THE NATURE OF GEOGRAPHIC INFORMATION SYSTEMS

Over The last two decades the steady growth in information technology has provided planners and others with new tools to process, analyze and present spatial data. One set of such tools, known as Geographic information systems (GIS) has been defined as: "a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the Earth. This normally considered to involve a spatially referenced computer data base and appropriate applications software." (Lord Chorley, 1987). Han and Kim (1989) define GIS as "one of the formalized computer-based information systems capable of integrating data from various sources to provide information necessary for effective decision making in urban and regional planning". Whereas Joao and Walsh (1992) define it as "an automated approach to locational and nonlocational data synthesis which combines a system capable of data capture, storage, retrieval, analysis and display."(See Figure 1 and Figure 2).

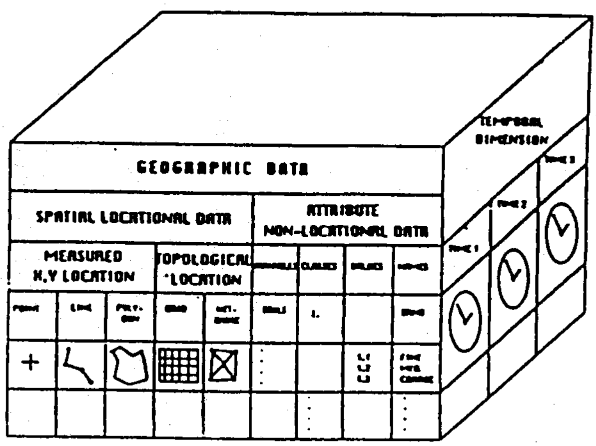

FIGURE 1: Conceptual Components of GIS.

THE ROLE OF GIS TECHNOLOGY IN URBAN DEVELOPMENT IN THE ARAB GULF STATES

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ABSTRACT

The purpose of this paper is to illustrate the role of the geographic information systems (GIS) in improving urban development in the Arab Gulf States. The paper is structured as follows. Background information on the definition of GIS, its usage, and recent trends is given. The implications of GIS in some Gulf States are discussed. Recommendations and concluding remarks are presented.

INTRODUCTION

Geographic information systems (GIS) appeared in the 1970s as a new approach to organizing spatial data in computers. GIS combine a database of attributes with one of geographical coordinates, where the attributes refer to points, lines or areas defined by the coordinates. Although the majority of GIS applications are concerned with mapping, the term GIS is increasingly used as a shorthand for a great diversity of computer-based applications involving the capture, manipulation, analysis, and display of geographic information and the associated services that go with them.

Since the computer technology to manage large amounts of geographic information and display it in graphical form became available in the 1980s, sale of GIS hardware have grown at rates over 10% per annum, and sales of software have increased by 15% - 20% each year. The main users of GIS are central and local government agencies and utility companies. Other important areas of application are in the field of environmental management and facilities planning. There has been a considerable increase in the number of business applications for sales analysis and marketing (Masser and Wegener, 1996).

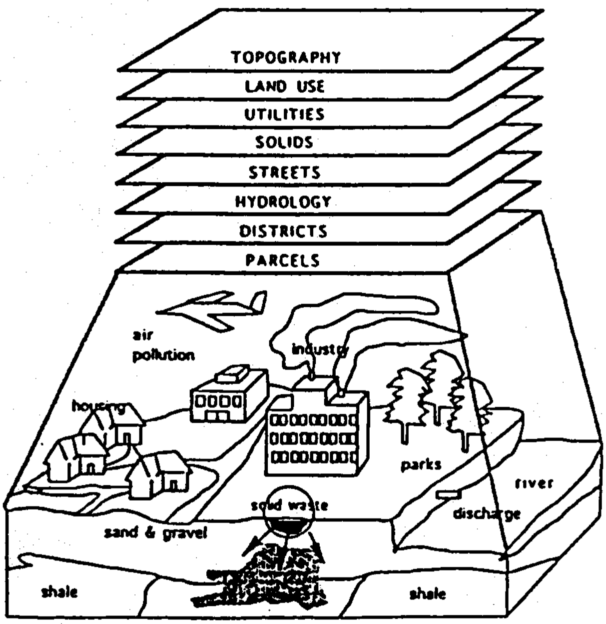

FIGURE 2: The Concept of GIS.

More Comprehensively, GIS can be described as: "a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems" (Worrall, 1991). However, a simple definition for GIS is given by Rhind (1989) which is based on the fact that the real world consists of many geographies and implies that GIS is "a computer system that can hold and use data describing places on the earth's surface." (Figure 2).

TECHNICAL ASPECTS OF GIS

A GIS is made up of database extracted from the real world, processed through software, by the user in order to get the required results (Figure 3). Therefore, the central components of a GIS as defined above involve the following:

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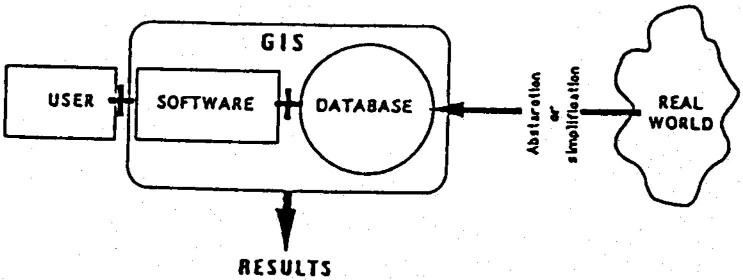

FIGURE 3: GIS Components.

1. Data capture or data acquisition

This is a process of transforming graphic and alphanumeric data into a form that is manageable by computer. Data may already be stored in paper records or may be derived from new surveys – for instance, from field or photogrammetric surveys or from data collection through questionnaires or on-site inquiries. New survey data may be collected from the start in computer readable form, the observations being linked electronically to direct digital recording system, or recorded by manual entry into electronic notebook or data logger. The conversion into digital form of existing paper records containing text and numbers may be undertaken by keyboard entry, typing in the lists by hand; by voice recognition where each word or number is dictated and the computer matches the voice pattern with a catalogue of words or numbers; or by scanning the page of text, each character then being recognized by the machine and translated into its own internal code.

2. Data Checking

Part of the process of data capture is quality control. Before entering the data into the archive each item must be checked and any errors eliminated. Good source data can be distorted through mis-typing, misidentification, inaccurate digitizing, wrong classification or, occasionally, corruption through the electronic processes. The computer can carry out some checks but others need human intervention. Further, the source data themselves may no be reliable and this may become apparent when different data sets are compared. Hence software must be included in the GIS so that corrections can be made to reconcile anomalies. In addition, some data may change over time so that information that is stored in the archive can be deleted or replaced by updated material. Hence the ongoing maintenance of a database can be a major expense, since it involves new data capture and alteration to old records.

3. Data Storage

Once the data are to a satisfactory standard they may be stored either on magnetic tape or disc, or on optical tape or disc. The volumes of data in a land or geographic information system are usually high and depend on the complexity and types of data and the number of different data sets that are incorporated. The quantity of data stored in any one system can be reduced by networking, so that separate databases can be linked together to form a heterogeneous whole. Most GIS are now designed around the relational data base model because this allows for the integration and distribution of data (McLaren, 1990). The relational model in essence stores data in rows and columns that can be checked to see where payment of its attributes occupying row) can be checked to see where payment of property tax is due – the date and amount being held in separate columns as attributes of each property.

4. Data Integration

Within an urban area different authorities or different sections and departments within one authority tend to build up their own data sets. Many of these are incompatible, the compilers of each data set having, for example, defined such a basic spatial unit as the land parcel in different ways – for instance some as a legal unit, others as a taxable unit or yet others as a unit of land use, each representing a different area on the ground.

From a technical perspective the data must be compatible not only in terms of definitions of the data types but also in terms of the formats and protocols used. The database should appear to be seamless, so that any chosen area can be investigated, not just a map sheet by map sheet. For this to be possible there must be integrity in the geometry, topology and attribute components of all the data. In a single database these matters should be checked at the data capture stage; but with networking, that is linking together the data sets held by different organizations, the management of the data as a consistent whole becomes a greater problem.

5. Data Manipulation and Analysis

The GIS must allow data to be retrieved from the database by object type (such as building) or attribute (brick built) and by combinations of features and attributes (brick buildings serviced by gas installed more than 50 years ago). Data must be able to be retrieved by spatial location or extent – for instance all data within a particular planning zone or within a certain distance from a specified point (such as all houses with children of school age that are located within three kilometers of the site of a proposed new school). The system must be able to handle both raster and vector data so that, for instance, land-use boundaries in vector form can be extracted from or added to remotely sensed imagery.

Ideally the GIS should be able to process field survey and photogrammetric data, to digitize data on existing maps and be able to transform the data from one coordinate system to another, including changing the map projection. It should also be able to handle three-dimensional data. In early days GIS concentrated on layers or levels of data (such as all roads, all rivers, all buildings or all planning zone outlines), each layer being treated as two-dimensional map that could be displayed on top of any other layers. The trend today is towards three dimensional data management (Raper, 1989), so that in an urban area, heights of buildings as well as, their location may be processed, or levels considered when planning improvements to the water supply system or designing new road alignments

6. Data Display

One of the most powerful elements of a GIC is its ability to display data in map form, providing virtually instant communication of the results of its analysis to the decision-maker. The resolution of modern graphic computer screens is directly related to their price, that of two colour screens (for instance, black and white) being, per unit cost, cheaper, crisper and clearer than for multi-colour. The quality of hard copy output of line maps also depends very much on the price that is paid for the plotter that produces it. A current weakness in many GIS is in the supporting cartographic design, the quality of the images and the symbolization often being poor and confusing.

THE IMPORTANCE OF GIS TECHNOLOGY

Importance Information: It can be argued that information is the most valuable resource of any organization. A Company may have tittle or control of thousands of hectares of land, the latest and best capital equipment, or thousands of well-trained employees. But at the end of the day, it is the information about these resources that allows the organization to manage them and put them to use. Information technology is the tool that allows an organization to manage and use its assets. The larger an organization is, and the more assets it must manage and maintain, the more important information technology becomes.

Geographic Components: It has been estimated that al least 85% of most organizations' data has a geographic component. Obviously, properties, roads, and buildings all have a geographic location, as do soil types, sewer lines, and zoning districts. But so do employees, clients, and suppliers, as well as inventories. Moreover, the geographic component is often the unique identifier for a database record.

Most information technology requires assigning a unique identifier to each item in a database. Since geographic data by definition has a unique identifier (its location), GIS can therefore often become applied as a key part of the information organizations, even those that aren't traditionally thought of as users of mapped information.

Hidden Data: GIS technology also has the ability to unlock the power of "hidden" geographic data. Location is a primary factor in most of decisions that people make on a daily basis. However, only by mapping the location and concentration of the pollutants can the data bye analyzed to reveal the source of the contamination. When viewed geographically, most data will reveal patterns and relationships that would otherwise be hidden.

To sum up, information management is a critical task for most organizations, and most information has a geographic component. As a tool specifically designed for the creation, storage, use, and analysis of large volumes of geographic information, GIS can be the logical information system for many organizations to use to manage their resources.

RECENT TRENDS IN GIS

Like most things in the computer arena, there have been many, many developments in GIS over the last few years. Two of the ones are a trend towards increased affordability and usability and, a change in how GIS software will store information.

Affordability and Usability: just a few years ago, the cost of hardware and software for a single GIS workstation could easily exceed Dhs 125,000. Until the advent of Windows NT, most of the more powerful GIS package simply required processing power that was not available from the PC. Software packages were powerful, but complex and expensive.

On the hardware and operating system side, Windows NT and the rapid advancement of the PC has made the PC platform much more powerful. At the same time the PC has become even more affordable. The major GIS software companies have rewritten their products to operate on Windows NT, and as the market has extended software prices have come down. Another change has been the advent of cheaper, easier to use "desktop" GIS software. Often this software will have fewer features for GIS data creation and editing, but is ideally suited for reading and analyzing data created by the GIS software packages.

It is now possible to get started in GIS for less than Dhs 15,000 for a workstation and software. This trend towards increased affordability and ease of use in hardware and software helps to broaden the market and appeal of GIS. It also means that an organization implementing GIS now, rather than a few years ago, will find it much more affordable and easier.

GIS Data Storage: The other major (and even more recent) trend is towards a new method of storing spatial data. Early GIS systems were stand-alone models, storing data in a proprietary format. The graphic (spatial) and non-graphic data were often stored separately, in separate file formats. For analysis, a snapshot of the non-graphic attribute data would be imported into the spatial data. Because the analysis was not done on "live" data, the results could not be posted back to the main system.

The nest development (what currently most commonly used) is hybrid system, where the GIS software maintains a live link between the spatial data and the non-graphic attribute data. The spatial data is stored in a format used by graphic engine (such as Micro station or AutoCAD). The non-spatial data is normally in a RDBMS (relational database management system) such as Oracle. The RDBMS data can be shared with other non-GIS users in the enterprise. The spatial data, however, is only accessible to those with GIS software.

For several years there has been a movement towards Open GIS – making GIS data more compatible between the various GIS software packages. The software users and manufacturers have been working towards design of a standard format that all GIS software can use read and write. Already there a number of GIS products that can read and work with data created by other GIS software.

Most recently there has been a trend towards saving the spatial data in the RDBMS along with the non-graphic attribute data. The power of the RDBMS brings even more to GIS software and allows for better use of GIS data on an enterprise-scale. Oracle has recently released their Spatial Data Option (SDO) which is geared for the storage of spatial data. The RDBMS will maintain database integrity for the spatial and non-spatial data, and make the data accessible to all applications. As this standard takes hold, it will help bring about a standard data storage format for GIS data, allowing the GIS software of the various vendors to use each other's data. The various GIS software vendors will still offer individual strengths and capabilities. But if this trend continues to develop, sharing of GIS data will become much more universal.

It is even likely that use of GIS data by non-GIS software will become common. Just as one can import a spreadsheet table into a word processing document, it should become possible to import GIS data into a spreadsheet.

APPLICATIONS OF GIS TECHNOLOGY

GIS technology has four roles to play in urban development: as a way to monitor the overall environment, as a tool to analyze planning options, as a guide to reduce risk for the decision maker and as a set of techniques to assist those who must implement the decisions. As a support for monitoring it is dependent on the availability and quality of the data that are supplied. Given good, accurate and up to date data, the GIS can be used in many activities (Table 1), for example, to identify areas of land dereliction, analyze changing patterns of land use, examine records of land ownership and their relation to land transaction values and indicate areas suitable for further physical development. A GIS should be able to display vacant or marginal land and to monitor how these change over time consequent on the implementation of land development policies. The GIS should also help in the management of real property that is owned by the urban authority – very often neither central government nor local authorities have integrated records of what land they own and cannot therefore properly manage their own basic resources.

Once problems have been identified, the GIS technology can be used to investigate possible solutions. Alterations to traffic flows or the impact of new housing schemes on shopping or transport requirements can be examined and the results displayed in various cartographic forms. Given suitable models, alternative solutions can be examined. Here, however, there is a potential weakness in that the algorithms underlying the models in a proprietary GIS may not be fully explained for commercial reasons or because the validity of their conclusions is simply unknown – the analysis and manipulation may be based on accurate and reliable data but still produce wrong information through incorrect and reliable data but still produce wrong information through incorrect assumptions underlying the mathematical models.

TABLE 1: Activities that Benefit From GIS

. Archaeological site recording and monitoring
. Billing customers and ensuring that no address is missed
. Building permits allocation, control and monitoring
. Central government reporting, supplying data and maps
. Communication through maps and graphics with decision makers and with the public
. Competitive tendering, for instance assessing areas for grounds maintenance or street cleansing
. Compulsory purchase orders, identifying and monitoring those affected demographic analysis, including socioeconomic data
. Development control, planning and implementing enforcement
. Emergency planning, in case of major disaster
. Emergency services management on a routine basis or in times of crisis
. Environmental control and enforcement of regulations
. Environmental impact assessment for proposed development
. Financial control
. Finding sites for new developments
. Fire services management, including checks on buildings
. Footpath maintenance

. Land-based taxes, ensuring complete cover and collection
. Land ownership records, possibly linked to national registers
. Land searches for local land charges
. Land-use management, including monitoring of present use
. Links to other sets, based, for example, on parcel identifiers
. Managing building assets, ensuring the efficient use and maintenance of urban authority property
. Management of mineral resources
. Monitoring contracts that have been let to the private sector
. Monitoring energy use
. Monitoring the land market over space and time
. Physical planning, identifying resources and constraints
. Police management and analysis of patterns of crime
. Pollution control, identifying sources and monitoring effects
. Population forecasting over time and space
. Pupil data for school resource planning
. Resource optimization in general
. Road traffic orders
. Route planning, optimizing services such as refuse collection
. Social services, optimizing and managing their work
. Street light maintenance
. Targeting mail shots for more efficient mail distribution
. Traffic accident analysis and planning road improvements
. Traffic modeling to predict traffic flows
. Transport planning in general
. Tree preservation orders
. Utility management (water, sewerage, gas, electricity, telephones)
. Valuation and property assessment for acquisition or taxes

Source: LAMSAC, 1989.

IMPLICATIONS OF GIS IN ARAB GULF SATES

The use of GIS in urban and regional planning in the developing countries is at the early stage of development (Yeh, 1991). In the late 1980's, a few large-scale GIS projects were developed at the planning stage of development. The most notable one are examples in the Arab Gulf States in Qatar, Oman and Saudi Arabia (ARC NEWS, 1989; Yeh, 1991). Three examples are briefly described here to give a flavor of applying GIS techniques in these countries.

The first example is a GIS research project concerning the construction activities in Doha, Qatar (Figure 4). The purpose of this research was to guide the growth management policy by constructing a model that could be used to identify the land available for urban growth, to monitor the rate of land development, and to highlight areas that were close to reach saturation.

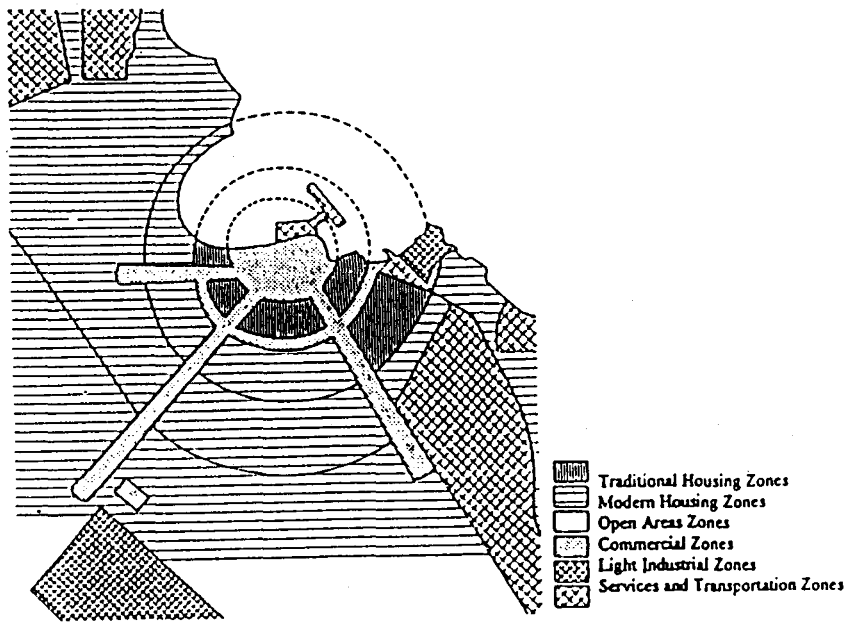

Figure 4: The Internal Structure of Doha, 1995.

The adapted model was aimed at estimating the time frame (number of years) required for a given municipality in Doha to reach the level of urban saturation. The conception of the model was based upon the calculation of the residue of land in each municipality and the consumption rate of built-up area per annum. The steps followed to estimate the urban saturation index were:

1. Calculation of land area of each municipality.
2. Calculation of the deductible land areas (e.g., road network, industrial, ... etc.)
3. Calculation of the net land area.
4. Subdivision of the net area into sections of similar allowable FAR values.
5. Calculation of allowable total built-up area in each municipality.
6. Calculation of the remaining built-up area available for development.
7. Calculation of the time index for saturation.

The final outcome was the index of urban saturation in Doha. It shows the number of years needed for a municipality to reach its saturation. It also highlights areas nearest to saturation and would, therefore require immediate attention of urban planners.

The second example is a Land Information System (LIS) Conceptual Design Study for the Sultanate of Oman. The study consisted of eight stages: inception seminars, user surveys, systems review, and data survey, database design, system specification, implementation plan, and final report. The system design developed for Oman provided a structure for development of four components of an LIS: organization/staffing, software, hardware, and database (Figure 5).

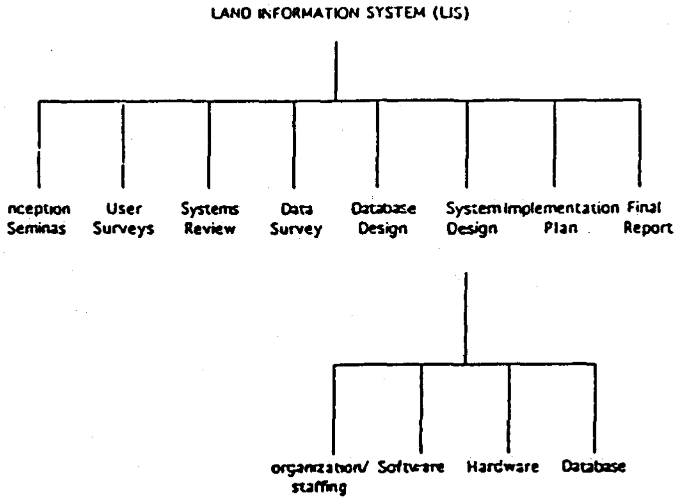

FIGURE 5: The basic components of LIS in Oman.

First: A distributed organizational approach was recommended for Oman in which each ministry would operate as a node on a network. The network would be managed by a technical group within the Supreme Committee for Town Planning. The existing staff would be trained to conduct their jobs with new LIS tools.
Second: Software requirements for the LIS would include geoprocessing and database management software, which would be integrated to appear to the users as a single system.

Third: And with regard to hardware, each ministry would require a CPU and related peripheral devices. The size and selection of hardware would depend on a number of users, size of database, and software requirements.

Fourth: The database developed for Oman consisted of several data layers that would be shared among the land-related ministries. Six major categories of data have been defined: Base map, land records, transportation, facilities, environmental, and administrative areas.

The final outcome of this project was an implementation plan which presents a work program, schedule, and cost estimate for implementing the Oman LIS (Figure 5).

The third example is a major nation-wide project for providing environmental support information to the nomads of Saudi Arabia (Figure 6). The Meteorology and Environmental Protection Administration (MEPA) sponsored the project. The project was aimed at protecting the rangelands of the country and their resources through the development of nomadic life and improvement of the nomadic people's strategies.

The project adopted a holistic approach by bringing together the various factors making up the decision-making base of nomads. These factors included the physical characteristics of the rangeland resources, the technological capabilities of rapid assessment of rangeland resources status, and the requirements for education and information distribution.

A pilot study area, in the mid-north of the Kingdom and covering an area of 65,000m2, was selected. A number of field surveys was carried out for collecting information, such as mapping of land systems and the physical resources of the rangelands. The outcome of the project was a database developed on MEPA's VAX minicomputer using ARC/INFO for continual input-retrieval assessment and display of data (Figure 6).

FIGURE 6: The generalized geology, one of the layers of Environmental management database developed by MEPA to support nomads.

CONCLUSIONS AND RECOMMENDATIONS

The basic concept of GIS is ever appealing, as the map without the problems of the conventional map. Given the widespread use of the conventional map it seems only natural to assume that in time the computerized map will be widely used.

The development of GIS is reliant upon the collection of accurate data, which if undertaken independently can amount to a significant investment. At present there are several developers of GIS technology, each one with their own data-collection and access arrangements. Widespread implementation of GIS will only occur when there is a more co-ordinated approach with regard to data management as one of the very features of a database is its ability to compare like with like given a common identifier, which in the case of GIS is its spatial reference.

Another area where GIS offers scope for development is with regard to its ability to interface with other software programmes. In the more quantitative disciplines such as Engineering, Accountancy, Planning and administration, computer software exists which facilitates the practice of that discipline. Developers of GIS could liaise with the developers of these other computer software to develop the linkages between the respective software so that the full potential can be achieved. However, the direction of GIS is now shaped by its investors, who after all will have the first hand knowledge of disciplines that the GIS technology will be applied to.

An important feature of GIS in the Arab Gulf State is the adoption of the techniques that GIS technology implies at different levels of planning, be they national (as in the example of Oman) or regional (as in the example of Saudi Arabia). However, the common characteristic that is shared among these two levels is the concern with land information.

It has also been observed that most of the problems in using GIS in developed countries often occur in developing countries (Masser and Campbell, 1989; and Yeh, 1991). These are funding, data state-of-the-art of planning, manpower and training, maintenance, software development, and standardization. However, The crucial question is often not whether a country can afford to have a system, but rather whether the cost of not having a GIS can be sustained.

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