The Feasibility of GIS in Urban Planning in Riyadh

By

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ABSTRACT

Over the past decade, Riyadh, Saudi Arabia has experienced rapid growth in its urban industrial areas. The municipal government has responded by creating a Geographic Information Systems (GIS Centre), but its usefulness in urban planning is unclear.

This research will address this question by: 1) examining The different ways GIS can be; 2) assessing existing industrial land use conditions as well as critical issues that the city presently faces in planning; 3) analyzing current GIS applications being used by Riyadh Municipality and the GIS Centre; and 4) recommending improvements to urban land-use planning through enhanced GIS applications. This research concludes that a step-by-step approach that can be embedded into ArcMap Software that is currently being used by the Task Force Centre would be the optimal solution. Advantages and disadvantages of the approach are critically examined, including a discussion of future goals for this project.

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Glossary of Selected Terms

For the purposes of this thesis the following definitions are provided:

Terms Essential to Urban Planning

Planning: The art and science of ordering the use of land, and the characteristics and location of buildings and transportation networks, so as to ensure the maximum degree of economy, convenience, and beauty (Ralphs & Wyatt, 2003).

Urban Planning: A municipal department responsible for developing the urban landscape in a way that allows social services, housing, education, and employment opportunities to be accessible to all inhabitants, and is at the same time harmonious with the natural surroundings (Birkin, Clarke, G., Clarke, M. & Wilson, 1996). Urban planning strives to maximize land-use while preserving the natural identity of the landscape.

Land-use Planning: The process in which the planner weighs various information, interests and values against one another in a regulated and defined process before making a decision regarding how a parcel of land will be used in the future (Grinderud, Holten, Lillethun, Nillsen, Rasmussen & Sanderud, 2009). By receiving information from municipal zoning plans the planner can produce a master plan to determine how and for what purpose a parcel of land is most frequently used.

Since the 1970s, the study of land-use has been a very important area in GIS applications (Coppock & Rhind, 1991; Tomlinson, 2011) and has played a critical role in securing the acceptance of GIS in the policy domain (Bibby & Shepherd, 1999; Campbell, Masser, Poxon & Sharp, 1994). Throughout the history of GIS there has been a relationship between GIS applications and land-use analysis (Bibby & Shepherd, 2000). By analyzing the characteristics of a land parcel the planner can determine how it should be used in the future.

CHAPTER 1

INTRODUCTION

Introduction

In the increasingly global twenty-first century, technology has become very important. Today, numerous professions require the use of technology, one of these being the Geographic Information System (GIS) (Timmermans, 2004). This new computer system has become an important tool when surveying the landscape where natural or unnatural changes occur. This research will explore some of the ways GIS is used in urban planning to improve the efficiency and effectiveness of the planning process, taking under consideration an appropriate use of the environment. More specifically, three topics will be considered of relevance for this study: GIS, GIS and urban planning, and GIS and land-use analysis.

The latest uses of GIS have defined this emerging science as a computer based system that combines a variety of information ranging from computers to people, to be applied geographically to solve management operations strategically, as mentioned in (Couclelis, McMaster, &Nyerges 2011). This definition encompasses three important aspects of GIS: the social, the environment and the applications in projects that will serve the purposes of this study.

In response to the growing pressure in urban development in Saudi Arabia, the government has created an urban land use plan (High Commission for the Development of Riyadh, 2007). The objective of the land use plan is to respond to a growing interest in Saudi Arabia's economic development generated by an urban growth in its cities (High Commission for the Development of Riyadh, 2003). One of these cities is Riyadh; the capital city of Saudi Arabia, that has experienced an incredibly rapid development in various fields. A massive expansion of industrial activity has also led to an increase in the number of factories sprawling within cities with a negative impact on the environment.

This land use plan is responsible for managing urban development plans at the national and municipal levels that focus on transportation, energy, water, agriculture, and industrial sectors (Ministry of Economy and Planning, 2011). Its goal is to provide developers with a basic land use plan, and supervise them following accepted policies (High Commission for the Development of Riyadh, 2003). This strategy has been used in the development of various sectors, including the industry, one of the most productive sectors contributing to the national income.

The Riyadh Municipality began using GIS in 2001 following the establishment of a special unit called Geographic Information Systems, which falls under the management of the General Administration of Urban Planning (GIS Centre, 2008). The objective of the unit at that time was to create a basic digital map of the city of Riyadh in conjunction with approved building plans (Riyadh Municipality, 2012). This objective became especially important in 2005, when the GIS Centre was put in charge of a three-phase plan (Riyadh Municipality, 2008).

The three-phase plan strives for maintaining an updated databases map and building applications for all municipal departments. At the same time, this GIS Centre expects to create studies that will aid the decision making process, which will be augmented through applications for an organized urban development.

The Centre connects all of Riyadh's provincial departments and is responsible for providing services to the municipality departments and the public through the preparation and implementation of GIS applications. The ATM Monitoring System application, System of Records of the Technical Committee application and the Land Survey Report application are three examples of work produced by the Task Force Centre.

This research will examine the feasibility of using GIS in urban planning in Riyadh by: 1) examining The different ways GIS can be; 2) assessing existing industrial land use conditions as well as critical issues that the city presently faces in planning; 3) analyzing current GIS applications being used by Riyadh Municipality and the GIS Centre; and 4) recommending improvements to urban land-use planning through enhanced GIS applications. This research concludes that a step-by-step approach that can be embedded into ArcMap Software that is currently being used by the Task Force Centre would be the optimal solution. Advantages and disadvantages of the approach are critically examined, including a discussion of future goals for this project.

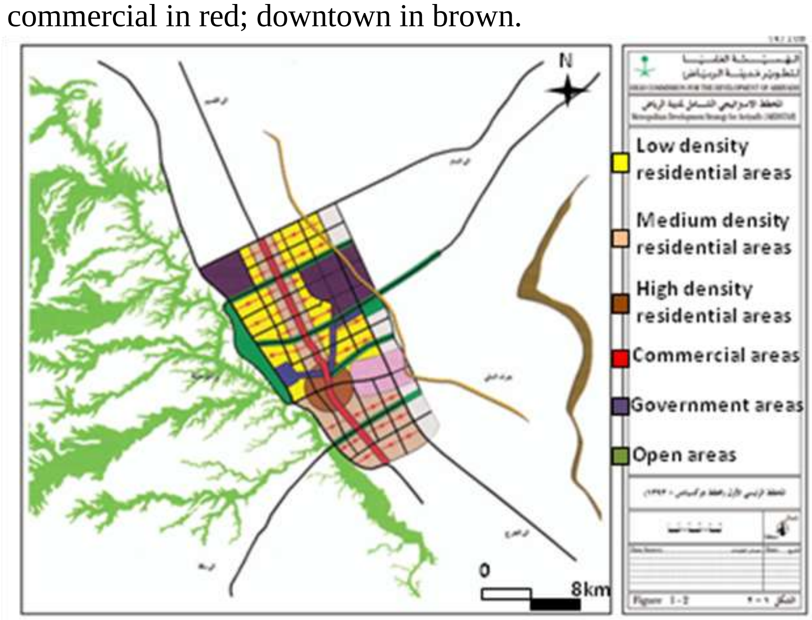
History of Riyadh's Development

When one compares the new versus old areas of Riyadh, a city which is located in the centre of Saudi Arabia, they will see that it was created over a period of time (Figure 1.1) (Ministry of Economy and Planning, 2011). The capital city of Riyadh grew and developed into its present day size from a small village, surrounded by the vast desert plateau of Najd. Since that time to half a century ago, the city's growth occurred at normal rates; less than one square kilometer was inhabited by fewer than 10,000 people, whereas 8 square kilometers was home to about 60,000 individuals. However, since the beginning of the last century urban development in Riyadh has taken a new turn (Riyadh Municipality, 2011).

Today, Riyadh has a population of 4.8 million people, which increases annually by four percent; and a physical area of 2,435 km^2 (High Commission for the Development of Riyadh, 2007). However, the overall growth of Riyadh took place in three phases, the first of which started in 1971 and was carried out by a company called Doxiadis, hired by the Saudi government (High Commission for the Development of Riyadh 2003). Since plans were designed with the help of Doxiadis, one can see similarities between the physical layout of Riyadh and that of Western cities (Riyadh Municipality, 2011). During the first phase, growth occurred in a northward direction parallel to the Hanifa Valley, which runs along the north-western to south-western length of Riyadh (High Commission for the Development of Riyadh, 2007). The overall structural design during this era was to create neighbourhoods with a 4 km^2 area (Figure 1.2). Their goal, by 1985, was to expand the overall size of Riyadh to 300 km^2, with residential areas comprising 150 km^2, housing a total of 760,000 inhabitants (High Commission for the Development of Riyadh 2003).

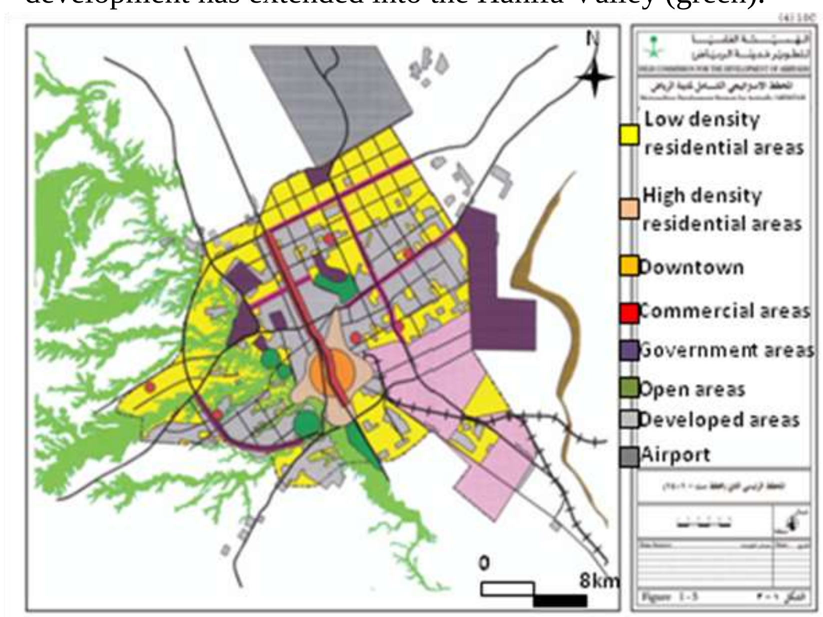
Figure 1.1 Location of the city of Riyadh.

Figure 1.2 First phase of Riyadh's development; residential areas in yellow; commercial in red; downtown in brown.



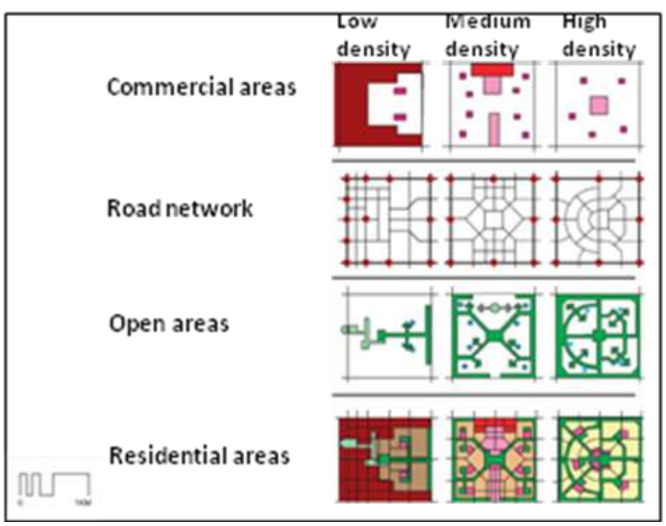
The second phase of development started in 1976 and was carried out by a company called Sit International (Riyadh Municipality, 2011). Their goal was to further expand the size of the city to an area of 850 km^2 by the year of 1990, which would accommodate a population of 1.6 million people (High Commission for the Development of Riyadh 2003). During this phase, development of the 4 km^2 neighbourhoods took on a new style, as they no longer included just residential homes, but commercial areas as well (Figure 1.3). This new addition showed a small movement towards acknowledging the fact that cities need to be well integrated.

Figure 1.3. Phase 2 of Riyadh's development; residential areas contain commercial areas; development has extended into the Hanifa Valley (green).



The third phase of development began with a population of 1.4 million in 2000, which rocketed to 4.8 million by 2009 (High Commission for the Development of Riyadh, 2003). One of the central goals of this phase is to expand the total area of the urban context of Riyadh to 4900 km^2 with a projected 7.2 million people by 2023 (Figure 1.4) (High Commission for the Development of Riyadh, 2007). However, not all aspects of phase three development were intelligent decisions. For instance, one large industrial area was created in the south end of Riyadh, instead of spreading out the industries along the outskirts of the city (Ministry of Commerce and Industry, 2009). This shows a lack of concern for the effects of pollution on neighbourhoods situated next to the southern industrial end. As well, during this time a central commercial area was created in Riyadh, in addition to ensuring that commercial services were evenly dispersed throughout the city's neighbourhoods (Figure 1.5) (High Commission for the Development of Riyadh 2003). Also, ditches which were once made to divert water during the occasional rainstorm were filled in to create flat building surfaces onto which new businesses were constructed; consequently, rainstorms often result in partial flooding of streets.

Figure 1.4. Top row shows commercial area with high density on the left and low density on the right; second row shows road networks; third row shows green space; last row shows all three rows combined into a neighbourhood design.



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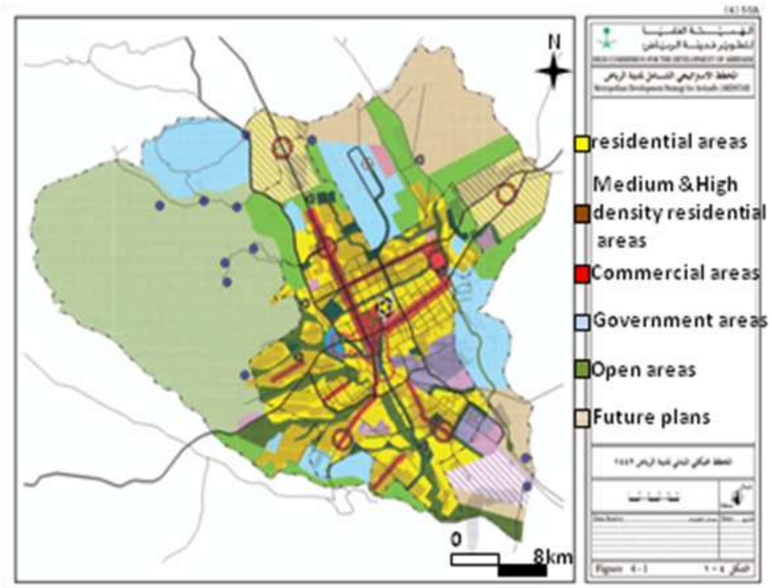


In addition to these illogical methods of development, which are likely the result of the oil revolution that has led to developing cities rapidly regardless of whether an ecologically sound approach is implemented, decisions made during phase three often ignored wildlife and nature (Presidency of Meteorology and Environment, 2011). A case in point is the Hanifa Valley which is home to a variety of flora and fauna. The environmental significance of this natural feature of Riyadh is unrecognized by the government and public; instead the government treats the Hanifa Valley as recreational land for the public’s use (High Commission for the Development of Riyadh 2003). The Hanifa Valley which extends a length of 80 km across the western axis of Riyadh, varies in depth from anywhere between 10 to 100 metres. During the flooding season the valley is capable of retaining an area of 4000 km^2 of flood water. As well, with 40 tributaries running off the main waterway, the Hanifa Valley can contain a volume of 700,000 cubic meters (Figure 1.6) (High Commission for the Development of Riyadh 2010). It is clear that the Hanifa Valley is a natural feature that should not be ignored by city officials or the inhabitants of Riyadh.

Figure 1.6. Hanifa Valley (top); Hanifa Valley (green) in relation to Riyadh (bottom).

There are several negative results of mismanaged development that Riyadh's municipal government is still trying to combat, such as adverse impacts on the environment. For instance, many designs are made without taking into account Riyadh's natural topography. Hills and valleys are made flat simply to make better building surfaces onto which businesses and homes are constructed (High Commission for the Development of Riyadh 2003). As well, the industrial area of southern Riyadh is continually growing without considering the harmful effects pollution has on surrounding neighbourhoods. In addition, transportation networks have been constructed in a way that makes them exclusively used by cars, which in turn rely on oil (Figure 1.7) (Ministry of Economy and Planning, 2011). Riyadh has failed to tap into other forms of transportation such as buses and a metro system. Even simple features such as pedestrian pathways for travelling by foot from one area to another are a rare sight in the capital city. All of these examples are side effects of ineffective planning.

Figure 1.7. Riyadh's road network which has been designed for motor vehicles only.

In the past, especially during the first and second phases of Riyadh's development, the method of planning that was implemented did not show an understanding of Riyadh's natural ecosystems. This is somewhat understandable as the designs that were created during these initial phases were carried out by foreign companies that first, probably didn't have extensive knowledge about the natural features of Saudi Arabia and secondly, the employees perhaps didn't have a strong personal interest in seeing appropriate development take place as this wasn't their home country. However, it seems that the main fault of past development was that plans lacked a systematic approach.

GIS Centre (Task Force Centre)

Riyadh, the capital city of Saudi Arabia, has experienced rapid growth over the past decade (Riyadh Municipality, 2012). The municipal government has tried to respond to this problem by implementing technological resources, developing a three stage project, and creating a Task Force Centre that employs city planners, geographers, computer programmers, and network specialists (GIS Centre, 2008). The Task Force is engaged in training its employees in the applications of GIS taught by ESRI, a software company specializing in geodatabase management. In addition to the Task Force, members within each of the fifteen municipal districts are also being trained in ESRI's GIS applications. The Task Force has already completed stage one of the project.

The first step completed in stage one was the establishment of a Task Force Centre and the recruitment of qualified professionals who would work towards achieving the three stage project (Riyadh Municipality, 2012). The Task Force Centre was an entirely new department created within Riyadh Municipality and as such, offices, equipment, and networks needed to be set-up (GIS Centre, 2008). Once the Task Force became a functioning entity and everything was put into place they then began collecting information about infrastructure from all of Riyadh's municipal departments (Riyadh Municipality, 2008). The information gathered was then complied into a Base Map using GIS software provided by ESRI. The Base Map is a geodatabase that provides the reader with information regarding Riyadh's infrastructure, including but not limited to transportation networks, sewer systems, electrical grids, and residential and commercial areas. By clicking on different areas of the map the reader is able to access infrastructural information specific to that particular location of the city. Once the Base Map was fully completed, the Task Force was able to move onto the next stage.

The Task Force is currently in the second stage of the project which consists of analyzing the Base Map's visual representation of Riyadh, as well as the geodatabase that has been embedded within it (GIS Centre, 2008). The Task Force will also examine the location of all infrastructural components with respect to one another and areas of the city which are in need of further development or improvement (Riyadh Municipality, 2008). New information obtained by any of Riyadh's fifteen municipal districts is automatically sent to the Task Force Centre to ensure that the geodatabase is constantly updated. From the analysis of the Base Map, a list of priorities will be developed by each district, who will then request the Task Force to create applications relevant to the district's needs. Currently, the applications being designed provide only businesses and real estate developers with access to information that may be require in the construction process and facilitate the procedure of obtaining building permits. Finally, in order for inter-communication to occur among all sectors of Riyadh Municipality, it is imperative that the Task Force Centre be linked to all of Riyadh's municipal departments and districts.

In the third stage, the Task Force will focus on aiding municipal departments in their decision making processes, by compiling and presenting information pertaining to the issue the department is trying to remedy (GIS Centre, 2008). During stage three, it is hoped that the Task Force Centre will also be connected to all of Riyadh's provincial departments, in addition to the municipal departments and districts (Riyadh Municipality, 2008). Similar to the other two stages, in stage three the Task Force will continue to update its geodatabases using information it obtains from provincial and municipal departments, as well as municipal districts.

The Task Force Centre has a positive effect on the way city planning is now taking place. In the past it was predominantly geographers and programmers who used GIS applications; city planners did not have much training in this technology. However, the establishment of the Task Force Centre and the use of GIS software have created an opportunity for geographers, programmers and city planners to work together; with geographers ensuring that the coordinates of digital maps realistically represent the area of land in question, programmers creating applications that are relevant to the needs of the public and government, and city planners ensuring that development is occurring according to regulation. The cooperative effort among members of the Task Force is sure to result in more effective urban development of Riyadh.

The current software being used by the Task Force in Riyadh Municipality provides tools for creating maps that are embedded with geodatabases and can be updated as needed, however, it does not provide planners with a laid out approach or a series of steps for changing already existing sections of the city, or developing new areas. If the software program were to have a general approach that city planners could follow its popularity would increase. Of course, the approach would have to be updated annually so that it would remain relevant and useful, and it would have to be compatible for improving existing areas, as well as developing new areas of Riyadh.

GIS technology will be required to bring this approach into existence and create it in a logical and sequential fashion that will not simply focus on creating maps from geodatabases. Generally, when one hears the acronym 'GIS', they automatically think of maps with layers, and an example that illustrates this is a case study that examines how GIS can be used for rural land use and livestock policy within the Selkirk District Planning Area. The case study discusses how the government in this area finds GIS applications useful in making sustainable resource management decisions as the applications allow them to spatially and accurately display information through maps (Boles, Glavin, & Kalztzke 2007). These spatial representations help the planners find appropriate solutions to their complex resource management problems.

Problem Statement

From examining the history of Riyadh's urban development and the establishment of its three-phase plan, it is evident that land use management lacks an approach, which can consequently impact the quality of the environment. It is clear that GIS technology has the potential to play a very effective role in urban planning. GIS provides planners with tools that allow them to spatially display infrastructural data and use it to produce maps with layers (Timmermans 2004); however, this is not enough, as GIS has the ability to do far more than carry out these simple functions. In addition to this, Riyadh's Task Force Centre, in and of itself, is not the sole solution to urban planning; it is crucial that planners develop a method that will allow them to establish an approach that will be feasible for the planning process. This method will be accessible through GIS software and can be used anywhere in the world; it is hoped that this method will be the first step to establishing a standardized approach to city planning.

The Objective

The objective of this thesis is to examine the feasibility of using GIS in urban planning in Riyadh. This objective will be addressed by:1) Examining the theoretical aspects of GIS in land use and which will look into the different ways GIS is used and the tools that are available to the user; 2) Assess the existing land use conditions of Riyadh in terms of industrial areas and will examine the critical issues that the city presently faces.

3) Provide case-studies for the application of GIS in Riyadh Municipality. This will include an analysis of the usefulness of the applications created by the Task Force Centre, and potential ways of improving these applications; 4) Recommending improvements to urban land-use planning through enhanced GIS applications.

This research concludes a step-by-step approach that can be embedded into the GIS software that is currently being used by the Task Force Centre. It is hoped that using a method for city planning such as this will lead to a more efficient and effective planning process for city planners. Both advantages and disadvantages of the method's approach will be critically examined, including a discussion of the future goals of this endeavour. A variety of resources will be used in the research process; information will be obtained from the King Saud University, Riyadh Municipality, The High Commission of Development for Riyadh City, Saudi Industrial Property Authority, the GIS Agency, and the University of Manitoba.

Methodology

The methods employed in the study of GIS applications will be qualitative, and will assess the feasibility of GIS in urban planning in Riyadh through the use of a GIS method, which in turn will support city planners in the process of making decisions. In today's modern era, the means for developing an approach will inevitably come from technology, and in this case from GIS. It is hoped that a general step-by-step approach will be created within GIS software, and that this approach will eventually be adopted on a global scale. Case studies showing how GIS can be used and applied in urban designs, and through this give rise to an approach to urban planning will be examined in books and journals, and the knowledge I have gained from the four courses with ESRI Canada.

Through the use of maps and data from the Comprehensive Summary Report for Riyadh, the city's three phase plan will be examined, including Riyadh's existing land uses conditions. Reviewing Riyadh's current city planning process will highlight its disadvantages, especially the fact that it lacks a step-by-step approach to guide city planners through the planning process.

At this point, it will also be important to review how ESRI's GIS applications are currently being used in Riyadh Municipality, specifically within the Task Force Centre. In addition to the Task Force Centre, the GIS applications developed for each municipal district must also be analyzed, for the sake of proving that Riyadh's current urban planning process lacks a systematic approach.

The next stage is to develop a strategy for introducing a method within GIS that can then establish a general approach for city planning. The first step of the strategy will involve collecting a variety of information about GIS applications to show how GIS can be used in urban planning. Step two will involve collecting data about Riyadh's past and present urban plans to demonstrate that the planning process lacks an approach. In step three, data about GIS applications used specifically within Riyadh Municipality will be collected to show that their applications simply focus on making maps and organizing data.

It is hoped that all of these steps will help develop the fourth step, which is creating a method that is the first of its kind, which can be used for developing city plans. It is hoped that this method will be the first step to establishing a standardized approach that can be used by city planners around the world. This method will not simply focus on analyzing data, but will show the best alternatives for each planning project depending on the data that is stored within the geodatabase. However, one weakness of this endeavour is that the method will not be accessible to any person as a costly software license is necessary to access the method.

CHAPTER 2

Defining GIS's Scope in Land Uses

Introduction

In the increasingly global twenty-first century, technology has become ever more important. Today, numerous professions require the use of technology, and as a result professionals must know how to use technology to their benefit; one of these being Geographic Information Systems (GIS) (Timmermans, 2004). To be successful, professionals working in the field of GIS need to be aware of all the opportunities GIS has to offer, and have a clear understanding of the basic elements of GIS.

Almost thirty years ago, geographers conceived a system for storing and organizing spatial information in a computer software format (Goodchild, Lomgley, Maguine, & Rhind, 1999). GIS, which has evolved immensely over recent years, consists of high quality applications that are capable of land-use planning, natural resource management, environmental assessment and planning, demographic research, utility service distribution, and business applications (Avelar, Tavares-Correa & Zuh, 2009; Changhe, Huiyi & Xiubin, 2004). The applications and tools of GIS have the capacity to store, manipulate, analyze, and present any type of information (Ghaemghami, Kolodziej, Lejano, Maharjan, Plant & Sassa, 2004; Craig, Harris & Weiner, 2002). This chapter will explore some of the ways GIS is used in urban planning to improve the efficiency and effectiveness of the planning process. More specifically, three main topics will be of significance: defining GIS, GIS and urban planning, and GIS and land-use analysis.

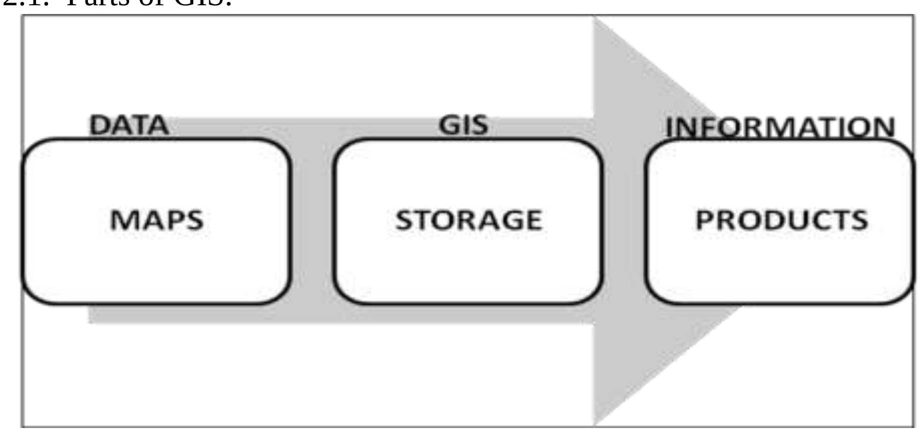
Defining GIS

In the 1980s, a definition of GIS was developed by a group of researchers, software industry experts, and US Federal Agency Personnel who stated that GIS is a combination of people, data, hardware, software, procedures, and institutional arrangements for collecting, storing, analyzing, manipulating, and displaying information about spatially distributed phenomena for the purpose of problem solving within management operations and strategic contexts (Couclelis, McMaster & Nyerges, 2011). This definition highlights three key aspects of GIS. First, it illustrates the fact that GIS has a social aspect; the data and machines that physically comprise GIS would be useless without people and institutions that operate them. Second, the field of GIS is about more than just accumulating geographical data; it is about the presentation of the data in relation to the surrounding environment. Lastly, GIS applications have an important role in public governmental projects, and should not be viewed exclusively from a profit making perspective.

GIS

By examining the individual words that form the acronym, GIS, one can see that it is a field comprised of several different subjects, the most apparent being geography. The academic study of *geography* investigates the places and spaces of our planet and analyzes geographic information to explain natural phenomena (Fisher & Unwin, 2005). *Information* is a record of facts that becomes useful when interpreted and assimilated in a certain fashion (Ralphs & Wyatt, 2003). A *system* includes the computer hardware, software, and the tools employees use to input, analyze, manipulate, and present GIS data (Korte, 2001). *Geographical Information* is data that contains geographical references relating to a specific location. *Information Systems* are the hardware and software capable of processing certain information within a given time. Inclusively, GIS is a group of information systems specifically designed to process, manage, and visually represent geographically referenced data (Ralphs & Wyatt, 2003). Evidently, GIS has three essential features: its ability to map, store and analyze geographically referenced information about the Earth; a level of functionality determined by the creation of suitable applications; and its versatile, multi-use nature which is determined by the quality of applications created by software companies (Figure 2.1).

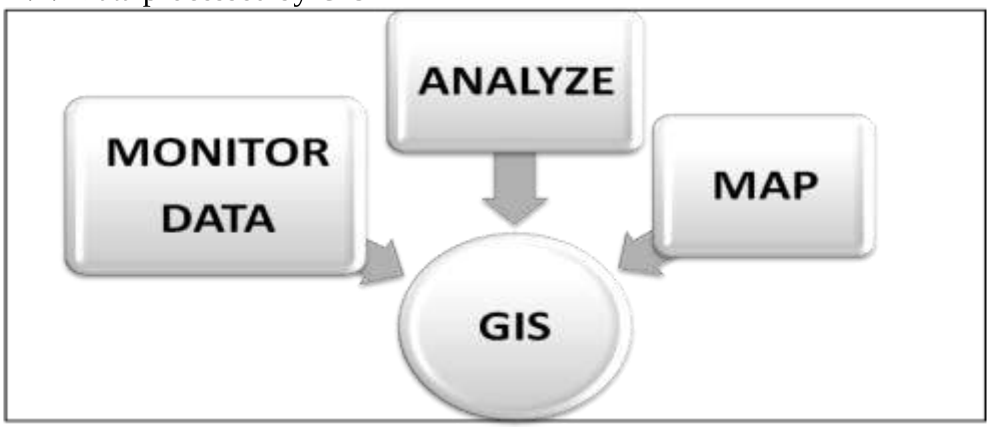
Figure 2.1. Parts of GIS.



Uses of GIS

In recent years, GIS has proven to be an important development in information technology (Gupta & Nair, 2010). The integration of GIS into fields such as urban planning has helped resolve management and logistical issues (Lewis, 1997), as GIS has the ability to map, analyze, and monitor data, making it possible to visually represent the surrounding geography (Figure 2.2) (Grinderud, Holten, Lillethun, Nillsen, Rasmussen & Sanderud, 2009).

Figure 2.2. Data processed by GIS



Since the 1970s, GIS has been used to identify land suitability for several different purposes, including potential business development (Gupta & Nair, 2010). In this area, GIS has proven to be an effective tool as it enables the planner to immediately collect and manage all data relevant to a plot of land, such as soil type, topography, land use, vegetative cover, and climate (Aggett & McColl, 2007). Businesses that are considering whether to invest in a plot of land have a substantial stake in the viability of the land, and need planners to determine water resources, infrastructure, and geo-environmental and climatic conditions present (Gupta & Nair, 2010).

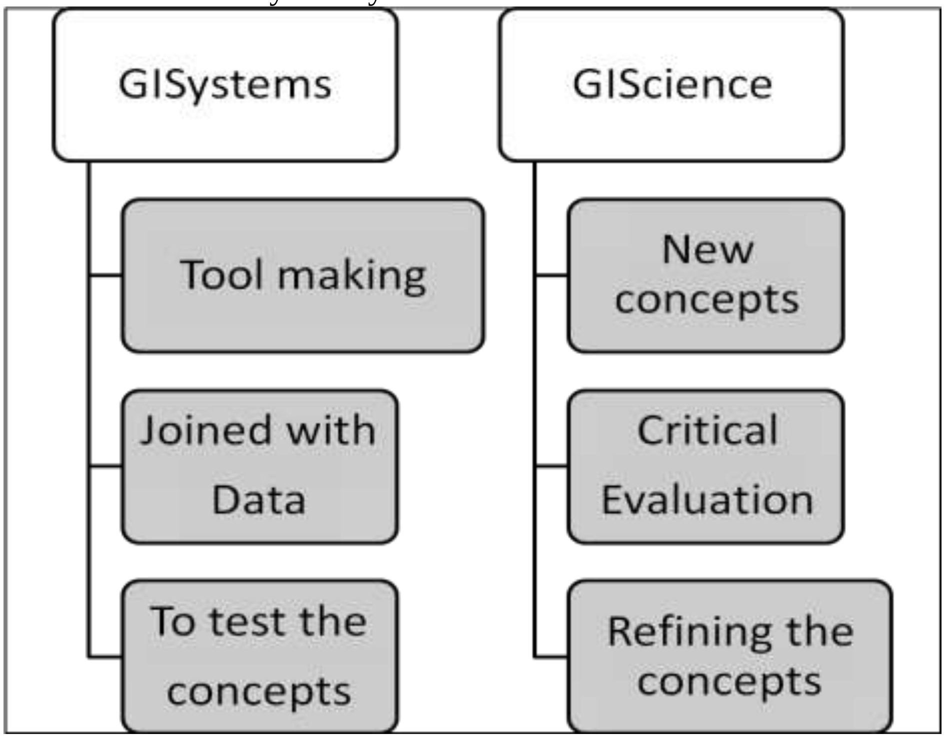
The collection, storage, and presentation of data in GIS allows planners to efficiently reach a decision about a plot of land, in terms of its ability to meet the needs of a future business. GIS enables all the features and data pertaining to a map to be organized into a table of contents, allowing the user to select data relevant to a specific task. The dynamic nature of a GIS mapping program is that it allows the user to add layers to a basemap as new information is discovered. For example, a social analyst in Eugene, Oregon selected datasets from the US Census Bureau and added layers to the map of Eugene which depicted employment status, age, and residents' education levels, combining a variety of datasets into one map (ESRI, 2007).

Geographic Information Systems have also been of great use to the public safety sector, with applications allowing the user to quickly view current accidents, access structural photographs, as well as other information relevant to the location (Anonymous, 2005). As a tool, GIS can be used in a variety of disciplines, with its geographic advantage allowing the user to become more productive, aware and responsive to the environment.

GISystems & GIScience

GISsystems and GIScience are interrelated, with GISystems focusing on software applications and GIScience focusing on the theoretical aspects of Geographic Information Systems. Together, both GISystems and GIScience give rise to GIS tool making components (Figure 2.3) (Fisher & Unwin, 2005). In order to create tools for GISystems, computer programmers must have knowledge of GIScience. GISystems, GIScience, and tool making are so intricately connected that it would be impossible for one to exist without the other.

Figure 2.3. The GIScience–System cycle.



GIS & CAD

Technology is widely used by many professionals, including engineers, architects, and planners to draw and design plans and maps (Korte, 2001). Geographic Information Systems and Computer Aided Design software are both programs used by urban planners, with GIS having more advanced capabilities than CAD. Unlike CAD, maps created with GIS software are embedded with a geographical coordinate system, making any location on the map identifiable in reality (Korte, 2001). In GIS, the entire area being mapped is divided into separate files with all of the data concerning the map's individual layers being complied into one geographically referenced map file (Korte, 2001).

Computer Aided Design, on the other hand, can be used to create a map with layers, but the user is unable to incorporate geographical coordinates into the map. As a result, the user would not be able to determine the location of two intersecting roads in relation to the rest of the world (Korte, 2001). Whereas in GIS, a relationship exists between the spatial elements and data files in what is known as data topology, which describes the locations and geometry of the map's features; this property is not present in Computer Aided Design.

GIS and Urban Planning

Geographic Information Systems has multiple uses and functions within the field of urban planning. An invaluable tool, GIS has proven to be tremendously beneficial to urban planners, aiding them in the decision making processes of their projects. However, as a tool GIS requires human judgement to effectively manipulate the technology (Carver, 1991), and for optimal results in an urban planning project, GIS must be used within a pre-established set of policies (Malczewski, 1999; Alshalabi, Bin Ahmad, Bin Mansor & Shiriff, 2006).

In terms of the general administration and development control of a project, there are three GIS applications that are of great significance (Yeh, 1999). The most apparent application is the use of GIS as a tool to support the land-use planning process. As well, GIS is used to assess the land's suitability for the proposed project, and to determine the feasibility of the new development. Finally, GIS serves to forecast the effects of the project on the surrounding environment (Couclelis, McMaster & Nyerges, 2011). It becomes clear that in urban panning GIS is a tool that helps determine how geographic resources should be utilized, and aids the planner in determining how to redevelop an already developed parcel of land. Additionally, GIS helps synthesize and present all of the information regarding land-use and the environment that is relevant to the project and the natural landscape.

Urban Planning Before GIS

Prior to the introduction of the innovative applications of GIS technology to urban planning, land-use and zoning maps were created and updated with ink and paper by skilled draftsmen. The maps depicted parcels of land, major streets, and landmarks. Due to the small scale of the maps, with each inch on the map representing 1,000 feet of land, they were very difficult to label, and so draftsmen were required to construct a text map, which decoded the symbols drawn on the official map. As planners acquired new information about land-use patterns they would update the official map. Unfortunately, planners would often fail to update the text map and over time this resulted in conflicting data between the text map and the official map.

The current use of GIS technology within the field of urban planning has greatly diminished the margin of error that was observed during the time of text and official maps (ESRI, 2007). Instead of having to cross-reference information pertaining to specific parcels of land between the text map and official map, GIS software has simplified the process by compiling all geographic data into one user-friendly system (Korte, 2001). The digitization of the urban landscape through GIS technology has allowed for a dynamic online medium through which maps can be continuously reviewed, updated, and managed (ESRI, 2007). GIS benefits planners by allowing them to make more effective decisions for their projects, conduct special planning studies at faster rate, and has reduced the project review timeframe.

GIS and Land-use Analysis

Geographic Information Systems has the potential to make immense contributions to the field of urban analysis, in terms of land-use analysis, and is necessary for effective city planning. In San Diego, urban planners have identified parameters for a potential expansion project of the city's boundary. Planners have met with the developers to establish the goals of development which take into account the existing infrastructure, protection of established parks, and the preservation of the natural landscape. The use of GIS software has enabled planners to create a map of San Diego highlighting the city's characteristics, and through landscape analysis has allowed them to identify the best route for expanding the city's perimeter (Keranen & Kolvoord, 2012). By conducting land-use analysis, planners are able to identify the best route for the expansion of San Diego.

Urban planners have also used GIS to determine how land is occupied by various types of buildings. By creating a digital map of the city, planners can add consecutive layers corresponding to specific building types. A map of this kind allows the planner to identify which buildings have been inappropriately located in terms of the surrounding land-use characteristics. All buildings that are identified as being unsuitably located must be corrected. For example, in Ichikawa, Japan a manufacturing plant located in a residential neighbourhood was identified as an unsuitable building with regards to the area's surrounding land-use. Multiple situations exist where an unsuitable building has been identified in terms of the city's current land-use policy, but was constructed before these laws came into effect.

GIS allows the planner to easily identify which buildings would be classified as illegal under current municipal laws (Table 2.1) (Kohsaka, 2001; Ohba, 1992). Table 2.1 shows the number of unsuitable buildings in Ichikawa, with 12.7% of the buildings in a quasi-industrial area being classified as heavy chemical facilities, and as such, unsuitable for their location (Webster, 1993). GIS offers tools that allow for the efficient analysis of the urban landscape and its land-use patterns.

Table 2.1. Unsuitable buildings in Ichikawa.

Classification of Areas	Quasi Industrial	Industrial	Industrial exclusive
Unsuitable Area Ratio	12.7	1.65	0.87

Many cities are experiencing development at unprecedented rates. The haphazard manner in which some development projects occur creates deleterious effects on the city's landscape. Today, the land and environment have to endure a tremendous amount of pressure as buildings are continuously torn down to construct more modern and appealing versions. An examination of any city will show how incredibly complex an urban landscape is, with all of its individual components fitting together into one functioning unit. It is of great importance that new developments are sustainable and well thought through; the eventual consequence of the misuse of land is its transformation into wasteland.

Geographic Information Systems can be used to prevent ineffective development of the urban landscape, as it provides a very organized classification system in which the planner can map, monitor, identify, and forecast the location and type of land-use problems likely to arise. Table 2.2 demonstrates how GIS uses a combination of photo interpretation, spectral analysis, and data integration to describe the different land-use categories (Kumar, Kumari & Tiwary, 2002). By investing time in the study of a region's land-use suitability before constructing a new development, planners can ensure the land is used appropriately and in a manner that can be sustained in the future.

Table 2.2. Land use and their image characteristics.

Land use	Urban land	Agriculture land
Image Characteristics	Light grey	Brownish

Geographic Information Systems can be used to model future land-use distribution patterns as it supports many aspects of land-use planning such as, land suitability analysis, forecasting future land-use demands, allocating land-use demands to a suitable location, and evaluating the future impacts of land-use (Kolsterman, 2001; Johnson & Lachmand, 2001). Although the model does not predict the future in terms of how land will used, it helps forecast what may happen if various future scenarios were to become reality. Through observation and analysis, this model acts as a tool that can determine what would happen if defined policy choices and assumptions regarding land-use were to come into effect in the future (Klosterman, 1999).

In Kittitas County a 'what if' model and GIS were used to identify areas of land suitable for particular types of future land-use. The model consisted of specific factors determined by a planning committee (Klosterman, 2001), focusing on flood zones, hydrology, road infrastructure, and taxation parcel data, producing a comprehensive land-use plan. The model identified regions with hazardous slopes, the cause and creation of the flood zone, and the overall hydrological cycle of Kittitas County, in order to establish criteria for classifying flood plain hazards. From GIS mapping and land-use analysis it was determined that the best location for future growth was beyond a 2 km buffer zone with the major transportation network (Aggett & McColl, 2007). The integration of GIS and a land-use model helped planners determine possible future impacts on the land and to plan the development of Kittitas County accordingly.

Cities and counties that want to attract industries must find suitable sites which fulfill the requirements of the prospective company, and match the industry's needs with the right resources. In Virginia, GIS was used to identify the industrial sites within its boundaries. Several factors were considered when determining which sites were suitable for further industrial development, such as soil features, geology, zoning, land-use regulations, accessibility to transportation corridors and public utilities, each having an assigned weighting value. Other factors taken into consideration were geographical and cultural obstacles, such as flood plains, wetlands, national forest areas, and historical districts, which planners had to work around when identifying prospective 200 acre industrial sites. The mountainous terrain in parts of the region presented another challenge, with slope playing a critical role in the land's suitability for industrial use. For this reason, planners classified the land into three slope categories: good (0-10%), acceptable (10-20%), and bad (more than 20%) (Chuck & Kindleberger, 1992). GIS and land suitability analysis helped planners obtain descriptive information about potential sites for industrial development, while seeking to preserve the environment and serve the needs of the surrounding communities.

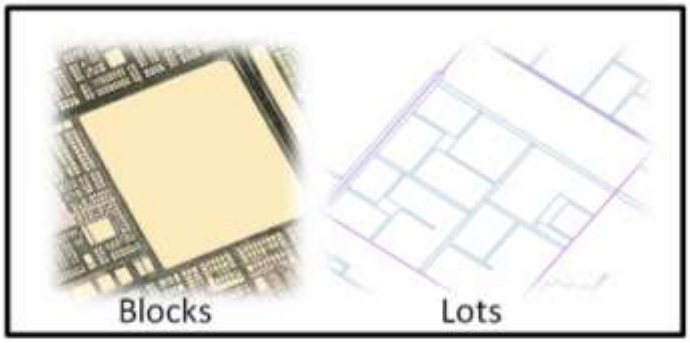
GIS & Industrial Use

Case Study 1- Using GIS to Visualize Land-use in Nagoya City

The local government of Nagoya, Japan uses GIS to analyze land-use distribution in the city and to calculate land-use ratios for each city block. These ratios are then used to create a visual representation of the city's land-use patterns. To calculate the land-use ratios for each city block the planner must determine the number of lots inside the block and obtain the total area of the individual lots. All city blocks were classified into one or a combination of commercial, industrial, and residential land-use categories.

The land-use data was based on information collected in a survey from the year of nineteen ninety-five. Figure 2.4 illustrates that the land-use data consisted of two polygon layers: a large-scale representation of city blocks and a small-scale representation of the individual land lots, with each polygon having its own area data and land-use code (Okunuki, 2001).

Figure 2.4. Block polygon layer and lot polygon layer.



Case Study 2 – Using GIS to Assess Land-use Status in Tosci Village, Turkey

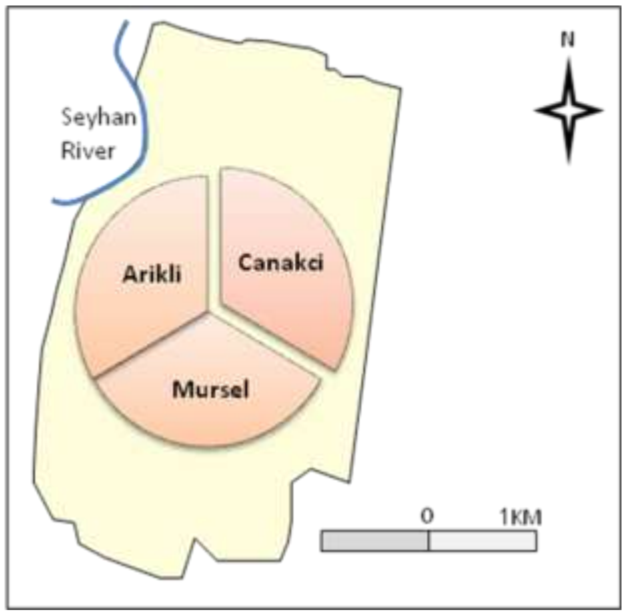
Soil types affect the kinds of crops that can be grown and how much produce each harvest will yield. This study examined crop land-use for three different soil types on a topographically flat 920 ha plot of land, with a slope of 0.5-1% in Tosci, Turkey (Agca et al., 1990). Figure 2.5 consists of a distribution map of the soil series, which is comprised of three varieties: the Arikli series, covering 590.4 ha in the eastern region of the study area; the Canakci series, located next to the Seyhan River and covering 259.7 ha; and the Mursel series, covering the remaining 669.9 hectares.

Table 2.3 shows the Canakci series soil as having a silty-clay-loamy texture with 22-35% of its make-up comprised of clay particles. The high permeability of this type of soil can be attributed to its proximity to the Seyhan River. In contrast, the Arikli series showed wide variability in permeability, as a result of its high clay content ranging from 62-67% (Table 2.3). Due to its low infiltration, high clay content soils of this type need to churned down to approximately 1 m in order to prevent the cracking and hardening of the soil's surface.

Table 2.3. Clay content in some soil series.

Soil Types	Arikli	Canakci	Mursel
Clay Content	62-67 %	22-35 %	25-43 %

Figure 2.5. Proportions of soil series.



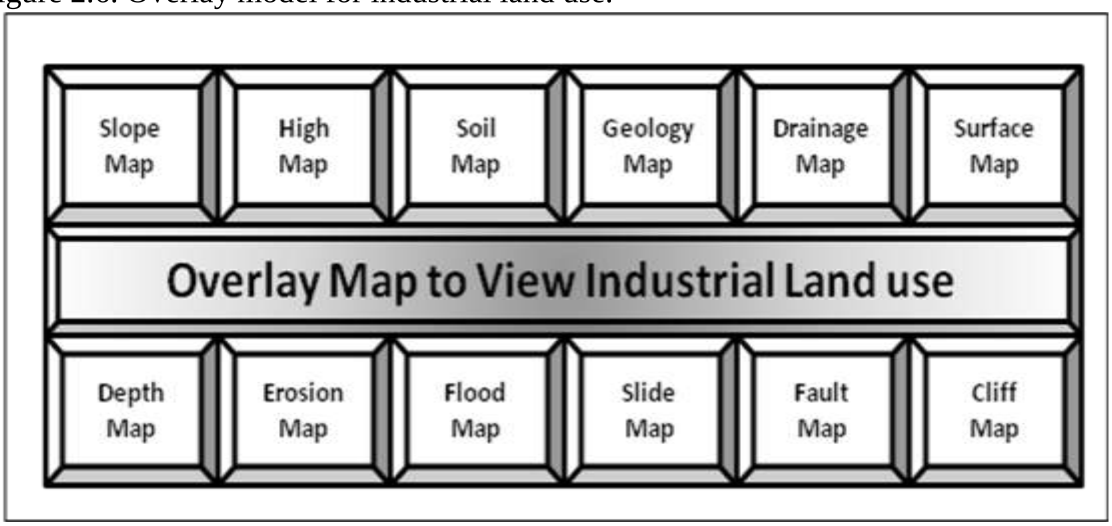
In terms of growing citrus and vegetable crops, the loamy textures of the Canakci and Mursel series proved them to be suitable for all land-use types, unlike the Arikli series with its high clay content. However, when an overlap of soil series and crop growth was conducted, it was shown that a number of crops were not being grown on suitable soil; a result of this inappropriate land-use was low crop yield (Cetin, Diker & Ozcan, 2003).

Case Study 3 – GIS & Industrial Land-use of Enugu Area, South-Eastern Nigeria

The Enugu Area, located in the rainforest belt of Nigeria is undergoing rapid population growth. It is predicted that by 2020 its current population of 3.2 million inhabitants will increase by 300 % and as such, it is important that industrial development in this region occurs in a sustainable yet cost efficient manner, so as not to diminish the quality of life of its future residents.

Twelve thematic maps of land-use determinants were gathered from a variety of sources to help planners identify which regions of the 630 km^2 study area would be ideal for industrial development (Figure 2.6). Thematic maps of land-use determinants included: slope, elevation, soil depth, soil class, geology, drainage, surface water, depth to water table, erosion, flooded/land-slide, fault, and escarpment maps, all of which were data layers in the GIS software and each having been assigned a degree of influence in the decision making process.

Figure 2.6. Overlay model for industrial land use.



After all of the data was collected from the field studies, each thematic map type was classified on a scale of 0-2, inclusive, creating three categories into which the environmental factors were placed: suitable (2), low suitability (1), and unsuitable (0).

The final result of the overlay operation identified areas of suitable land for future industrial development. Section 7 of the map, occupying 10 % of the study area is suitable for industrial development. Section 8, covering 70 % of the study area has low suitability for future industrial development. The remaining 20% of land in section 9 has environmental conditions that are unsuitable for industrial development (Onunkwo, 2011). GIS software helped planners identify which regions of the Enugu Area are suitable for future industrial development.

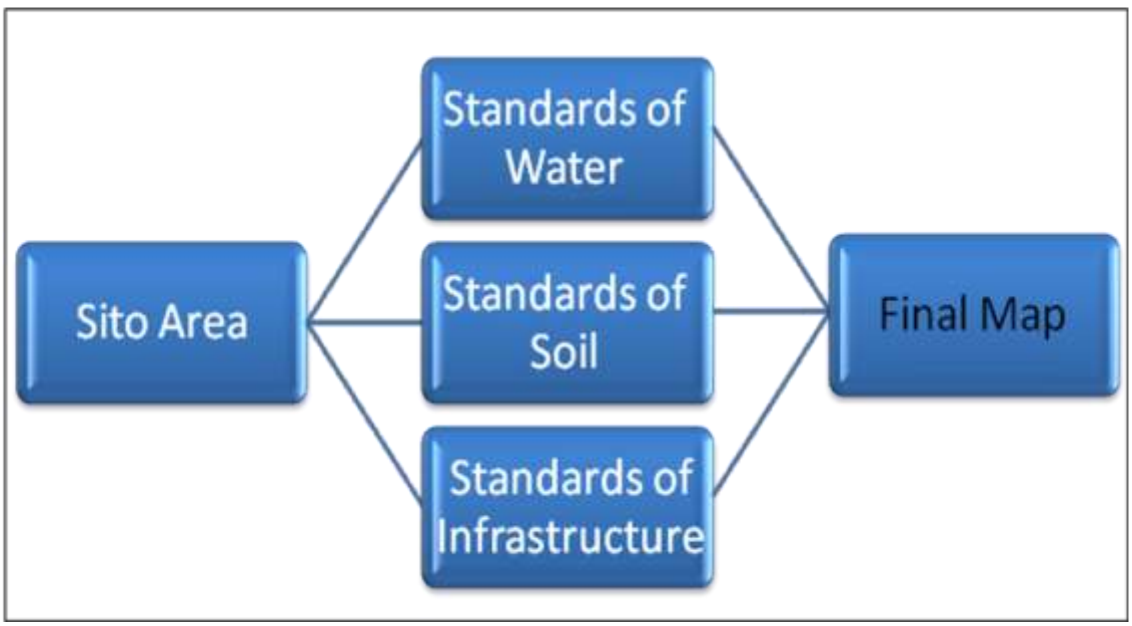
Case Study 4 – GIS Modelling to Evaluate Land Suitability in Noakhali, Bangladesh

Land suitability analysis for prawn farming was conducted in Companigonj of Noakhali, Bangladesh with hopes of improving the quality of life of the poor by providing employment opportunities and a more diversified diet. These economic benefits for the population were seen as achievable with Bangladesh having favourable natural conditions which support aquaculture.

The study area of 22,998 ha was situated in the south-eastern part of Noakhali District with a population of 183,451 inhabitants (Bangladesh Bureau of Statistics, 2004). The aim of the study was to classify the land in this region as being most suitable, moderately suitable, and not suitable for prawn farming so as to achieve better farming results in the future.

Prawn farming site selection was determined through the use of a GIS model with the final output being an overall site suitability map. Figure 2.7 shows the intermediate level for the site selection model as being represented by water quality, soil quality, and infrastructure factors, each of which were paired with bottom level criteria relevant to their respective categories. Themes were derived from all three previous levels which evaluated and weighed the information collected about the study area (Das & Hossain, 2010). GIS was then used to synthesize all of the data into a land suitability map that could be used for planning the location of future aquaculture farms. The generated map from the GIS evaluation showed 11,999 ha (52%) and 10,219 ha (45%) of the land were most suitable and moderately suitable, respectively, for futre prawn farming.

Figure 2.7. Schematic diagram of modeling for Sito selection.



Case Study 5 – GIS Application for Environmental Zoning & Management in Sontay, Vietnam

Sontay, a city located in close proximity to, Hunoi, Vietnam's second largest city, is comprised of 12,000 hectares. Planners want to ensure that urban expansion of Sontay follows rational land-use measures, and as a result have divided the city into four zones: urban settlement, built up area for industry, tourism development, and agriculture. The goal is to employ an Environmental Zoning (EZ) Model to assess and analyze the suitability of future socio-economical development plans.

EZ Model illustrates the process of the suitable land analysis model which is based on the goals and trends of socio-economical planning in terms of economical development and human activities. The assessment of the suitability of human activities in relation to the environment can be carried out once land-use maps have been made for Sontay. The database for the EZ Model includes four groups of information: natural, socio-economical, environmental quality, and trends of socio-economical development (including industrial development plans) (Table 2.4). The land-use suitability results of this model can be determined through the completion of six steps: defining the aim of the assessment process and the main human development activities, establishing the criteria for suitable analysis, incorporating the data into the GIS software, evaluating the output maps and information, and making comments and proposals for the decision making process (Le thi thu, 2008;2009).

Table 2.4. Database for the EZ of the Sontay.

Data groups	Data format	Data layers
Natural data Socio-economical data Environmental Data Trend of economical Development	Raster Point Polyline Polygon	Suitable Maps

Case Study 6 – GIS Application for Detecting Change in Villivakkam, Chennai

The Villivakkam block in the Thiruvallur District of western Chennai, with an aerial extent of 17,609.93 ha has experienced a doubling of its population over a fifteen year time period. In this study a series of satellite images were used to monitor the urban development of this region from the year 1990 to 2005, with satellite images being compared to a topographic map, prepared in 1976, of the Villivakkam block.

Figure 2.8 illustrates the series of steps that were carried out to produce a comparison of land-use between 1990 and 2005. The change detection method classified the land in each image into categories such as agriculture, fallow land, scrub land, industry, and built-up areas. The overall accuracy for land classification of the Landsat image (1990) was 82.14%, and for the IRS- IC LISS III image (2005) 86.46% (Figure 2.9).

Figure 2.8. Flow chart depicting the change detection method

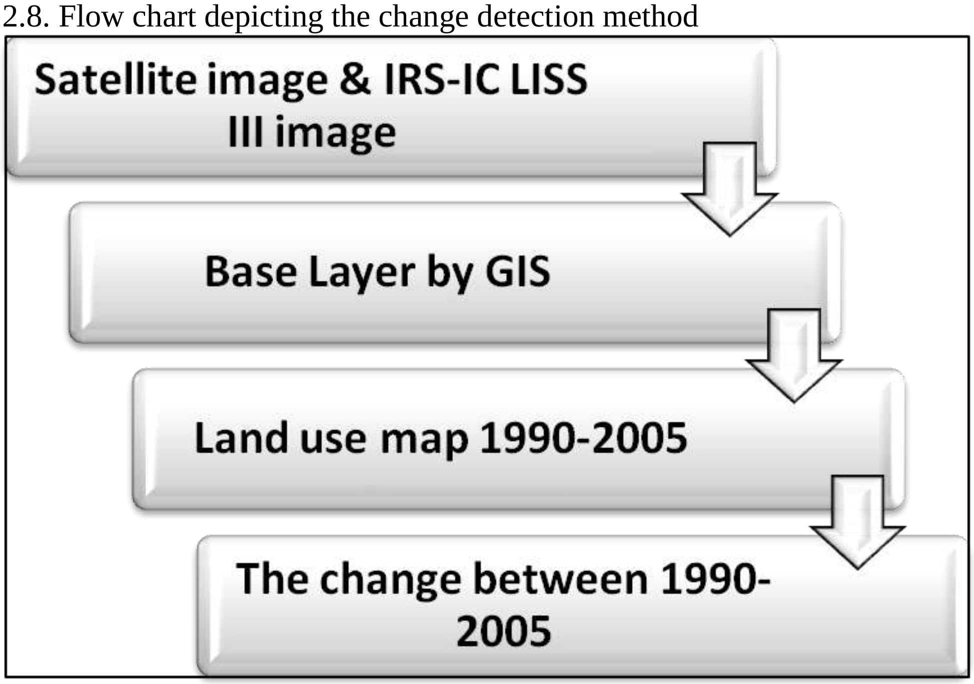
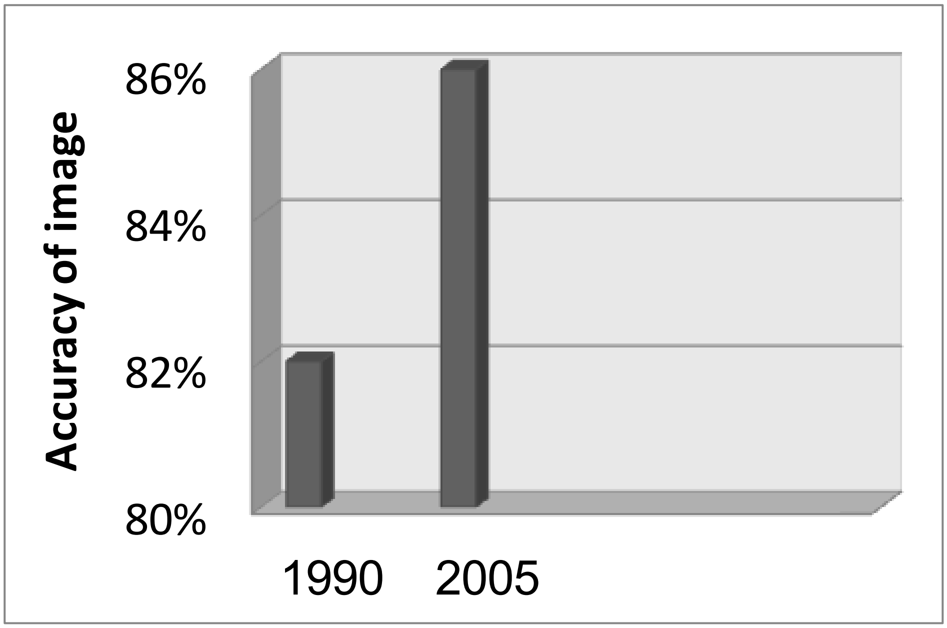
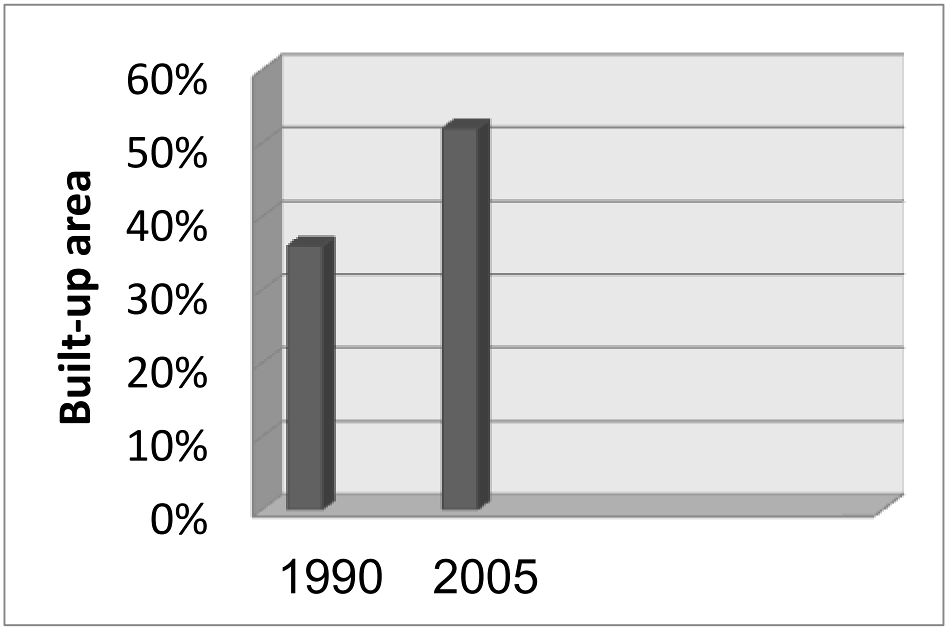


Figure 2.9. Land use chart for the year 1990 (Left), 2005 (right).



The results of the change detection chart show that in 1990 36.99% of the land consisted of built- up areas, compared to 52.82% in 2005 (Figure 2.10) (Manonmani & Suganya, 2010) (Lamine & Yan, 2010). The rapid development of this land has a significant impact on the area's natural resources; potential solutions to this problem may be achieved through the use of GIS.

Figure 2.10. Change detection chart for the year 1990-2005.

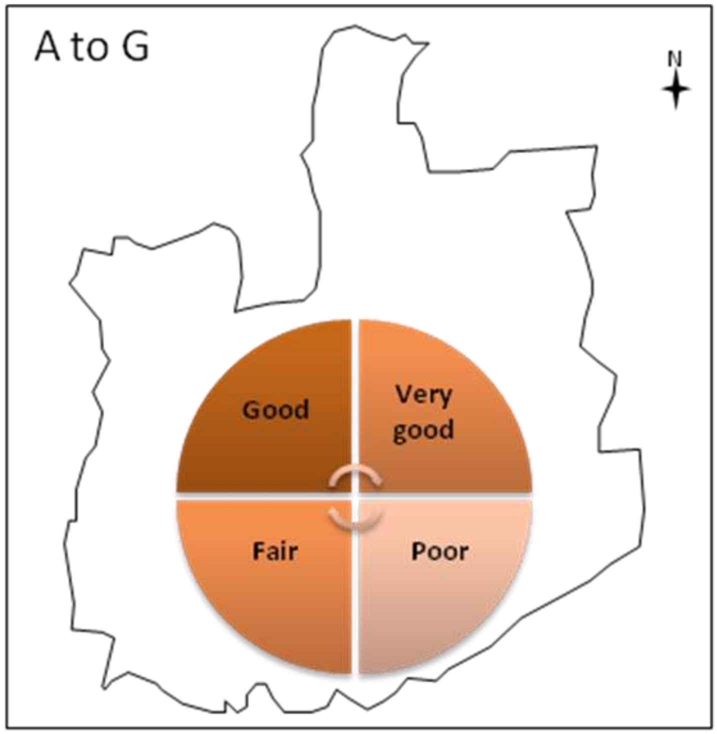


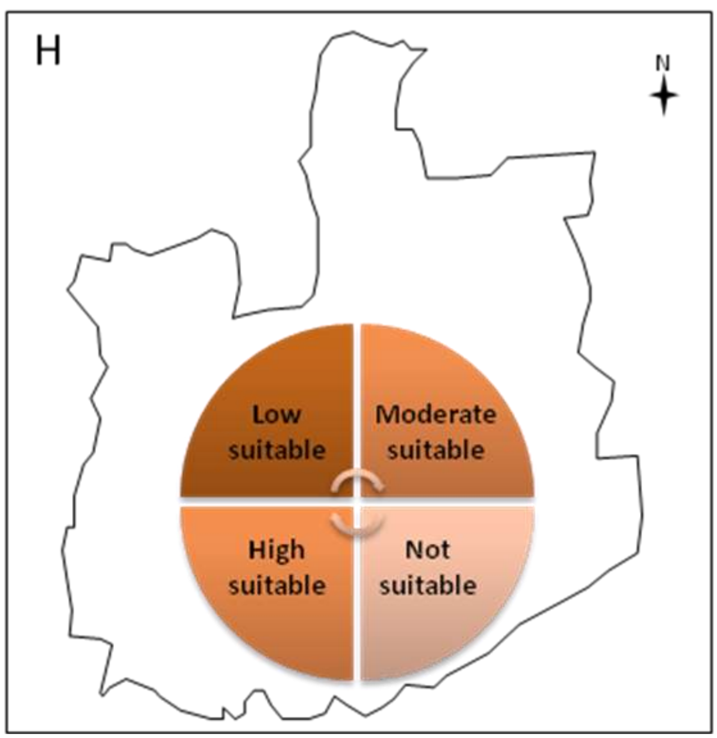
Case Study 7- Land Suitability Assessment for Phra Nakhon Si Ayutthaya, Thailand

The purpose of this study was to assess land suitability for industrial development through the use of GIS in the Phra Nakhon Si Ayuttaya province of Thailand. The study area, which is located in the central region of Thailand, just 75 km north of Bangkok consists of 16 districts with a total area of 2,556.60 km^2. The steps in the assessment of land suitability for industrial development involved first selecting the factors which affect the industrial location and from these, establishing location criteria indicators. The next step involved is assigning all relevant factors a score in the suitability range and weighing the factors using a pairwise method. Finally, using the data layers assembled in GIS, land suitability was determined by applying a Simple Additive Weighted decision rule (Malczeski, 1999).

In this study seven factors affecting industrial site location were selected by the Industrial Estate Authority of Thailand. These were: accessibility, which is essential for the transportation of raw materials; electricity, which is necessary for the production process; labour, which is vital for industries (those that are located near labour sources will be advantaged); facility, as the successful operation of the industrial plant requires special services; agglomeration, as it will reduce transportation costs; land price, which influences the profits of the manufacturers; flood hazard, which is a threat to the success of all businesses and industries. The results of the criterion scores for all of the map factors is displayed in Figure 2.11a to 2.11g, with each map having four ranges of suitability: 4-very good, 3-good, 2-fair, 1-poor (Charungthanakij & Sarapirom, 2010). The final industrial site suitability map (Figure 2.11h) will be useful to the government in terms of land-use planning in the future.

Figure 2.11. Criterion maps and industrial suitability map: (a) accessibility (b) electricity (c) labor availability (d) agglomeration (e) facilities (f) land price (g) flood hazard (h) industrial land suitability.





Case Study 8 – GIS in Industrial Land-use and Children's Perception of Safety and Their Environment – Austin, Texas

The purpose of this study was to use GIS to examine how children who live in heavily industrialized neighbourhoods perceive their surrounding environment. Data pertaining to race, income, and level education were collected from the demographic that comprises the feeder district of Zavala Elementary School. A team then created a map with different layers, each having their own shape and colour, ranging from yellow to brown; for instance, with a small, yellow shape indicating a noisy environment (Ford, Moore, Niswonger & Walsh, 2007). The analysis of the descriptive map of children's perceptions shows that children who live in industrial neighbourhoods are more likely to have negative thoughts about their surrounding environment and avoid walking home.

Case Study 9 – GIS Analysis of the Metropolitan Area of Istanbul

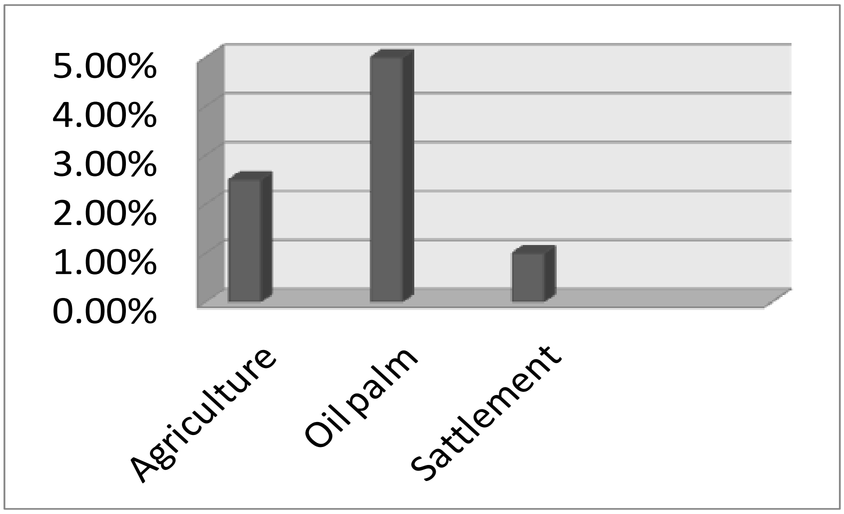
The goal of this study was to use GIS to identify existing settlements and sustainable development areas of Istanbul, the largest city in Turkey with an area of 5,750 km^2, to foster rational decisions concerning the city's future environment conditions and natural resources. The methodology of the study focuses on how areas were classified into spatial and administrative groups based on environmental sustainability.

The methodology included the five main components. They first examined environmental sustainability principles, which included the protection of natural resources, surrounding nature, decreasing energy consumption, improving air quality, and living areas in general. The second component examined strategies for improving urban environmental sustainability, such as urban forestry, water resources, biodiversity corridors, protection of valuable agriculture, and the integration of transport with land-use. Spatial evaluation, the third component of the study's methodology, examined life support systems (forest, water, and earth), sensitive ecosystems such as dunes, natural hazard areas prone to earthquakes, floods, and landslides, and ecological corridors. The fourth component, spatial and administrative groups, identified functionally important areas to preserve, sustainable developable areas, problematic areas, and current settlement areas. The last step involved the creation of the evaluation map (Baz, Geyman & Nogay, 2009). GIS was linked to all of these components to produce a multi-criteria evaluation map.

Case Study 10 – Using GIS to Assess Land-Use in the Tasik Chini Catchment Area, Puhang, Malaysia

This study was undertaken in order to use GIS to explore the temporal and spatial land use changes during the periods 1984, 1990, 2000, and 2002 of the Tasik area (Figure 2.12) (Ismail, Mohd, Muhammad, Sahibin & Sujaul, 2010).   This case study demonstrates another use of GIS analysis in terms of representing the information in the chart and relating it to the map.

Figure 2.12. Trends in land use and land cover change in Tasik Chini, Malaysia.



<u>Conclusion</u>

Geographic Information Systems continues to make a great contribution to the field of urban analysis. Urban planners can use GIS to conduct multiple tasks such as, identifying the best routes for expansion of land-use; examining how land is occupied by various types of buildings; determining which land will be suitable for particular types of future land-use; visualizing, assessing, and evaluating land suitability; locating the right resources to meet an industry's needs; and allowing for planners to map, monitor, identify, and forecast the location and type of future land-use problems. There is no doubt that urban analysis has advanced substantially as a result of the efficient methods offered through Geographic Information Systems. In particular, the efficacy of GIS as a tool to urban planners has been witnessed in its use to mitigate problems and arrive at solutions for Riyadh's rapid expansion.

CHAPTER 3

Core Needs of Existing Conditions in Land Use in Riyadh

Introduction

Riyadh, the capital city of Saudi Arabia, is one of the fastest growing cities in the world and has achieved rapid development in various fields (High Commission for the Development of Riyadh, 2007). Growth and advancement has been observed in the areas of transportation networks, reconstruction of existing infrastructure, and basic improvement to the city's overall layout (High Commission for the Development of Riyadh, 2003). With regard to speed at which development is taking place, city planners have recognized the need to institute a strategy which ensures that development occurs in a logical, efficient, and environmentally sound manner.

Officials have been able to control and manage urban development through the establishment of municipal and national comprehensive plans that focus on transportation, energy, water, agriculture, and industrial sectors (Ministry of Economy and Planning, 2011). One such plan deals with land-use issues in Riyadh and provides planners and developers with a basic implementation strategy and related policies for developing land-use plans (High Commission for the Development of Riyadh, 2003). This strategy has been used in the development of various sectors, including industry, one of the most productive sectors contributing to the national income.

The massive expansion of industrial activity, which has led to an increase in the number of factories found within cities, has had a negative impact on the environment in a variety of ways. One can gain an understanding of the complexity of Riyadh's development by examining the evolution of the city, analyzing its land-use strategies, and by assessing the environmental conditions of industrial areas.

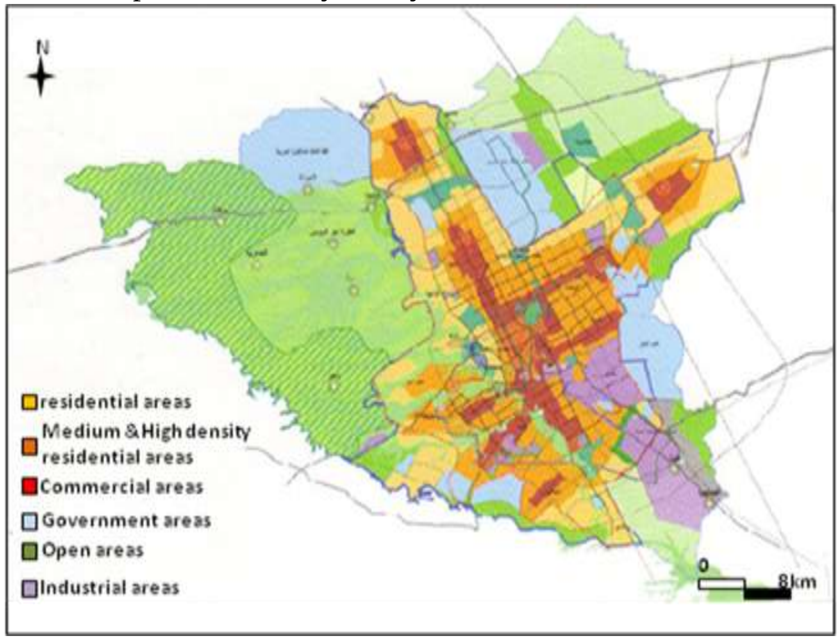
The Development of Riyadh

The infrastructural development of Saudi Arabia has been greatly affected by the country's oil revolution, which has in turn impacted the national economy (Ministry of Economy and Planning, 2011). The effects of this development can be readily observed in Riyadh, the capital, located in central Saudi Arabia. The evolution of Riyadh, a city comprised of 15 districts with a total population of 4,878,723 in 2009, has occurred in a series of stages over an extended period of time; from the year 1943 to 2000 (High Commission for the Development of Riyadh, 2007). Since the onset of oil exporting, revenues have been used for the reconstruction and development of Riyadh. Other initiatives have included a plan for the settlement of Bedouins within Riyadh; the installation of electricity in all buildings; the opening of Riyadh Rail train lines; the restoration of the capital's outdated airport; the linking of Riyadh to the eastern region of the country through Dammam; and in 1955, the creation of the ministries and other central government agencies (Riyadh Municipality, 2011).

The twentieth century saw urban development in Riyadh take a new turn, as the expansion of the urban landscape reached an unprecedented rate (Riyadh Municipality, 2011). Urban planning authorities recognized the need to establish control of the city's rapid development by preparing land subdivision plans for the city (High Commission for the Development of Riyadh, 2007). The first master plan proposed an urban area of 300km^2 to accommodate 760,000 inhabitants by the year 1985. A second master plan, completed in 1990, allocated an area of 850 km^2 for an additional 1.6 million inhabitants (Figure 3.1) (High Commission for the Development of Riyadh, 2003). It is expected that by 2023, Riyadh's total population will reach 7.2 million inhabitants, within an urban context of 4,900 km^2 (Figure 3.2) (High Commission for the Development of Riyadh, 2007). Several municipal and national policies played a significant role in the formation of this three phase plan.

Figure 3.1. First and second phase of Riyadh's development.

Figure 3.2. Structural plan for the city of Riyadh until 2023.



Urban Development Policies

Currently Riyadh's urban planning strategies focus on how to process problems of the past and present through six developmental policies.

Economic Policy

Planners recognize the urgent necessity of tapping into other resources, aside from the main resource: oil. The goal is to achieve a balanced economy, which in turn will allow the city to become more stable and resilient (Ministry of Economy and Planning, 2011). For instance, other resources might include advanced technological industries; traditional and local industries; information, communication, and technology companies; financial institutions; health services; educational facilities; and tourism, which can be improved through the protection and preservation of the Riyadh's natural habitats and by upholding the city's heritage (High Commission for the Development of Riyadh, 2007).

In order to establish a large resource of skilled workers, Riyadh Municipality must develop youth training centres which provide young people with basic vocational and technical skills, with the focus being on practical application, which will qualify them for high-demand jobs (Ministry of Economy and Planning, 2011). To ensure that post-secondary graduates achieve employment, a Saudiazation program has been recommended, providing incentives to companies and organizations that increase the percentage of Saudis they employ (High Commission for the Development of Riyadh, 2003). The continual improvement in the quality of public service and facilities, and the further development of the Saudi workforce by increasing the efficiency and standards of educational institutions, as well as offering educational programs that relate specifically to certain jobs within the labour market, will provide Riyadh with a competitive economic advantage on a global scale (Ministry of Economy and Planning, 2011).

The apparent need for the review of the legislation of financial institutional laws that create bureaucratic obstacles for urban development plans has been recommended by city planners. Future success depends on the establishment of specialized management for economic development, which will be responsible for executing economic development strategies, as well as following up on their success (High Commission for the Development of Riyadh, 2003).

Environmental Policy

Urban development can not proceed without environmental awareness and recognition of the significance of the natural surroundings to urban landscape (Presidency of Meteorology and Environment, 2011). Planners have established a municipal authority for environmental management which will be responsible for monitoring environmental issues within the city, the coordination of environmental affairs with various municipal departments, and the environmental evaluation of all urban development projects (High Commission for the Development of Riyadh, 2003).

The main goal of this initiative is to preserve natural resources, especially water, and to improve natural landscapes (Ministry of Municipal and Rural Affairs, 2011). This can be achieved by controlling sources of pollution; setting up a plan for the environmental reform of the southern region of Riyadh; and through ongoing assessment of the city's environmental quality, including air, water, natural areas, and noise levels (High Commission for the Development of Riyadh, 2003). It is of equal importance to prepare an executive plan for the Hanifa Valley, one of Riyadh's most prominent geographical features, and to prevent mining, waste dumping, and earth removal in this area (Presidency of Meteorology and Development, 2011)

Infrastructure Policy

Riyadh's desert environment necessitates effective management of municipal water usage, which can be achieved in part through the decentralization of water facilities by establishing water treatment stations in various parts of the city (Ministry of Municipal and Rural Affairs, 2011). By creating a water recycling program that will capture rainwater and re-use water for various purposes, consumption reduction will decrease future demands for potable water by approximately 40 percent. City officials hope to reduce present rates of consumption from 500 to 300 litres per day, forecast future consumption rates, and ensure that natural drainage of the Hanifa Valley remains unharmed by development projects (High Commission for the Development of Riyadh, 2007). Finally, planners aim to establish a program in conjunction with the Provisional Plan for Land Development, which will encourage the participation of both stakeholders and land developers in creating plans, with the goal of leading the private sector to aid in financing public facilities (High Commission for the Development of Riyadh, 2003).

Public Service Policy

When creating new public services venues planners examine population dispersal in Riyadh and establish a standard of quality in order to achieve a balance and interconnection among workplace, residence, the location of public services, and appropriate means of transportation, in accordance with city standards. A common problem observed by city officials is the change of land-use for land that has already been assigned to public services; regulations need to be put into place to prohibit this activity (High Commission for the Development of Riyadh, 2003).

Planners also recognize the need to restructure subdivision plans, as much development from the past failed to take into account Riyadh's natural physical features and accommodate the desires of the public (High Commission for the Development of Riyadh, 2007). Future development will ensure that projects occur according to provisional policies rooted in sustainability and the ability to promote public services (High Commission for the Development of Riyadh, 2003).

Housing Policy

Currently, Riyadh's goal for the housing sector is for 80% of residential land to consist of houses exhibiting a villa pattern, double units, or two-story buildings. The other 20% of residential land will be allocated to multi-family designs with some taking on the form of multi-story apartments (High Commission for the Development of Riyadh, 2003). In addition to this, municipal government officials see the need for giving priority to goals that were established specifically for the second phase of Riyadh's development and to ensure that they have been achieved before moving onto new goals (Ministry of Economy and Planning, 2011). City officials must also take into account areas of Riyadh that already have been developed and have the required facilities, but may simply need to be renovated or updated, instead of ignoring these existing areas and quickly building new subdivisions (High Commission for the Development of Riyadh, 2003).

A common trend for residential areas in some urban centres is to build higher in order to combat issues of high population density; instead the city of Riyadh would prefer to expand its residential areas outward. Lastly, to ensure that local history and heritage is not lost, city officials must create a plan to ensure that antiquated homes and buildings are preserved, and to make certain that customary design patterns are followed so that neighbourhoods maintain their collective identity (Ministry of Housing, 2011).

Transportation Policy

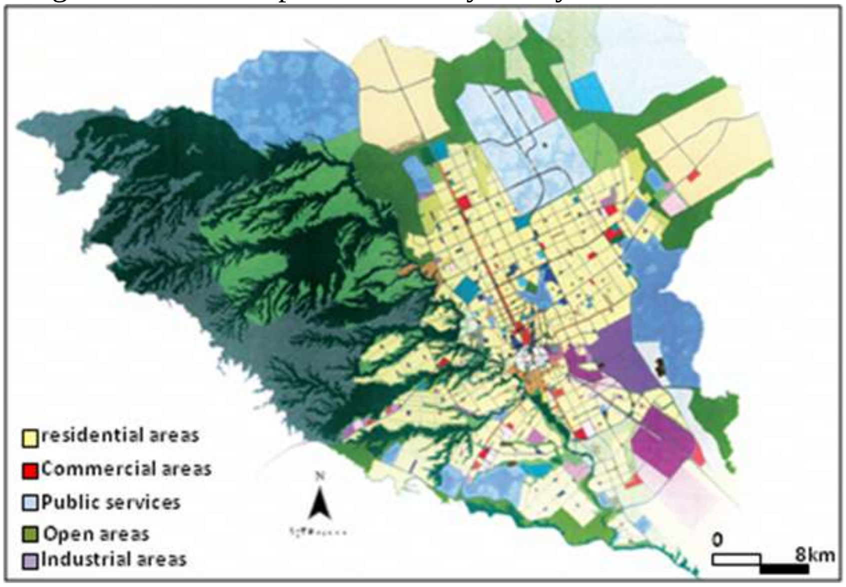
Central to the development of transportation infrastructure is the High Commission for the Development of Riyadh and Riyadh Municipality; as such, they require continued support so that they can provide an administrative body capable of planning, implementing, and managing Riyadh’s transport system (High Commission for the Development of Riyadh, 2003). When developing transport networks, city officials must consider future demands on public transportation services with respect to population growth, as well as economic resources available to create and maintain the network (Ministry of Transport, 2011). The transportation network must reflect the foreseen growth of the city and prove to be highly accessible to all its inhabitants (High Commission for the Development of Riyadh, 2003). As well, when designing new transport networks, engineers must first institute a pilot project for their design to make certain that it increases transportation choice and meets the needs of the evolving city.

Another important issue is safety along road networks. To ensure a high level of road safety for motorists in Riyadh, it would be beneficial for the city to introduce a comprehensive program for the management of traffic movement on freeways and local roads (Ministry of Transport, 2011). It is hoped that with the modern transport technology that is currently available, the city of Riyadh will be revitalized through the use of SMART transport (High Commission for the Development of Riyadh, 2003). Collectively, these policies helped create the framework for several municipal plans, including land-use allocation plans.

Progressive Land Use Plan

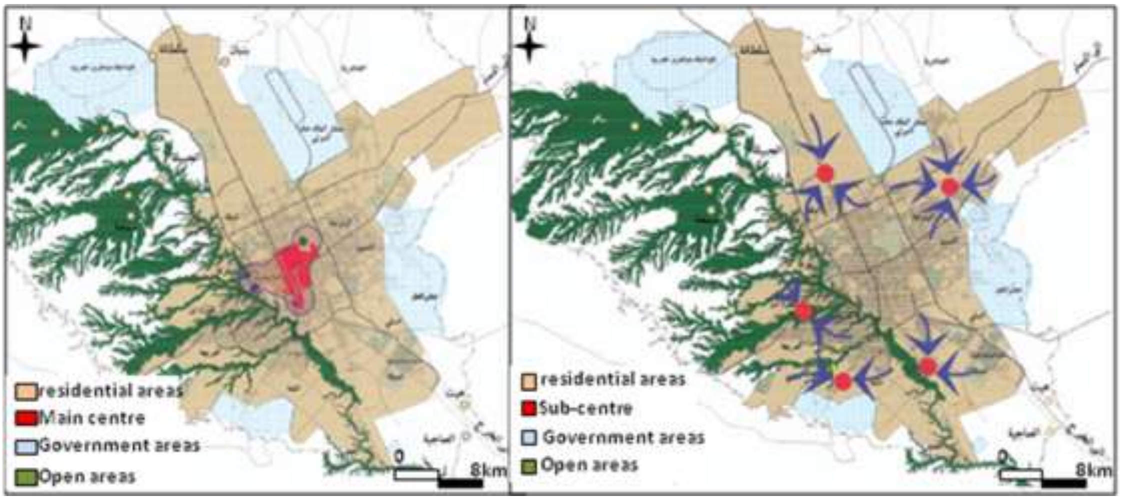
Riyadh Municipality has created a progressive land-use plan with the goal of establishing implementation mechanisms, programs, and executive projects, which will become the starting point for directing ongoing urban development through to the year 2020 (Figure 3.3) (High Commission for the Development of Riyadh, 2003). The plan includes a detailed description of the types and sizes of current land uses, including residential areas, commercial public services and facilities, transportation and other special activities, and their spatial distribution at the city level.

Figure 3.3. Progressive land use plan for the city of Riyadh until 2020.



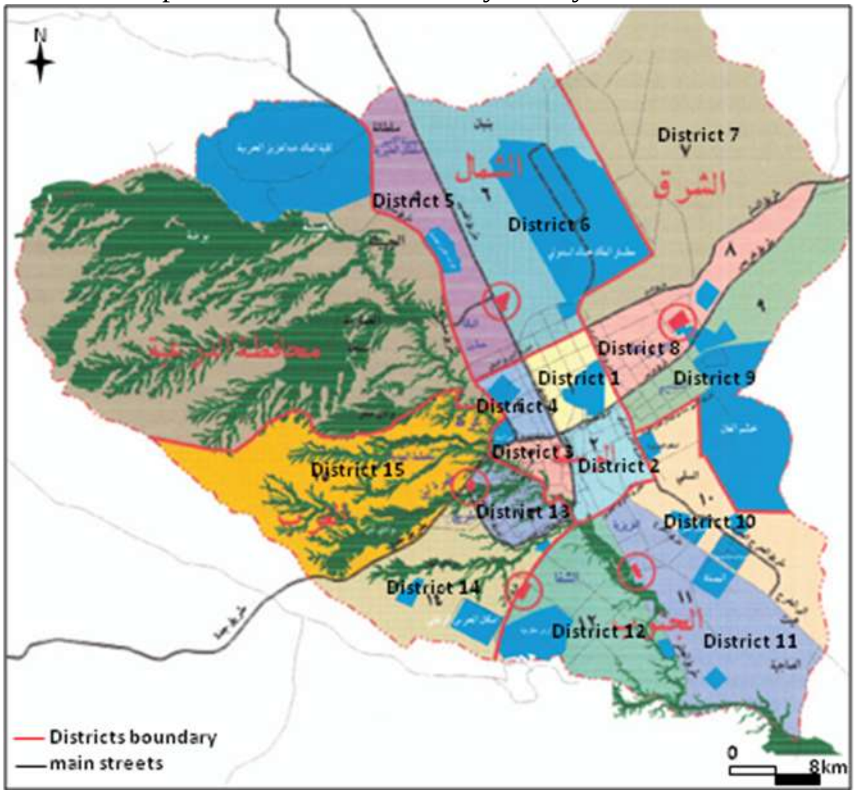
The plan will be implemented and function through a hierarchy of centres, with each centre serving inhabitants of a specific geographic region in Riyadh (High Commission for the Development of Riyadh, 2007). The downtown core is situated at the top of the hierarchy of services, with an additional five sub-centres, each of which is targeted to serve approximately 1-1.5 million inhabitants. The first sub-centre is located in the northern region in the city of Riyadh, 16 km north of Cairo Square, with the eastern region of Riyadh being served by a sub-centre 21 km east from Cairo Square. The southern region has two sub-centres, one located in the south-east and the other in the south-west; these two centres are located 20 km and 18 km away from Cairo Square, respectively. The fifth sub-centre serves the western region of Riyadh and is located 12 km west from Cairo Square (Figure 3.4) (High Commission for the Development of Riyadh, 2003).

Figure 3.4. The centre of urban Riyadh (left); sub-centres of Riyadh (right).



The next level in the service hierarchy is comprised of administrative centres, with approximately 2 to 4 in each sub-centre region of Riyadh (High Commission for the Development of Riyadh, 2007). The progressive land-use plan has designated 15 locations for administrative centres, with each serving 300,000 to 500,000 inhabitants (Figure 3.5). Following the administrative centre echelon are the local centres, representing the lowest level of the hierarchy, with approximately 6 local centres located in each administrative centre's catchment area, serving about 50,000 residents (High Commission for the Development of Riyadh, 2003). The progressive land-use plan will focus on several elements that are of great importance to the efficiency and success of Riyadh's urban landscape.

Figure 3.5. Sub-municipal boundaries for the city of Riyadh.



Economic Activities

A central aim of the progressive land-use plan is to assign tracts of land to meet the needs of the continuously growing economic activities, such as locating areas for new industries and warehouses (High Commission for the Development of Riyadh, 2003). The main goal in assigning land-use for economic activities is to make each region of the Riyadh more self-sufficient in terms of employment opportunities for the surrounding labour force, while at the same time ensuring that new industry is environmentally sound and does not pose potential problems, such as air and noise pollution, for the region's residents (High Commission for the Development of Riyadh, 2007).

Recreation and Open Spaces

At the local level, the progressive land-use plan has asserted that open spaces, in the form of parks, are an essential component of a residential neighbourhood; with typically half of the land (approximately 10 hectares) assigned to the establishment of parks. Being that these opens spaces are characteristically designated to the wide area located alongside a built area, they also serve to define neighbourhood 'boundaries' (High Commission for the Development of Riyadh, 2003).

Public Services

Riyadh's growing population and increase in economic activities augments the need for public services (High Commission for the Development of Riyadh, 2007). The progressive land-use plan has selected locations for the construction of four additional universities to educate the labour force, enabling them to meet challenges presented by future economic activity. Other facility increases include police departments, civil defence, and hospitals at all three levels of the service hierarchy: metropolitan sub-centres, administrative centres, and local centres. To ensure efficient use of land, planners forecasted the location, variety, and extent of public services that will be required by 2020, so that service organizations will be able to prepare their plans accordingly (High Commission for the Development of Riyadh, 2003).

The Phased Development Plan

The progressive land-use plan is crucial for effective development of Riyadh's urban landscape and can be achieved through the following procedures: forecasting the demand for housing and land requirements over the next ten years, reviewing all current public service projects, identifying land that was provided with services, and preparing a plan for the phased development of land (High Commission for the Development of

Riyadh, 2003). An examination of the land-use plan indicates that industrial activity was not included in this plan; industry will be examined through other sources unrelated to this plan.

Assessment of Industrial Areas in Riyadh

The oil revolution has created a flow of continuous oil exports from Saudi Arabia and the great source of revenue generated from these exports has allowed for rapid urban development within the nation. Other industrial nations that have experienced economic success include South Korea, Brazil, and India; however their growth was the product of diversified industry. Since the 1970s, Saudi Arabia has tried to establish a strategy for reinforcing its stability within the world by adhering to a set of development guidelines created by government (Ministry of Commerce and Industry, 2009).

The first aim the government tried to fulfill was to improve the strength and flexibility of the nation's economy by diversifying income sources through the expansion of non-oil industrial sectors, such as agriculture. To increase the strength of the whole nation, officials recognized the need to create a balance in economic growth among all of the country's provinces, and to involve the private sector in economic and social development (Ministry of Economy and Planning, 2011). Equally important to the economy is a country's labour force; leaders saw the need to develop the skills of the workforce and encourage scientific research and technological development. Lastly, through the generation of export revenue planners saw the potential to invest in urban infrastructure in a way that is harmonious with the city's natural landscape (Ministry of Commerce and Industry, 2009).

After careful assessment of development in Saudi Arabia during the years 1971 to 2005, it is clear that expansion of urban centres relied solely on the revenue generated from the oil industry. A strong effort will be made to implement the above mentioned strategies until the year 2025 (Ministry of Economy and Planning, 2011).

Riyadh's Current Industrial Condition

Industry is what fuels urban development; without the profit gained from industrial activity cities would not be able to provide infrastructure and services to their inhabitants. In order to balance incoming profit from the industrial sector and to reduce congestion due to high population density, fourteen geographically dispersed industrial cities were established in Saudi Arabia (Saudi Industrial Property Authority: Cities, 2010).

To encourage both Saudis and foreigners to invest in new industrial projects the government has created the Saudi Industrial Development Fund, which provides short and long-term loans that cover up to 50% of the total project cost (Saudi Industrial Property Authority: Investing in Industry, 2010). In addition to providing financial support, the development fund offers investors marketing, consulting, and technical assistance for new and existing projects, and continually monitors the performance of the industrial project (Arab Institute for Urban Development, 1993).

During a thirty year period, from 1974 to 2005, the Saudi Industrial Development Fund has provided 2,731 loans totalling $13 billion. In recent years, investment loans have been dominated by the manufacturing sector, such as metals, petrochemicals, and plastics. The total number of factories in operation by the end of 2006 was 3,906, employing 395,609 people, with the factories' collective worth estimated at $71 billion. The metal industry, with 1,080 factories comprises 27% of the total factories and has received 13% or $10 billion of the total investments from the development fund (Chamber of Commerce and Industry in Riyadh, 2001). Following are the chemical and plastic industries, together making up 22% of the factories having received 59% of the investment loans. On a smaller scale, the building materials, ceramics, and glass industry consists of 15% of the factories with 13% of the investments, followed by the food industry with 15% of the factories and 8% of the investments. Finally, the remainder of factories and investments includes papermaking, textiles, clothing, wood, and furniture (Ministry of Industry and Electricity: Statistical Bulletin Industrial, 2001).

National Industry Strategy

In an effort to improve practices in the industrial sector the Saudi Arabian government has formed the National Strategy for Industry, whose goal is to achieve high rates of industrial performance in local industry (Saudi Consulting House, 1999). This strategy operates on the premise that industrial success is a responsibility that must be shared between the public and industrial sectors. The government must be committed to investment, productivity, and creating services that compare with international standards; the private sector is responsible for converting this opportunity into reality by building a wide, varied, and sophisticated industrial base (Table 3.1) (Saudi Industrial Property Authority-Cities-, 2010).

Table 3.1. The investment for industrial areas in 2008.

Projects	Allotted Amounts (SR million)
Development of Industrial cities	377
Re-qualification	25
Conduction of services	485
Studies, designs and supervision	38
Water	580
Total	1505

By the year 2020, it is hoped that the National Strategy for Industry will raise industrial contribution to the gross domestic product to 20%, which is the minimum expectancy in comparison with the rapid economic growth that Saudi Arabia has undergone. This goal, which is intended to elevate the country to a level of excellence in global industry will be achieved by focusing on the most important variables affecting industrial performance. The National Strategy for Industry will increase the collective industrial value by 8%, increase the proportion of industries with a technical base from 30% to 50%, the percentage of industrial exports from 18% to 35%, and the proportion of national employment in industry from 15% to 30% (Ministry of Economy and Planning, 2009).

Future generations will benefit from current industrial development in Saudi Arabia. The government initiated a series of consecutive five-year strategic plans to develop the local industry in 1970, as the industrial sector is regarded as the nation's main source of income. The Saudi Industrial Property Authority is the umbrella under which local factories in fully serviced and equipped industrial areas are built (Saudi Industrial Property Authority-Cities-, 2010).

Saudi Industrial Property Authority

In 2001, the government of Saudi Arabia established the Saudi Industrial Property Authority (MODON) under a royal decree issued specifically to create a responsible entity for industrial areas and technology zones. MODON's role is to develop, supervise, and establish industrial areas within Saudi Arabia and to encourage the private sector to participate in the creation, operation, and maintenance of these areas (Saudi Industrial Property Authority-Cities-, 2010).

MODON has several responsibilities to fulfill, one of which is creating guidelines and procedures, and executing a predetermined strategy for the establishment of a new industrial area. MODON must also allocate new areas of publicly owned land for future industrial areas, as well as submit proper documentation to the Higher Economic Committee for privately owned land to be used in urban industrial centres (Saudi Industrial Property Authority-Guidelines-, 2010). MODON has the task of organizing infrastructure, services, and facilities in partnership with specialized companies, and encouraging the private sector to assist in the building, development, operation and maintenance of the industrial areas and technology zones. Through MODON, the Saudi Industrial Property Authority must also provide licenses to contracted developers, and supervise their progress and performance in terms of following the strict guidelines issued the governing body (Saudi Industrial Property Authority-Cities-, 2010). MODON takes necessary action to preserve the environment in industrial centres by requiring developers to follow specific building regulations appropriate for the geographic region (Saudi Industrial Property Authority-Green Industrial Cities-, 2010). As well, MODON acts as a mediating body which solves conflict among developers, tenants, employers, and residents of the industrial area. In a constant effort to further industrial and economic development in Saudi Arabia, MODON encourages the establishment of industrial and technology centres by providing state of the art services that will attract investors with innovative ideas (Saudi Industrial Property Authority-Cities-, 2010).

Industrial Areas in Riyadh

The year 1973 saw the onset of three industrial hubs in Saudi Arabia, in the cities of Riyadh, Jeddah, and Dammam, totalling an area of 14 million meters^2. In 1975, the government put forth the goal of establishing an additional 14 industrial areas by 1995 to meet the growing needs of the nation; these areas were located in Riyadh, Jeddah, Dammam, Makkah, Qassim, Ahsa, Madina, Asir, AlJouf, Tabuk, Hail, and Najran would consist of $53 billion in investments and employ over 300,000 workers (Table 3.2) (Saudi Industrial Property Authority-Annual report-, 2010). In Riyadh, the country's capital city, reside three of the largest industrial areas.

Table 3.2. The size of industrial areas.

No	Industrial City	Total Area (M^2)
1	1st Riyadh Industrial City	451,000
2	2nd Riyadh Industrial City	18,000,000
3	Jeddah Industrial City	12,700,000
4	1st Dammam Industrial City	2,704,000
5	2nd Dammam Industrial City	25,000,000
6	Makkah Industrial City	730,000
7	Qassim Industrial City	1,500,000
8	Al Ihsa First Industrial City	1,044,000
9	Madina Industrial City	9,949,000
10	Asir Industrial City	3.000.000
11	Al Jouf Industrial City	3,000,000
12	Tabuk Industrial City	4,000,000
13	Hail Industrial City	2,560,000
14	Najran Industrial City	6,500,000

Riyadh, located in the centre of Riyadh Province, with an area of 500,000 m^2, was established as an industrial area in 1973 and contains more than 50 factories producing a variety of products from the electrical, plastic, metal, and wood industries (Figure 3.6). By 1976, in an effort to meet the growing demand for industrial land in Riyadh city, the government started to construct a second industrial area in the south-eastern of the city. The development of this area was carried out in four stages on an area of land totalling 18 million m^2. This area houses world famous factories including ABB in the electrical industry, Industry Controls Automation, and Henkel Detergents Limited. Other major industries include factories from the food, metal, and chemical sectors (Figure 3.7) (Saudi Industrial Property Authority: Cities, 2010).

Figure 3.6. The first industrial area in the city of Riyadh.

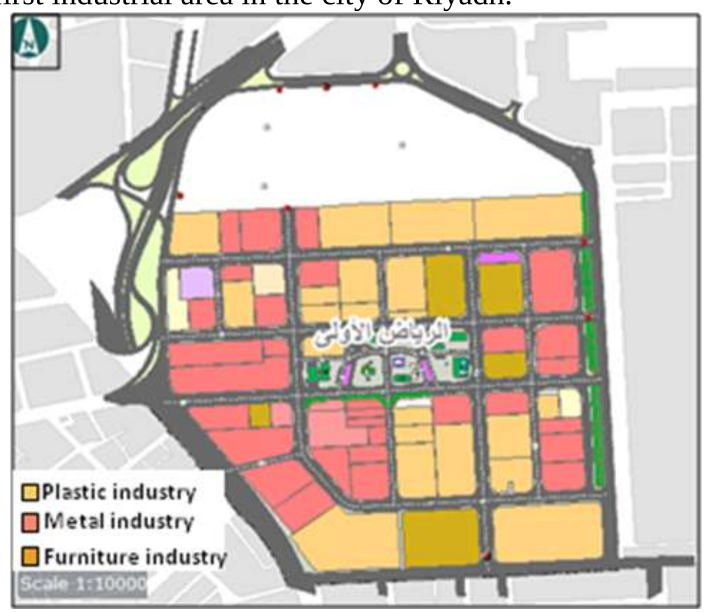
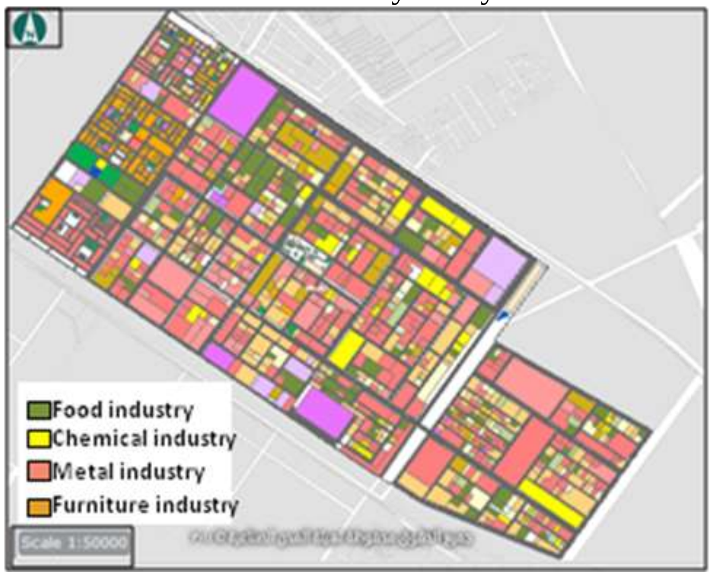


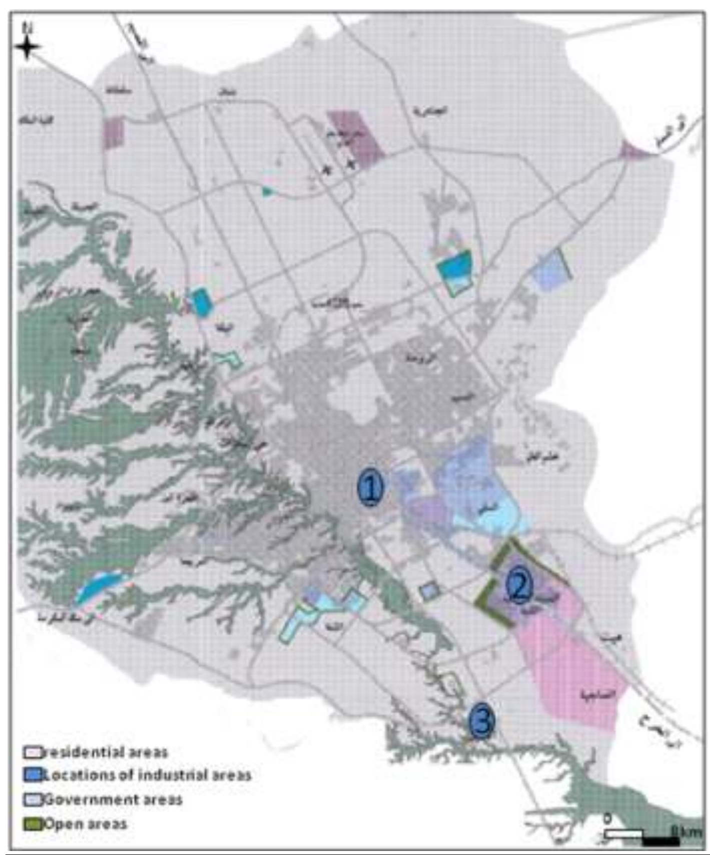
Figure 3.7. The second industrial area in the city of Riyadh.



Unlike the others, the third industrial area established in Riyadh city is unique in that it provides employment opportunities to prisoners. Located in the southern of Riyadh city, 72 km from the center of the Riyadh city, its partnership with MODON and the General Directorate of Prisons allows industries in this city to provide prisoners with skilled labour jobs, in hopes that they will have a better chance of obtaining employment at the end of their prison sentence. Investors who want to establish a factory on the city's 1.5 million m^2 area of land must commit to employing a certain percentage of prisoners in their factory, which is determined according to the type of factory and its surrounding location; vice versa, the type of factory proposals that receive permits depends on the skills of the prisoners (Figure 3.8) (Saudi Industrial Property Authority: Annual Report, 2010).   When examining the layout of industry in Riyadh, one will observe that all industrial areas are located next to residential neighbourhoods (Figure 3.9).

Figure 3.8. The third industrial area in the city of Riyadh.

Figure 3.9. The location of the industrial areas relative to residential areas.



Layout Drawing Requirements of Industrial Plants

When developing industrial plants, developers must create their designs in accordance with guidelines established by MODON. All layout drawings must depict the total area of land, the location of the plant, boundaries, main streets, and neighbouring sites, with measurements being reported in meters (Saudi Industrial Property Authority: Guidelines, 2010).

All approved layout drawings will include the location and dimensions of the site area; plant buildings, production areas; stores and maintenance workshops; electrical and guard rooms; administrative buildings, and staff facilities; as well as the entrances for personnel, vehicles, and emergency exits, which should be located a far distance from the main entrance with doorways no less than 5 meters wide (Alshuaibi, 1987). The distance between the plant and its boundary between neighbouring sites should be no less than 5 meters in all cases, 30% of a 10,000 m^2 plot of land, 20% of a 30,000 m^2 plot of land, and 15% if the plot is more than 30,000 m^2 (Ministry of Industry and Electricity: Industrial Cities, 2001).

Environmental Conditions of Industrial Areas

The rapid growth of the industrial sector in Saudi Arabia has provided the country with many economic benefits, but it has also presented several environmental concerns (AlAwadi, 1992). An increase in the number of factories throughout the nation has produced an influx of pollutants, including air and noise pollution, and high levels of liquid and solid waste (Saudi Organization for Industrial Estates and Technology Zone, 2007). Pollution levels, including those of sulphur and nitrogen oxides, have exceeded both national and international environmental standards (AlAbood, 2008). The high concentration of pollutants found in industrial waste water received by water treatment plants is the most pressing issue faced by industrial areas (Saudi Industrial Property Authority-Industrial sewage water treatment-, 2010). The low number of water treatment facilities and the quality of treated water do not meet present day environmental standards for direct discharge and reuse of treated water in irrigation and agriculture (Presidency of Meteorology and Environment, 2011).

It is estimated that Saudi Arabia produces 900 thousand tons of solid industrial waste a year (Abdulrahim, 1987). Current practice confirms that there are not enough environmental regulations and programs to control the transportation, storage, and handling of waste in industrial cities, or any strategies aimed at controlling air pollution (Alsalia, 1990). An analysis of industrial area pollutants shows that air pollutants, effluents, and solid waste present great danger to the environment (AlJahdali, 2003).

Industrial Emissions

Industrial nations with lax environmental regulations plague the atmosphere with high levels of industrial emissions (Fares, 1987). In recent decades Saudi Arabia has detected an uncontrolled amount of harmful air pollutants consisting of toxic gases and particulate matter (Saudi Organization for Industrial Estates and Technology Zone, 2007). Toxic gas pollutants, many of which contribute to severe health defects over time, typically consist of carbon monoxide, carbon dioxide, nitrogen oxides, sulphur oxides and ground level ozone. Contaminants in the form of fine particles and aerosols have been found to contain substances such as minerals, metals, and organic compounds (AlLababidi, 1992).

Research has shown that there are two main types of air pollutants; primary and secondary. Primary pollutants, such as sulphur dioxide and oxides of nitrogen, are directly emitted into the air from factory and power plant chimneys. Secondary pollutants, on the other hand, are formed from an interaction between primary pollutants; for example, ground level ozone is formed from UV rays interacting with primary pollutants found in the atmosphere (Saudi Organization for Industrial Estates and Technology Zone, 2007).

Studies on the emission of air pollutants in industrial areas indicate that many industrial centres exceed their annual air pollutant emission budget (Alruby, 2008). For example, the second largest industrial area in Riyadh Province annually produces 9,000 tons of suspended particles, 3,400 tons of sulphur dioxide, 4,700 tons of nitrogen oxides, and 60 tons of carbon monoxide; all of which have significant affects on the respiratory system and are a contributing factor in terms of cancer development (Figure 3.10) (Saudi Organization for Industrial Estates and Technology Zone, 2007).

Figure 3.10. Gaseous emissions from factories.

Industrial Liquid Waste

One of the greatest risks of dumping industrial waste is its ability to leech into and contaminate ground water (AlLababidi, 1992). The industrial sector is one of the largest consumers of natural resources such as water and raw materials, which when processed are some of the most polluting substances (Council of Saudi Chamber of Commerce and Industry, 1990). With the rapid advancement of technological and industrial development, Saudi Arabia has seen an increase in the volume of gaseous, liquid, and solid pollutants, some of which have the potential to make their way into water bodies, soil, ground water, and public sewer systems (Saudi Organization for Industrial Estates and Technology Zone, 2007). The resulting contamination of these water sources often impair aquatic life or have negative impacts on human health.

As soon as industrial waste finds its way into a water body it affects the natural properties and chemical composition of the water, which is in turn hazardous to the aquatic life present within that ecosystem (AlLababidi, 1992). The continual destruction of a water body and its aquatic organisms through dumping of industrial waste eventually renders it invalid for use; it is unfit for drinking, swimming, or fishing.

When industrial waste finds its way into natural water sources, water treatment facilities experience greater difficulty in returning the contaminated water to a useable state for either domestic or industrial reuse; for example, the presence of phenol in waste water adds an odd taste and odour after the chlorination process. High fat and oil content in waste water forms thick layers with accumulated dirt and dust which are difficult to remove and reduce the water's cleansing capability; as well, high salinity content makes the water unacceptable for domestic consumption (Saudi Organization for Industrial

Estates and Technology Zone, 2007). In addition, water from wells that tap into ground water sources must be frequently tested for liquid waste contamination to prevent ingestion of toxic components which could have devastating effects on human health (Figure 3.11).

Figure 3.11. Industrial liquid waste.

Industrial Solid Waste

Solid industrial waste is a solid or semi-solid material which may come from human, industrial, or agricultural sources and has no economic value. Residues found within solid waste can be classified on a hazardous spectrum, with differing contaminants handled in accordance with regulations established by environmental organizations. Solid waste from industrial activities is often the result of the processing of raw materials into a manufactured product, which usually involves energy consumption through the burning of fuel (AlLababidi, 1992).

International conventions have identified the characteristics and types of hazardous waste that are susceptible to explosion, flammability, and spontaneous combustion, as well as materials that release toxic and flammable gases. Other waste materials of great concern are those that are radioactive and carcinogenic, or are infectious and biohazardous. Waste materials can be classified as those that contain elements, such as beryllium, hexavalent chromium, copper, arsenic, zinc, selenium, cadmium, antimony, tellurium, mercury, thallium, or lead (Saudi Organization for Industrial Estates and Technology Zone, 2007). Some wastes are from the treatment of metallic surfaces, the manufacturing of plastic products, or the remains of dry or liquid batteries, while others contain resins, inks, dyes, paints, and varnishes (AlLababidi, 1992).

The varying risk that industrial emissions, and liquid and solid waste pose depends on the type of contaminants they contain and the quantity in which they are found. The type of industry; age, size, and maintenance protocol of the plant are all factors that play a role in the quantity and type of contaminants contained in waste (Saudi Organization for Industrial Estates and Technology Zone, 2007). Other contributing factors include industrial processes, the quality of fuel and raw materials used, and the level of efficiency standards and measures to reduce the quantity of pollutants discharged from the plant (Figure 3.12).

Figure 3.12. Industrial solid waste.

Conclusion

Over the past three decades, Saudi Arabia has witnessed a tremendous development boom. Growth has been observed in all fields of the national structure; economy, education, health, industry, transportation, and urban development, all of which have contributed in some way to natural resource consumption.

The nation's overall development has been an important factor in the rapid development that has been observed in the capital city of Riyadh. As a result of Riyadh's unprecedented rate of growth, policies focusing on the economy, environment, public services, housing, and transportation have been put in place, leading to the development of plans and strategies that will help regulate and direct the city's growth. Among these plans is one that focuses on land-use in terms of economic activities, recreation and open spaces, and public services; however, it has been concluded that this phased development plan lacks specific information regarding industrial zones.

Industrial areas have been evaluated through government organizations such as the Saudi Industrial Property Authority (MODON) to ensure that industrial plants are evenly dispersed throughout the country. MODON's specific role is to ensure that industrial growth takes place in Riyadh, however this has occurred at the cost of environmental health of the city as it has seen a large influx in industrial emissions, and industrial solid and liquid waste. The Government of Riyadh has acknowledged the high level of toxic emissions produced by local industries as a result of urban expansion, and in an effort to reduce and alleviate the environment hazards they pose, has established the

GIS Centre, which will become the focal point for creating plans that will improve the overall environmental health of Riyadh.

CHAPTER 4

Gaps of Using Standard Data in GIS in Land Uses in Riyadh

Introduction

Riyadh Municipality began using GIS in 2001, through the establishment of a special unit called Geographic Information Systems, which falls under the umbrella of the General Administration of Urban Planning (GIS Center, 2008). The objective of the establishment at that time was to create a basic digital map of the city of Riyadh in conjunction with approved building plans (Riyadh Municipality, 2012). The crucial importance of GIS use in the daily work of the sub-municipal departments became especially great in 2005, through the establishment of the GIS Centre's three phase plan (Riyadh Municipality, 2008).

The three phase plan aims to create architectural design that meets the demands of all infrastructure categories, with departments using equipment and survey tasks to construct a basemap with an embedded database. The plan strives to ensure that digital map databases and building applications are updated for all municipal departments, and to link all departments to the GIS Centre (GIS Center, 2008). The three phase plan also hopes to prepare studies that will aid the decision making process, which will be augmented through application development and constant updating of the basemap.

The Task Force Centre connects all of Riyadh's provincial departments and is responsible for providing services to the departments of municipality and the public through the preparation and implementation of GIS applications. The ATM Monitoring System application, System of Records of the Technical Committee application and the Land Survey Report application are three examples of work produced by the Task Force Centre.

ATM Monitoring Systems (A.M.S.)

The ATM Monitoring System is a development project that manages public investments and aims to monitor and supervise ATM sites, compiling information for each location (MIS Company, 2008). By analyzing the success of existing sites, planners aim to identify new areas of the city might benefit from ATM services (Riyadh Municipality, 2012). A bank that wishes to establish a new ATM location first requires an ATM building permit from the Department of Licenses, which is responsible for assessing the viability of the new site which will determine licensing approval (Riyadh Municipality, 2008). Banks that construct an ATM site on public land must pay a rental fee to the municipality, however, in the case of private land only licensing fees are collected.

Defining AMS

AMS is a management program that aids in the investment and development of new ATM sites (MIS Company, 2008). The AMS program, which is based on Geographic Information Systems technology, monitors ATM usage in the capital city of Riyadh by following up on new locations, assessing data irregularities and mitigating them through modifications to the sites, such as implementing new advertising schemes (Riyadh Municipality, 2012). A program user can view the geographic dispersal of ATM sites on an interactive map which includes street views, or can query and search for a specific location (Riyadh Municipality, 2008). This application also deals with data associated with advertising boards, client banking fees, and the physical condition of the ATMs, compiling reports that highlight any discrepancies in these areas (Figure 4.1).

Figure 4.1. ATM Monitoring System application.

Application Objectives

The AMS application monitors ATM transactions and all information related to contracts; identifying any irregularities that occur (MIS Company, 2008). The application visually displays ATM locations on a map of Riyadh, encoding them according to the different services they provide, which enables the municipality to determine areas of the city that would benefit from ATM installation, thus allowing the city to increase its profit through the collection of rental and licensing fees (Riyadh Municipality, 2012). The application has been developed so that the user can geographically query any ATM by its location, using metadata stored on the ATM (MIS Company, 2008). AMS links the ATM sites with their photos and other documents relating to the ATM, providing municipal employees easy access to an organized database (Riyadh Municipality, 2012). By using one application instead of multiple programs, there has also been a reduction in error enabling the production of accurate results and facilitating the establishment of infrastructure for e-municipality.

Application Functions

Entering all data for each ATM site, including information regarding its physical aspects, the services it provides, and its methods of advertising, allows the user to efficiently survey the data and scan for specific information related to a particular task. For instance, tasks such as licence renewal are easily managed by the AMS application, notifying sub-municipalities regarding the collection of fees, and at which sites violations and irregularities have occurred, prompting officials to follow up on these cases (Riyadh Municipality, 2008). AMS also has the ability to alert sub-municipalities as to which ATMs are out of service, reporting the nature of the problem and the required repairs. The general statistics provided by the AMS application allows users to ensure constant functioning of the city’s ATM sites (MIS Company, 2008).

Application Components

The application interface consists of several different menus and a toolbar that allows the user to manipulate the ATM site map, with its encoded databases. Using the toolbar, a selected portion of the map can be minimized or enlarged allowing the user to examine specific sections of the map in detail. The toolbar also enables distances between ATMs to be calculated using map units (Riyadh Municipality, 2008).

The menu located on the right hand side of the application interface consists of several sub-menus, such as: content of the map, map dimensions, search box, and ATM violations. Each sub-menu is made of multiple layers; for instance, the content of the map sub-menu is comprised of the following layers: ATMs, roads, districts, municipalities, and aerial photographs (MIS Company, 2008). Through a series of check boxes adjacent to each layer the user can hide or view the required layers.

The top menu is the starting point to all parts of the map system, allowing the user to navigate between the various functions of the application (Riyadh Municipality, 2008). This menu is made up of a series of selections, such as homepage, which allows one to search for ATM locations by entering the municipality, selecting the desired neighbourhood, and then choosing the closest ATM location. For example, the user can search for an ATM location by selecting the municipality, followed by the neighbourhood and the street, and finally choosing the ATM that meets the individual's required needs (MIS Company, 2008).

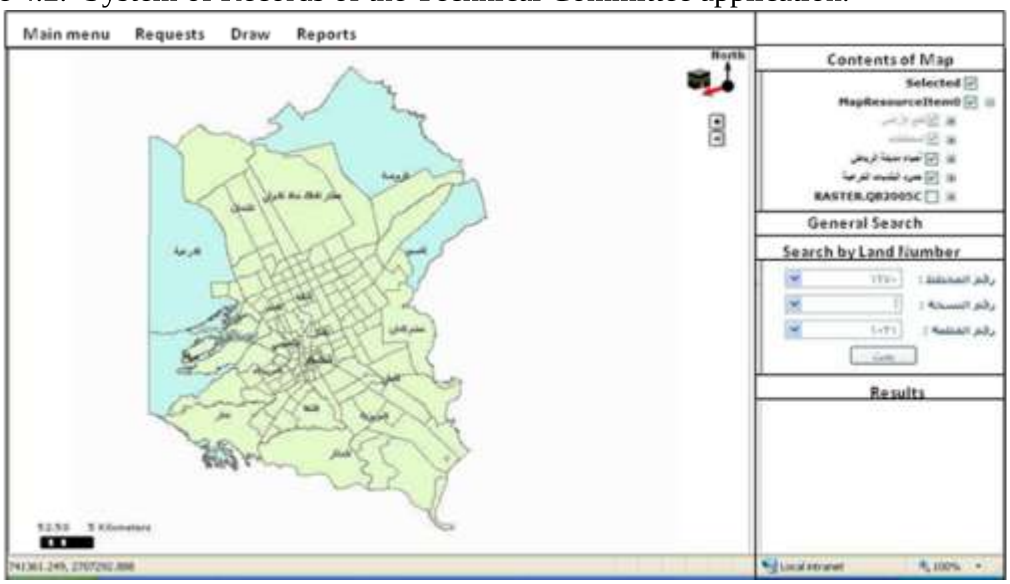
The daily operations menu allows the user to add new ATMs and advertising information (Riyadh Municipality, 2008). The follow-up menu can be used to identify which ATM locations need to pay fees, and display photos from that location and information regarding the revenue of that site. The reports menu provides access to ATM cards, the advertising strategies used by the banking branch, the physical condition of the ATM locations, as well as reports detailing action taken to repair out of service sites. The map itself is the central component of the system where all processes are taking place, facilitating ATM access and manipulation (MIS Company, 2008).

System of Records of the Technical Committee

Riyadh Municipality seeks to create job opportunities in its departments and sub-municipalities to improve the functioning of services it provides to its citizens. Its aim is to develop systems, procedures, and services that will improve the quality of life for its citizens and help improve the work performance of its employees (Riyadh Municipality, 2012). To achieve this goal it has been necessary to support the technical committee and planning department (GIS Center, 2008).

The role of the technical committee is to issue statements for the municipality to amend development plans within certified or raw areas of public or private land less than 80,000 m^2 (MIS Company, 2008). The GIS application used to carry out this task focuses on follow-up procedures for application forms transferred to the department of planning, and organizations and business responsible for zoning, annexation, or changing land usage or land settlement patterns, according to land planning conditions of Riyadh (Riyadh Municipality, 2012). The application requires the user to enter all information relevant to the task, including graphic illustrations and records produced for the site, which are then sent for approval by authorities including the notary, land property and designs department, as well as others both inside and outside the municipality (MIS Company, 2008). Data entry record forms that need to be completed include models based on reorganization of built land and the redivisions of raw land (merge-split), and models based on land-use change and settlement boundaries (Figure 4.2) (Riyadh Municipality, 2008).

Figure 4.2. System of Records of the Technical Committee application.



Application Objectives

A key objective of the application is to compose an integrated database to serve professionals and facilitate the work procedures between the citizen and the municipalities, sub-departments, and the planning and technical committee departments (Riyadh Municipality, 2012). The application will provide automatic release of the technical committee's results, with the outcome of the technical committee's periodic reports being passed onto relevant authorities (MIS Company, 2008). After the record has been certified, the user will be able to update the basemap to help establish an infrastructure of requirements for the e-municipality (Riyadh Municipality, 2008).

Application Functions

By entering information related to a certain task and evaluating the conditions, including data documents of ownership and location, the user can study the stored information to meet the requirements for the project plan (MIS Company, 2008). The application can be used to graphically or geographically query the issued records and draw the current and proposed conditions for the plan. There is also the ability to perform statistical analysis related to the records of the technical committee (Riyadh Municipality, 2008).

The main screen of the application consists of a content menu of the map including the names of the layers that comprise the map, which can easily be viewed through a colour coding scheme (MIS Company, 2008). The user can control the layers that are displayed simply by checking the boxes in front of the layer names (Riyadh Municipality, 2008). The map contains tools so that the user can zoom in and out, as well as drag the map in any direction to examine a specific portion of the city (MIS Company, 2008). A toolbar allows one to draw a rectangle on the map to enlarge that portion, thumbnail it, and move it to display data specific to that portion of the map (Riyadh Municipality, 2008). The general research component of the application allows one to search for a specific record using the record or application number, or by using the land number to search the master plan.

Request Submission

To submit a new request the user must include a number and date, in order to link the request to the previous activity, and classify the purpose of the record such as land division, merging, or re-division (Riyadh Municipality, 2008). The user must source the request by designating it as municipal or residential; if the request is approved, future access to the file will be granted by entering the survey number (MIS Company, 2008). Text documents and pictures may be attached to the files, which can be saved and stored.

To review a request, the user can simply select the option from the main menu, enter the request number, and conduct the search process. The right hand side of the application interface summarizes the steps that have been completed and those awaiting completion; allowing the user to access any steps during the process (Riyadh Municipality, 2008). Land data can be reviewed by clicking on the data location link, allowing the user to scan through land plans, including information about the owner, site size, the deed used to survey the land, and the name of the district and sub-municipality the land falls under (MIS Company, 2008).

The user can review documents by selecting the link and browsing for the specific file. Before adding a new document under the storage option, the user must determine the file type; the application allows the user to view the document at that time (Riyadh Municipality, 2008). When all the required documents are completed, the application will collectively reformat the documents and save the results.

Plan rules for a request, including information regarding the location, the land's current purpose, and the land use of adjacent properties can be reviewed by selecting the appropriate link (MIS Company, 2008). By clicking on the view system construction link, the user can review any building construction activities that have taken place on the land. The user can add construction requests to obtain required approval for future building plans (Riyadh Municipality, 2008). When the building plan has been approved there will be a sign in front of the request indicating granted approval. By selecting the save option, the user will see all completed files on the right hand side of the application (MIS Company, 2008). The supervision staff of the department of licenses determines which building plans require a technical report, through which any irregularities in the plan will be stated. Irregularities are added to the technical report by choosing the irregularities link, typing out a description of the irregularity, and saving it, upon which and inventory of the steps will indicate completion.

Payment for the technical reports can be completed by selecting the payment link, at which point the voucher number and its value can be added. The user can save the payment transaction, completing the application process, releasing the final report from the technical committee to the applicant.

Application for the Preparation of Survey Reports

Riyadh Municipality is currently working on developing a system for the preparation and production of survey reports for purposes such as displaying computer generated reports to specialists and providing complete print-outs of the work procedures

(Riyadh Municipality, 2012). It is hoped that this application will augment building permit and technical records applications.

A survey report is a document issued by the municipality that proves the existence of a property and outlines the area of the site. The report highlights and addresses any difference in the information contained within the deed, the site plan, and pre-existing property data. Found within the survey report is detailed information and spatial diagrams depicting the dimensions of the property at an appropriate scale, showing the boundaries of all sites along a street, including street width, and the degree of real estate in the neighbourhood (MIS Company, 2008). In addition to identifying the location of the property, the owner's name is stated, including the deed number, and the approved property plan. The survey report is completed for many purposes, such as obtaining a building permit, redivision and fragmentation of land, creating a building plan that is congruent with the land survey, and ensuring that the site boundaries remain intact and are not infringed upon (Figure 4.3) (Riyadh Municipality, 2012).

Figure 4.3. The Land Survey Report application.

Application Objectives

Creating a spatial version of the survey report that can be easily transmitted across the network of various municipal departments is one of the main objectives achieved through the land survey application. The use of this computer application will also reduce error, providing more accurate results, match land surveys with approved building plans, and update the base map as planners obtain new information (GIS Centre, 2008). The versatility of the application eliminates the need to use several other programs at various stages of the planning process, thus simplifying the procedure, and also facilitates indexing, and search and query functions, helping to establish infrastructure requirements for e-municipality (Riyadh Municipality, 2012).

Application Functions

The application set-up allows the user to enter all information about the location of the deed and ownership, including the deed number and data, the name of the neighbourhood, land number, plan number, as well as other data that allows the owner to be identified (MIS Company, 2008). After a land survey, the user can enter information regarding the site's size and boundaries to ensure that construction does not interfere with neighbouring properties. A sketch of the site depicting the boundaries, lengths, and parameters of the site and neighbourhood completes the report, making it ready to print in its final form (Riyadh Municipality, 2008).

Main Menus of the Application

The application home page includes a general map, the names of each layer, public research tools, and tools for navigating the map. From the homepage the user can access the request menu, which contains options associated with requests for a survey report. Using the request review option the user can view and print the survey form, which is used by the surveyor to record measurements of land lifting (MIS Company, 2008). In addition, the user has the ability to print a map, with surrounding landmarks of the area to be surveyed, and obtain a survey request through the request number system.

The reports menu contains options associated with drawing after the completion of the survey for the land, such as reviewing survey reports, and allowing the user to search through surveys based on decision or request number; assessing all information before printing. After the completion of requirements and reviewing the decision, the certification of summary reports option allows the survey and any additional related notes to become certified. Upon completion of the certification process, the data in the survey report and the sketch can no longer be modified (Riyadh Municipality, 2008).

The request of a new menu is an option that starts the process of creating a new request to insert data for a public purpose into the survey report. The source of this data can be from a sub-municipality or a surveyor. The new data entered can be obtained from a person who wants to apply for a new request, including the owner or an individual with the deed ownership (MIS Company, 2008).

Submitting a Request

To request a survey, submission must include the following documents: the applicant's identity card, a mandate authorized by the land owner in the event that they are unable to attend, and documents proving ownership of the deed (Riyadh Municipality, 2008). The requested information is entered into the system through the following steps: first, by entering data related to the owner or multiple owners, so that every time the database is searched all names of ownership appear. Next, all information relating the site, including plan number, land number, and the status of the land, whether it's located in the database or satellite image, must be entered. Data related to deed ownership, which is associated with both owner and location, will be collected from all deeds (MIS Company, 2008). After completion of all data entry, a request file print-out including request number, date of request, name of the land owner, name of sub-municipality, and the purpose of the survey report will be issued by the sub-municipality to the owner (Riyadh Municipality, 2008).

Reviewing a request can be completed from the main menu by selecting the survey request tab (MIS Company, 2008). From here, the user can search for any land survey requests made in the past and view them to obtain necessary information. The application also allows the user to print the survey report and related site maps. If the user is unable to find site information by entering the plan number or land number on the site map, the database will then display a map of Riyadh from which the user can zoom in and out to find the desired location, at which point the site map can be printed. Survey forms can be printed by the surveyor and brought to the field site to record data and illustrations.

Site Map Drawing

Site map drawing can be carried out after land survey work is complete by using one of several approaches (Riyadh Municipality, 2008). One method involves entering the (x,y) coordinates into the application and using the tools to complete the polygon drawing (MIS Company, 2008). This method is used when the survey is completed by measuring the lengths of land and when the land has a shape that is not four sided with distinct north, south, east, and west sides, which the application then translates into (x,y) coordinates on the grid. Another method involves entering the lengths of the main sides, as the site appears regular in terms of a four sided shape (Riyadh Municipality, 2008). An illustration of the site can also be completed by downloading an AutoCAD file; this method is used if the work is completed using an AutoCAD or Microstation Program, with the output file being in either a dgn, dxf, or dwg format (MIS Company, 2008).

Using the basemap to create the drawing for the survey report is another method that is frequently used; illustrating the realistic dimensions of the site in a highly accurate drawing (Riyadh Municipality, 2012). Time can be saved from the task of drawing if the measurements of the plan are identical to the measurements obtained from the survey report. Creating report illustrations using advanced drawing tools is a method that requires the use of ArcGIS or ArcEditor 9.3 programs, which are installed on a computer and used as desktop applications (MIS Company, 2008). Adding topography and drawing sections are often a requirement when the survey focuses on a point on the ground, such as in the case of providing illustrations for a building permit report (Riyadh Municipality, 2008).

From the reviewing the survey reports menu option, the user can review survey reports which are issued through the surveying report number. The approval of surveying reports option allows the user to review reports which have been approved and certified by the director.

Conclusion

The municipal government in the city of Riyadh has implemented technological innovations to manage the urban centre's rapid growth over the past decade. One of the ways it has tried to accomplish this is through the creation of a Task Force Centre, which utilizes GIS technology and is responsible for providing services to the public and municipal departments in the form of GIS applications.

An application that is currently being employed by the Task Force Centre is called the ATM Monitoring System. This application has been designed to monitor the activity and physical conditions of the ATM sites and to identify areas in the city that would potentially benefit from having an ATM location. The establishment of new ATM sites creates income for the municipal government through licensing fees and in some instances, rental payments. The ATM Monitoring System application is also capable of following up on building permits and any irregularities that an ATM site might encounter.

The System of Records for the Technical Committee is an application used in follow-up procedures for individuals applying for document transfer between planning departments, such as zoning and annexation, in order to change the type of land-use in accordance with the planning conditions of Riyadh. The System Surveying Report is another application that is used for the preparation and production of a survey report which identifies the location of a property, and highlights and addresses any differences between the information collected by the surveying deed and the approved plan. Through these applications the Task Force Centre hopes to provide the public with useful and appropriate services. Although applications of this type have been beneficial to the public service sector, more attention and consideration must be directed towards the creation of GIS applications that deal with fundamental challenges, such as the variety of environmental issues stemming from Riyadh's increasing urban expansion.

CHAPTER 5

SUMMARY, CONCLUSIONS

AND

RECOMMENDATIONS

Summary

Under the urban development strategy of the Kingdom of Saudi Arabia, the overall strategic development plan for Riyadh has been used to determine the vision for the city over the next 50 years (Riyadh Municipality, 2008). This vision required the preparation of a strategic plan that provides a spatial database covering all parts of the city (GIS Centre, 2008). Therefore, it was necessary to develop a Geographic Information System (GIS) Project. The Riyadh Municipality created a GIS Centre to serve as coordinator of the urban planning exercise (Riyadh Municipality, 2012). This research shows the feasibility of using this GIS Centre to manage the urban development by using GIS applications.

One of the topics that has been examined in urban planning in Riyadh was the theoretical aspect of GIS to identify the best routes for expansion of land use. This expansion can be monitored and detected via ways of examining how various types of buildings occupy land. As a result, it can be determined which land will be suitable for particular types of future land use; visualizing, assessing, and evaluating land suitability; and locating the right resources to meet the needs of all user groups. Thus, allowing for planners to map, monitor, identify and forecast the location and type of future land uses could help to alleviate problems with rapid urban expansion.

This study determined, however, that these types of GIS applications have been disregarded in the functioning of the GIS Centre. In addition to this, Riyadh's existing land use conditions in terms of the development of strategies that will help regulate and direct the city's growth were not considered in planning.

In the second chapter of this thesis, it was clear that MODON (Saudi organization for supporting industrial development), which is responsible for encouraging the development and expansion of industrial areas throughout the city, was not taking into account the city's cost of environmental health. These critical issues presently faced by the city were ignored in the GIS Centre's projects.

These issues were also identified in the third chapter of the thesis that shows the gaps in the current GIS applications being used by Riyadh Municipality that focus on the municipality, its departments and the public. So, following the discussion of the previous chapters, it is clear that the use of GIS in urban planning in Riyadh currently is at a level that needs improvement.

Finally, this study gives evidence that a number of recommendations should take place as soon as possible to ensure an organized urban development for a healthy environment. I will provide a step-by-step approach that can be embedded into the GIS software that is currently being used by the Task Force Centre to identify gaps in the use of the application by this GIS Centre.

Recommendations

As a result of the previous chapters, the feasibility of GIS in urban planning in Riyadh has been discussed as follows: defining GIS's scope in identifying land uses, assessing core needs of existing conditions in land use and describing gaps of using standard GIS data in effective planning of land uses.

I have suggested two mechanisms to be used in GIS by the Task Force Centre that will be more feasible for Riyadh's development:

-The Task Force Centre must take into account the applications of GIS in terms of identifying the best routes for expansion of land use. This expansion can be monitored and detected via ways of examining how various types of buildings occupy land. As a result, it can be determined which site will be suitable for particular types of future land uses; as well as visualizing, assessing, and evaluating land suitability; and locating the right resources to meet an industry's needs. Therefore, allowing for planners to map, monitor, identify and forecast the location and type of future land use problems.

- The Task Force Centre must take into account the applications of GIS in terms of identifying an approach to organize urban development, which will stop the expansion of industrial areas throughout the city. The implementation of a specific approach by the Task Force Centre will allow data to be viewed and displayed in a way that identifies parcels of land suitable for a particular use. The benefits of using this approach to display various types of land use is demonstrated in Chapter 3, where planners have recognized the environmental contamination of a residential area situated adjacent to an industrial area. Consequently, the approach will allow the sustainability of a healthy environment.

Method's Approach

1- The first step includes four standards:

- Defining the land use area: Data which is pertinent to determining the area of land use will be stored in GIS. This standard will act as a link between the decision maker, government ministries, departments of government, and organizations.
- Land use regulations: Regulations which planners must adhere to when determining the land use area will be stored in GIS. This standard will provide a link between the decision maker, government ministries, and departments.
- Identifying the interest group: The collection and visualization of data in urban planning is dependent on the cooperation, consultation, interaction, and partnership between government and the private sector. Data related to the interest group, whether they are government or private organizations, will be entered into GIS according to the sector's specific regulations.
- Classifying the land use area: Data will be displayed through maps and layers in GIS, including residential, commercial, industrial, agricultural, entertainment, and other public services.

2- The second step includes two standards:

- An economic purpose of land use: Data which encourages economic diversity and increases the percentage of Saudi citizens employed jobs in certain projects will be collected and analyzed. Data that is important in determining the economic purpose of certain land uses will be stored in GIS. This standard will act as a link between the decision maker and the Ministry of Planning and Finance.

- Relationship between the land use and its surrounding area: Data will be displayed through maps, layers of data, and charts in GIS. The data will show the positive and negative side effects caused by the integration of land uses. For example, when the construction of a factory has been proposed, planners must determine which of three zones related to population density are suitable to contain the new building. In such a case, it is usually the zone with the lowest residential density that is chosen for the project (Figure 5.1).

Figure 5.1. Relationship between the land use and its surrounding area.

3- The final step includes one standard:

- Follow up the development of land use: Data will be visualized through maps, layers of data, and charts in GIS. This data will show the progress in the development for certain land uses over time. As exhibited in the previous figure 5.1, the illustration of data also allows the planner to discern highly populated areas (dark colour) which are unsuitable for future development, from areas with a low population density (light colour) and are favourable for future development.

Advantages and disadvantages of the method's approach:

-Advantages:

-This method approach will lead to an efficient and effective planning process for city planners.

- This approach is beneficial to the decision maker, allowing them to communicate with various government departments.

-This method is useful for decision making in Riyadh municipality that helps regulate the expansion of land use in the city.

-This method will employ the GIS software in a field of urban planning that improves the condition of existing areas, as well as developing new areas in Riyadh.

-Through this method approach, several fields will have the opportunity to work as a unit.

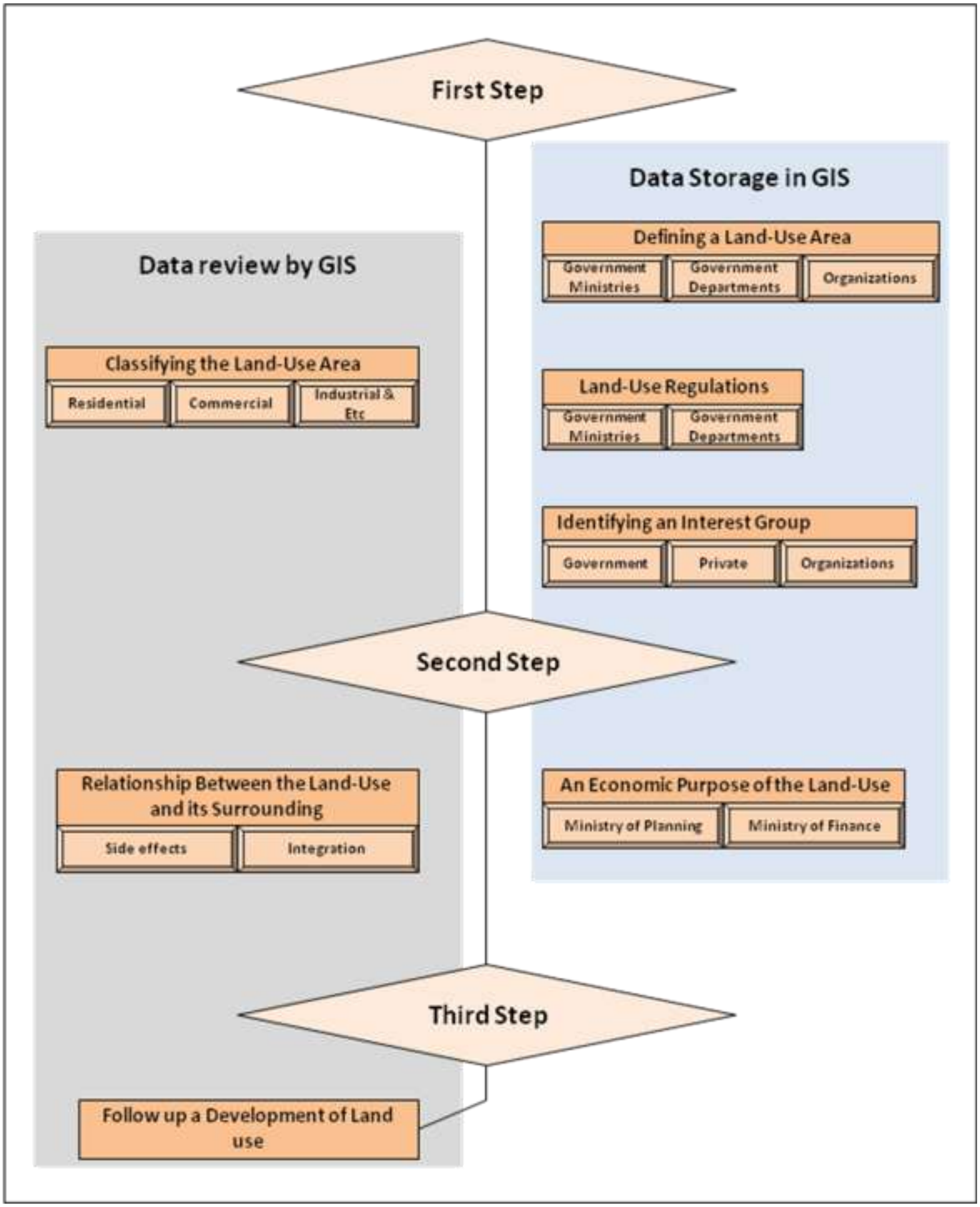
-Disadvantages:

-This method will be accessible through GIS software that cannot be used by all professionals because they need the software license to be able to work on these projects; and this license has a high cost, always.

-Future vision of this method approach:

-It is hoped that this method will be the first step to establishing a standardized approach to urban planning through GIS software. The standardized approach that has been described can be incorporated into GIS software (ArcGIS). The ArcMap program, which falls under the umbrella of this software, contains a Geoprocessing menu that allows the user to select a particular environment setting, and the standardized approach can be selected as an urban planning setting (Figure 5.2).

Figure 5.2. The idea of step-by-step approach.



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