ArRiyadh Geospatial Urban Information System and Metropolitan Development Strategy for ArRiyadh

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Abstract

ArRiyadh, the capital city of the Kingdom of Saudi Arabia, is one of the fastest growing cities in the world. It has become a remarkable capital in the region, due to its geographical location, strong political, administrative and financial status. Being the hub of all political, cultural and commercial activities, the city has been experiencing a very rapid urbanization process. Timely, accurate and detailed information on urbanization phenomena is of great importance for urban planners and decision makers.

ArRiyadh Development Authority (ADA), a government body responsible for the city’s planning and development has been mandated to develop such information systems in the city to help urban planners. Since its inauguration in the mid 80s, ADA has developed the state-of-the-art geospatial information system for the city. ADA started with CAD and mainframe computers and now is equipped with latest high tech hardware infrastructure and ESRI enterprise software suits. This paper documents the development history of the Geospatial Urban Information System and Metropolitan Development Strategy for ArRiyadh in ADA.

Keywords: KAS, ArRiyadh, Geospatial Urban Information System, GIS, ESRI, Metropolitan Development Strategy.

Contents:

1. Introduction
2. Geospatial Urban Information System
3. Metropolitan Development Strategy for ArRiyadh (MEDSTAR)
4. Using GIS in MEDSTAR process
5. Using GIS in MEDSTAR implementation
6. Conclusion
1. Introduction

1.1 Kingdom of Saudi Arabia

The Kingdom of Saudi Arabia lies in the southernmost part of western Asia. Its borders are set by the Red Sea on the west; the Arabian Gulf, the United Arab Emirates and Qatar on the east; Kuwait, Iraq and Jordan on the north and Yemen and Sultanate of Oman on the south (See Figure 1).

The Kingdom occupies about four-fifths of the Arabian Peninsula, with a total land area of around 2,149,690 km². There are various types of terrain in the Kingdom are resulting from its vast geographical area. In the west is a narrow coastal plain paralleled by a mountainous chain sloping eastwards to the Arabian Gulf. The Empty Quarter and An Nafud Deserts occupy the south-eastern and northern parts of the kingdom respectively. The Kingdom total population Saudi and Non-Saudi 27,136,977 (69% Saudi).

1.2 City of ArRiyadh

ArRiyadh is not just a city, it’s national capital city of the Kingdom of Saudi Arabia. Home of the two Holy Mosques, the heart of the Islamic world: Makkah and Medina. Subsequently ArRiyadh is expected to be not only a great city for its citizens, but also be a city that symbolizes the aspirations and values of Islam.

ArRiyadh is strategically located at a major crossroads of the continents of the world in the heart of Kingdom and eastern part of the Arabian Peninsula. It lies on latitude 38.24 N and Longitude 43.46 E and is about 600 meters above sea level.

Until 2011, the developed land in ArRiyadh city has reached 1219km². This area is expected to expand to 2500km² in 2029. The area allocated for urban development is expected to reach 2395km² in 2014, and 3115km² in 2029, while development protection area, the urban environs amounts to
5961km² (See Figure 2).

The area allotted for housing represented about 17.8% of the total area of the city, the area allotted for industrial purposes 1.88%, transport services 3.12%, commercial purposes 1.97%, health government and educational purposes 10.66%, and cultural and entertainment purposes 6.48%.

This rapid expansion beyond its original walls in 1950 (See Figure 3) has resulted that ArRiyadh city became one of the three largest metropolitan areas in the kingdom, together with Makkah and Jeddah and the conurbation of Dhahran, Dammam and Al Khobar in the Eastern Province. The City includes 13 municipalities in addition to Addiriyah governorate that accommodates 209 quarters.

Figure 2. ArRiyadh City 2010

Figure 3. ArRiyadh 1950
The climate of ArRiyadh is marked by extremes of temperature. It is very hot in summer and cold in winter with low humidity throughout the year, particularly in the summer season. The temperature varies greatly between night and day. In summer the lowest average temperature ranges between 22-27°C and the highest 40-43°C. Humidity ranges from 10% to 13%. It is cold in winter; the lowest temperature ranges between 8-14°C while the highest ranges between 20-28°C, the humidity ranges between 40% and 49%. Rainfall ranges from 10cm to 13.1cm (approximately four inches).

ArRiyadh city is one of the world fastest growing cities, and its population has risen steadily at a rate of 4% during the period 2004-2010. In the early 1970s, the population of the city was no more than 100,000 mostly of local heritage and following a pattern of life characterized by unified activities. Today the city accommodates more than 50 different cultures, languages and activities.

The increase in population is the most prominent feature of the City is responsible for the growth of other sectors. The most important advantage of this growth is the increase rate that has never been less than 8%, which is a high rate compared to similar cities. In the 1980s and 1990s that rate doubled to 16%.

The other factor of ArRiyadh population growth is characterized by qualitative features in the standard of living of residents. According to the preliminary results of the general census of population and housing, 2010, the overall population of ArRiyadh City reached more than 5.2 million: 59% males and 41% females. The Saudi population reached more than 3.1 million or 60% of the total, while the non-Saudi population reached 2.1 million or 40% (See Figure 4).

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Saudis</th>
<th>Non-Saudis</th>
<th>Total</th>
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<td>Males</td>
<td>1,645,060</td>
<td>1,460,578</td>
<td>3,105,638</td>
</tr>
<tr>
<td>Females</td>
<td>1,506,149</td>
<td>642,773</td>
<td>2,148,922</td>
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<td>Grand Total</td>
<td>3,151,209</td>
<td>2,103,351</td>
<td>5,254,560</td>
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<tr>
<td>Males %</td>
<td>52.2%</td>
<td>69.4%</td>
<td>59%</td>
</tr>
<tr>
<td>Females %</td>
<td>47.8%</td>
<td>30.6%</td>
<td>41%</td>
</tr>
<tr>
<td>Occupied Residences</td>
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</table>
2. Geospatial Urban Information System

2.1 Urban Information System

Since 1986 ArRiyadh Development Authority (ADA) has built a comprehensive urban information system using modern technology and technical qualified cadres. The system contains huge database on ArRiyadh city in fields of housing, land uses, environment, transportation, economy, etc... This system helps the different development programs and projects in the city. It also depends on very modern infrastructure in all its components such as networks, hardware, servers, storage units with high capacities related to it, along with all requirements of backup units. This system is supported by providing full technical services through multi disciplinary technical team for managing the system (See Figure 5).

Figure 5. Geospatial Urban Information System Infrastructure

2.2 Geographical Databases

A comprehensive geographical database for the city was built with the aim to shift from the former traditional system which depended on maps and paper plans into a sophisticated digital system to support strategic urban planning works and development growth of the city. The system was created on two integrated and interconnected databases which are the spatial and attribute database.

ADA has started to carry out studies and field surveys for various aspects of the city. These studies and surveys included information about land uses, population, economy, transportation, environment, land prices, services, utilities, water resources, as well as hydrological and geological characteristics of the city. This information was included in descriptive databases related to a unified basic digital map of ArRiyadh city built depending on accurate coordinate reference.

The database was largely expanded, where surveys have been recurred in relation to update of the main base for land uses, buildings, family and demographic surveys, and the related basic digital map produced over the years 1991, 1997, 2005. Therefore, information increased to nearly 3 million pieces of data on land uses that give chronological readings from 1986 up to 2005. High resolution satellite photographs have also been used as a major layer reliable in many cases for planning purposes.

Also, from the geographic database the first version of unified basic digital map of ArRiyadh city was produced. This map was distributed to all relevant agencies in the city to deal with it in the field of operation or fields of supporting the basic map with information related to all these agencies.

The multiple layers of urban information were beneficial in providing the urban information system of ArRiyadh city in the study of Metropolitan Development Strategy for ArRiyadh (MEDSTAR).

The Commission continues its efforts with the aim to attain access to integrated connection of the relevant departments in the city stakeholder (public and private) with a unified information system for the city (See Figure 6).
Figure 6. Integrated Connection Of The Relevant Departments In The City Stakeholder
3. Metropolitan Development Strategy for ArRiyadh (MEDSTAR)

3.1 The Previous Experience of the Urban Development of ArRiyadh

Until the end of the 1960s there was no comprehensive plan for the development process for ArRiyadh city (See Figure 7). The urban development used to be a direct result of the urban decisions made at that time on case by case principle (e.g. Almalaz, old airport etc.). The planning authorities recognized the importance and the need of establishing some sort of control on the urban development process by preparing land sub-division plans for the city, the most outstanding of which was Almalaz plan, during the fifties of the 20th century.

Figure 7. Urban Development for ArRiyadh 1970

3.2 The First Master Plan

The first master plan for ArRiyadh city was prepared in 1971, by Doxiadis Company and was approved in 1973. The plan proposed that the city growth should be in a north-south direction, parallel to Wadi Hanifa (See Figure 8). This plan assumed a linear development along the spine extending in a north-south direction, contrary to the traditional development corridor of east-west direction. This avoided directing the city growth towards Wadi Hanifa.

The plan proposed an urban area of 300km², of which 150km² will be assigned for residential purposes in order to accommodate 760,000 people till 1985 and 1.4 million people in 2000. The plan proposed blocks of 2km x 2km as basic planning unit for the city, covering all the planned sections.

The dynamic population growth which took place in ArRiyadh, between 1976 and 1990 was unexpected. This was not envisaged in the framework of the first plan. Due to the economic boom resulting from the rising of oil prices, the government expenditure has increased sharply and the rate of urban development has reached high levels according to international standards. A large area outside the city boundaries has been developed in a way that superseded this plan.

Contrary to the first Master plan Concept, service centers where developed along major roads and not in the center of the neighborhood patterns, as suggested by Doxiadis. The strong pressure of the east-west direction development along the traditional corridors had countered the concept of north-south direction development. But the planning of 2km x 2km blocks was followed and even repeated
outside the original area defined by the first master plan. Thus the city has changed from slow urban expansion of the central area into all directions.

Figure 8. The First Master Plan 1973

3.3 The Second Master Plan

The first master plan was revised and updated in 1976 by CSET International, and was completed in 1982 (See Figure 9), where an area of 850km² was assigned for development until 1990, in order to accommodate 1.6 million people. It should be noted that this plan was not approved officially, but its principles were applied on new areas outside the plan as well as the areas covered by the plan. The planning network for 2km x 2km blocks was maintained, the main streets were classified as commercial streets and the subdivisions along these streets were assigned for commercial or mixed use.

The city growth was affected by the strategic location of the big projects, which were sometimes integrated in the city fabric in an unsuitable manner. The development proposed for Wadi Hanifa, as a main green belt, in order to integrate in the park system at the city level, was not fully implemented. Also, the development of the old airport site as a key park for the city was not fully implemented.
3.4 The Urban Limits Policy of ArRiyadh City

In order to coordinate urban development and infrastructure staging the Council of Ministers approved under the resolution 175 the urban Limit Policy in 1989. The Urban Limits were divided into two stages 1995 to 2000 and 2000 to 2005 (See Figure 10).

By the end of the first stage of the Urban Limits Policy 1995, development in the city covered most of the parts of the first phase of the urban limits which is more than 632km2. In this time the percentage of the vacant land within that phase decreased from 50% to less than 30%. The planning process in the city is still related directly to the urban limits policies, in an attempt to concentrate development within a specific geographical framework in order to reduce the unplanned growth and the urban dispersal of the city.
3.5 Metropolitan Development Strategy for ArRiyadh MEDSTAR

3.5.1 Aims & objectives:
- A long term plan to guide the city future development in all sectors.
- Create urban identity for the different parts of the city.
- Help the government and private sectors to plan for their future development.
- Provide a sustainable urban Environment for the current and future generations.

3.5.2 Time Domain:
- Fifty-year vision
- Twenty five-year strategy
- Ten-year implementation plan

3.5.3 The Future Vision:

The vision statement has been identified in the form of elements supported by goals for the future of ArRiyadh (50 years). The future vision is articulated in the form of six interwoven elements: (The Capital of the Kingdom, Human City, A Contemporary Oasis, A flourishing Financial and Commercial Center, A Beautiful City, and a Center of Cultural and Scientific Enlightenment).

They are linked through the relationship between man and GOD (Allah), the relationship between man and man and between man and nature. They represent the dominant elements that integrate the other six elements. All that is framed with the idea of sustainability in accordance with the Islamic Principles (See Figure 11).
3.5.4 The Strategic Framework

Figure 11. The Future Vision

3.5.5 Methodology of Work

The work in the Metropolitan Development Strategy for ArRiyadh (MEDSTAR) has been divided into three main phases:

**The First Phase**: Review and evaluation of the current situation of the city and definition of the expected impacts of this growth on the present and future of the city. Preparation and drafting a future vision for the city for the coming 50 years by means of definition problems and critical issues, and
definition of a possible opportunities, for successful development of the city and its surrounding.

**The Second Phase:** Carrying out detailed studies about each sector of urban development, defining the development objectives for each sector. Generating possible strategic alternatives to achieve these objectives. Also assessment of development costs to be able to come out with an adequate proposal for the strategic development framework for ArRiyadh city. Therefore, prepare general and detailed structure plans for the city.

**The Third Phase:** this stage includes determining the mechanisms for executing the strategy based on the policies, programs, controls and codes.

### 3.5.6 Reports and Deliverables

There are 20 reports as deliverables of the first phase, through which the current situation is known, listed as follows:

2. The Economy in Retrospect.
3. Land use.
4. Existing Urban Form and Structure.
5. Identification of Metropolitan Area Specific Studies.
6. Housing.
7. Industrial Development.
8. Environmental Resources.
10. Open Space.
11. Infrastructure.
12. Transportation System.
13. Regional Context.
17. A Vision for ArRiyadh.
18. Existing Urban Regulatory /Management System.
19. Proposed Interim Development Control Framework.

The deliverables of the second and third phases included the final report for MEDSTAR, which was based on the urban development strategy prepared in the second phase and has been approved by the High Commission for the Development of ArRiyadh in their 2003 meeting. It consisted of the sectoral and land use policies, the Metropolitan Structure Plan, the Urban development management plan, local structure plans. It includes the following final reports (Arabic version):

1. The Economical Development Strategies.
2. The Environment Strategy.
5. Housing Strategy.
6. Public Services Strategy.
8. Land Use Plan.
9. Land Uses and Development Codes.
10. the Local Structure Plans.
12. The Comprehensive Report. (English version)
13. Summary Overview.
4. Using GIS in MEDSTAR Process

Sophisticated technologies have been used in study of MEDSTAR to support planners and decision makers. These technologies included engineering drawings systems, geographic information systems, geographic databases, statistical analysis systems, graphical forecast models, and office archiving systems.

Effects of using technologies were reflected on research methodologies and planning studies. Methodology of producing maps contributed in saving planners and researchers a lot of time and efforts when they need to collect miscellaneous information on ArRiyadh city. It has also contributed in facilitating the way of dealing with that information, analysis of data and producing it in the form of maps, tables and graphical forms, and using geographical research processes to provide quantitative and qualitative data with spatial dimension which effectively participated in taking advantage of the various geographical data in strategic planning fields.

4.1 Taking advantage in Urban Planning fields:

Among the most important planning fields are observing urban and spatial growth of the city. This was facilitated by the large expansion in the database of land uses. Land uses number at the city level include (3 thousand uses) along with number of buildings, family and demographic surveys, and the related basic digital map. This was in addition to updates made to hundreds of related maps which as a whole constitute basic map of the city including land subdivisions, land ownership, administrative and organizational boundaries, urban development limits of the city (See Figure 12), boundaries of development protection depending on high definition satellite photos along with aerial photography and plans approved by ArRiyadh Municipal. This has led to monitoring and updating urban boundaries of the city and setting up future urban development of the city and its trends.

**Figure 12. Urban Limits Phases**
By utilizing the recent technology, the future land use till the year 2030 for the city of ArRiyadh has been planned (See Figure 13), this has been achieved through using the statistical software in predicting the population growth based on the available data on household surveys, besides utilizing from the planning standards in identifying the land use distribution according to the population prospects. The future land use plan include many aspects of land use such the residential, commercial, public facilities, industrial, recreation and resorts, open places and public utilizes, whether at the level of the city or according to special regions and with special policies.

Figure 13. Future Land Use 2030

Linking the land use plans with Zoning plan and regulations (See Figure 14), in order to assist the planner and decision making policies in identifying the type of future land use in ArRiyadh city, that growing rapidly in all its aspects.
4.2 Taking advantage in Transportation Planning fields:

Network analysis was used to perform the necessary analyses for studying the current road network and building the future network. This helps in transportation planning with all its aspects such as: Study of traffic effect on roads when there are obstacles, Number of daily and annual trips, Volume of traffic on intersections, Traffic lights, Level of service on roads, Study of future network effects, Average speed (minimum – maximum – medium), Number of hours (time) spent daily and annually, Volume of traffic on road network, Mileage per day and per year in km, Number of road tracks. (See Figure 15 & 16).

Figure 17 shows current and future network of the city up to 2030 according to transportation strategy in MEDSTAR.
Figure 15. Daily Traffic Volumes

Figure 16. Volumes / Capacity Ratio
Figure 17. Future Road Network 2030
4.3 Taking advantage in the field of Infrastructure Planning:

The main Infrastructure lines were entered into GIS database where both of the major line tracks, capacity, and main plants were entered in addition to covering of the current city utilities such as electricity, water, sanitation, and storm water drainage, (See Figure 18).

GIS also facilitated setting up future lines of utilities based on future land uses and population forecasts.

Figure 18. Existing Infrastructure
4.4 Taking advantage in the field of Environmental Planning:

Many environmental layers were entered such as the natural information of the city (See Figure 19), and its topology, geology (See Figure 20), and soil maps of the city that helps in identifying areas of environmental sensitivity including locating of Wadis, and sub-Wadis and identifying environmental dangers.

Figure 19. Natural Setting

Figure 20. Geology
4.5 Taking advantage in other fields:

GIS made it easy to know public service domains at the level of the city such as schools, hospitals etc. It also helped in taking advantage of them in studies that address elevation at the level of the city and setting up interim plans of utilities and road networks.

Application of GIS also led to benefit from them in production processes and producing maps in a format that allows publishing any information (See Figure 21&22), and to deal with any new developments that emerge at the level of the city effectively which leads to accelerating decision making suitable for them. They also assisted in applying processes of land subdivision and matching them on the ground and linking them to the main maps, as well as using 3D to depict the city in the future.

Figure 21. Structure Plan 2030

Figure 22. Structure Plan 2030
Using satellite imagery for reviewing projects (See Figure 23), and printing satellite imagery in any size (See Figure 24).
5. Using GIS in MEDSTAR implementation

5.1 Mechanisms of Implementation and Follow up of MEDSTAR

Results of MEDSTAR included various strategies that covered development fields in the city. They comprise economy, environment, transportation, Infrastructure, housing, public utilities, public services etc. Results appeared in the form of reports indicating policies and procedures related to each strategy.

They also included plans indicating trends of development in the city, future land uses, systems of using and development of lands, road networks, and future utilities and the other maps related to databases relevant to MEDSTAR, (See Figure 25).

**Figure 25. MEDSTAR Implementation**

5.2 Geographic Databases

A lot of information entered into Geographical Information Databases related to MEDSTAR (See Figure 26), according to criteria and standards of ArRiyadh Geospatial Urban Information System, which facilitated linking between information and making the necessary analysis. These databases were connected to an application interface so that update and follow up are achieved through the interface then they are redeployed on the internet.

**Figure 26. MEDSTAR Geographic Databases**
5.3 Application Interface

An application interface was designed for Geographical Information Databases of MEDSTAR in order to help in implementation (See Figure 27&28), and follow up of the future plans through the following uses:

- Review and analysis of the existent geographical information databases of the city.
- Using aerial photos in planning studies and follow up the city growth.
- Implementation of the future building codes of the city using sophisticated system layers in the existent system layers.

Figure 27. MEDSTAR Interface

![Figure 27. MEDSTAR Interface](image)

Figure 28. MEDSTAR Application Interface

![Figure 28. MEDSTAR Application Interface](image)
5.4 Navigation through the Internet

The Geographical Information Database of MEDSTAR was linked to the internet browser (See Figure 29&30), to allow for reviewing plans of the future land uses and the sophisticated systems and the other strategic studies. The objective is to serve the public and private agencies, consulting firms, researchers, and investors.

Figure 29. Navigation future land use 2030

Figure 30. Navigation Zoning plan 2030
5.5 Geographical Statistical Analysis and Simulation System and Development of Databases

Geographical Statistical Analysis and Simulation System and Development of Databases (GSASSD), This system is developed to benefit from all data of MEDSTAR and the other information data for make them available in unified format that is easy to deal with inside the ADA and in a later stage outside it (See Figure 31).

Figure 31. GSASSD
6. Conclusion

Modern technologies participate in preparing urban strategies, physical plans, implementation programs and follow up and evaluating them. To benefit from these technologies in the field of urban strategic planning, the following are required:

1. Building a comprehensive urban information system with modern technologies and qualified technical cadres. This system should contain a database in the field of demographic, land uses, zoning, environment, transportation, and economy etc.. This system depends on very modern infrastructure in all its elements such as networks, hardware, software, and servers, and should have high related capacity storage with its requirements of back up. This would be supported by providing integrated technical services through multi discipline technical team to manage the system.

2. Developing and updating of complete spatial and descriptive database for the city that contains various studies related to the city and represented in study of land uses, population and economic studies, transportation and environmental studies, land prices, along with information about services, utilities and water sources. It also contains hydrological and geological characteristics of the city etc. and linking this database with a unified basic digital map of the city.

3. Providing geographical information systems and applications that help planners and decision makers in preparing studies and adopting policies related to the city.

4. Holding courses, forums, and seminars to train specialists and planners on these technologies to benefit from them during work phases in such planning studies.

When those technologies are available, they will contribute to support research methodologies and techniques and planning studies. They will also save planners and researchers time and effort in collecting vital and miscellaneous information about the city, and facilitate dealing with it. They will as well effectively participate in taking advantage of the various geographic data in the different fields of strategic planning.

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