aluood	0.35	0.45	0.04
Gubaira	0.35	0.43	0.02
Ulaishah	0.34	0.50	0.03
North Maather	0.34	0.48	0.03
Mursalat	0.33	0.50	0.04
Namuthajeah	0.33	0.50	0.05
Seah	0.33	0.43	0.02
King Faysal	0.33	0.48	0.04
Manfuha	0.33	0.43	0.03

Name	MIN	MAX	STD
Fakhereah	0.31	0.48	0.06
Um alhamam	0.31	0.50	0.06
Maather	0.31	0.48	0.05
Rayan	0.31	0.43	0.03
Manar	0.31	0.41	0.02
Zahra	0.31	0.43	0.03
Ureja	0.31	0.40	0.01
Durahemeah	0.31	0.45	0.04
Malaz	0.31	0.50	0.03
Etaigah	0.31	0.45	0.04
Sultanah	0.31	0.43	0.02
Rahmaneah	0.30	0.48	0.03
Gadeer	0.30	0.45	0.04
Shubra	0.29	0.47	0.04
Yamamah	0.29	0.45	0.03
Muhamadeah	0.29	0.40	0.03
Mugarazat	0.28	0.40	0.02
Hada - Maather	0.28	0.42	0.03
Raeed	0.28	0.47	0.04
Sahafa	0.27	0.49	0.05
Albadeah	0.27	0.50	0.05
Swaedee	0.27	0.43	0.03
Badeah	0.27	0.50	0.04
Waha	0.26	0.40	0.03
Ezdehar	0.26	0.40	0.03
Nafel	0.26	0.45	0.03
West Swaede	0.25	0.40	0.03
Nahda	0.25	0.43	0.04
Salah Aldeen	0.25	0.43	0.04
Shrafeah	0.25	0.40	0.03
West Naseem	0.24	0.43	0.04
Rawabi	0.24	0.43	0.04
Salam	0.24	0.45	0.05
Safa	0.24	0.41	0.05
Hamra	0.22	0.45	0.05
Nakheel	0.22	0.40	0.06
Aqeeq	0.22	0.45	0.05
Mansourah	0.21	0.43	0.04
Farooq	0.21	0.38	0.03

Name	MIN	MAX	STD
Nuzha	0.32	0.45	0.02
Qudus	0.31	0.47	0.03
Andalus	0.31	0.50	0.05
Maather	0.31	0.40	0.02
Murooj	0.31	0.50	0.05
Taawen	0.31	0.42	0.03
Rabuah	0.31	0.45	0.03
Derah	0.31	0.38	0.02
Mutamarat	0.31	0.42	0.02
Nasereah	0.31	0.50	0.04
Fayha	0.15	0.36	0.03
Faysaleah	0.15	0.31	0.03
Gurnata	0.15	0.43	0.06
Nada	0.14	0.33	0.04
Wadi	0.14	0.37	0.05
Heteen	0.13	0.35	0.04
Espeleah	0.12	0.35	0.06
Refeah	0.10	0.43	0.09
Meazelah	0.10	0.35	0.06
Saadah	0.10	0.33	0.05
Yarmook	0.10	0.33	0.03
EMBSU	0.09	0.36	0.06
East Naseem	0.08	0.50	0.10
Yasameen	0.08	0.34	0.06
Qadeseah	0.07	0.24	0.04
Ashefa	0.06	0.40	0.07
Nour	0.05	0.24	0.05
Eskan	0.04	0.33	0.07
Senaeah	0.04	0.33	0.06
Daralbaydah	0.04	0.40	0.10
Center Uraija	0.02	0.50	0.11
Hada	0.02	0.40	0.07
Jenadereah	0.00	0.38	0.10
Remayah	0.00	0.35	0.09
Natheem	0.00	0.33	0.07
Swlay	0.00	0.28	0.06
Manakh	0.00	0.34	0.08
Defaa	0.00	0.34	0.08
Heet	0.00	0.27	0.08

Name	MIN	MAX	STD
Rabee	0.21	0.40	0.05
Prince Abdullah	0.20	0.43	0.05
King Abdulaziz	0.20	0.45	0.05
KSU	0.20	0.42	0.05
Azezeah	0.20	0.44	0.05
Senaeah	0.18	0.45	0.06
Khalideah	0.18	0.38	0.05
Falah	0.18	0.37	0.04
Khaleej	0.17	0.42	0.06
Khashem Alan	0.17	0.30	0.04
Masfah	0.00	0.26	0.05
Hayer	0.00	0.25	0.06
Masanee	0.00	0.37	0.08
Marwwah	0.00	0.39	0.06
Bader	0.00	0.44	0.11
Ukaz	0.00	0.33	0.08
Uhod	0.00	0.36	0.09
Uraid	0.00	0.25	0.02
Wadi Leban	0.00	0.33	0.06
West Uraija	0.00	0.48	0.11
Uraija	0.00	0.43	0.11
Etaigah	0.00	0.45	0.14
Nemar	0.00	0.35	0.07
Derab	0.00	0.37	0.10
Hazem	0.00	0.43	0.12
Numar	0.00	0.43	0.13
Erqah	0.00	0.37	0.08
Khuzama	0.00	0.40	0.07
Mahdeah	0.00	0.27	0.01
Dahrat leban	0.00	0.27	0.06
Twaeeq - Erqah	0.00	0.40	0.14
KKIA	0.00	0.15	0.05
Dereah	0.00	0.26	0.08
Safarat	0.00	0.50	0.12
Gayrawan	0.00	0.27	0.03
Malqa	0.00	0.44	0.12
Elared	0.00	0.27	0.03
Nurjese	0.00	0.29	0.05
Remal	0.00	0.20	0.04

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