1

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISION^{3M} RESOLUTION TARGETS

PIONEERS IN METHYLENE BLUE TESTING SINCE 1974

1800 COUNTY ROAD 8, BURNVILLE, NH 03033, USA
TEL: 603 888 7887 FAX: 603 888 7887 TLA: 0100000000

National Library
of Canada

Acquisitions and
Bibliographic Services Branch

395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale
du Canada

Direction des acquisitions et
des services bibliographiques

395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Votre file - Votre référence

Votre file - Notre référence

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

**A FRAMEWORK AND CONCEPTUAL GUIDELINES
FOR THE IMPLEMENTATION OF
GEOGRAPHIC INFORMATION SYSTEMS
IN THE GOVERNMENT AGENCIES OF THE
KINGDOM OF SAUDI ARABIA**

**by
Saleh Alsawydani**

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of**

(Master of Arts)

Department of Geography

**Carleton University
Ottawa, Ontario**

April, 1992

**(c) copyright
1992, S. Alsawydani**

National Library
of Canada

Acquisitions and
Bibliographic Services Branch

395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale
du Canada

Direction des acquisitions et
des services bibliographiques

395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Votre titre / Votre référence

Our title / Notre référence

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-79845-9

Canada

Thesis contains black and white and/or
coloured graphs/tables which when
microfilmed may lose their significance.
The hardcopy of the thesis is available
upon request from Carleton University Library.

We the undersigned, recommend to the Faculty of Graduate Studies
and Research the acceptance of the thesis:

**A FRAMEWORK AND CONCEPTUAL GUIDELINES
FOR THE IMPLEMENTATION OF
GEOGRAPHIC INFORMATION SYSTEMS
IN THE GOVERNMENT AGENCIES OF
THE KINGDOM OF SAUDI ARABIA**

submitted by Saleh Alsawydani
in partial fulfilment of the requirements for
the degree of Master of Arts

D.R.F. Taylor

Thesis Supervisor

Michael Smith

Chair, Department of Geography

Carleton University
April 1992.

Thesis Summary

This thesis outlines a framework and development guidelines for the implementation of Geographic Information Systems (GIS) in government agencies of the Kingdom of Saudi Arabia (KSA) and provides an overview of GIS technology, its computer environment and fundamentals. Furthermore, it evaluates institutional and organizational issues related to GIS development in the KSA. Finally, it provides a pilot project for examination in the field of GIS as applied to transportation. This project was conducted at the Geographic Information Systems Division (GISD), of the Surveys, Mapping and Remote Sensing Sector (SMRSS), under the terms of a Memorandum of Understanding (MOU) between Carleton University and the Department of Energy, Mines and Resources (EMR), Canada.

The pilot project data was obtained through a questionnaire distributed to and interviews conducted with, several government agencies in the KSA. The resultant analysis indicated that the use of GIS technology is still in the early stages and provided an insight into the future direction of GIS in these agencies. The information derived from the above survey, combined with the current literature and practices of GIS technology was taken into consideration when developing the guidelines for GIS implementation in this thesis. The thesis will also indicate the need for complete cooperation and commitment by all concerned parties once the decision to implement a GIS has been taken. It is recognized that GIS implementation has more to do with institutional and organizational issues than strictly technical. It also emphasises that GIS development must merge with the functions of an organization rather than the other way around. One of the significant trends in this study is its recognition of the importance of the preparatory phase of system development, which is of particular importance to government agencies in the KSA where most of them have an entrenched tradition of "manual practices" when dealing with geographic information.

Acknowledgements

I would like to express my deep gratitude to the many people who have given me their help and support during the course of writing this thesis. It is impossible for me to mention all of them by name. However, I am especially grateful to:

-Professor Fraser Taylor, my supervisor, for ongoing encouragement, assistance and guidance throughout the entire project. Words can not really express my deep appreciation for him;

-Dr. Mosaad Allam, from EMR, who always devoted time for me to exchange ideas and read my work, which has been my richest source of knowledge;

-Ms. Angela Templin, Ms. Charlene Morisson, and Ms. Carole D' Aoust-Martin, from EMR, all of whom contributed and provided 'hands-on-training' with GIS systems in both theoretical and practical terms. Without their help this study would not be a reality;

-Mr. Alex Sturrock who took the time to read my work and gave me valuable feedback;

-Mr. Steve Prashker, from CU, for his help with computer systems at Carleton University;

Professor, John Robinson, from University of New Brunswick, who explained and provided me with materials on pavement research;

-Mr. Jacques Vermeersch, from Prime Computer of Canada Limited, for assistance with System 9, and programming procedures for distress value calculation.

-Major, Abdullah Al-shahrani and Mr. Muhammad Al-Momen, from Military Survey Department, for discussions on GIS and its applications and filling out the GIS survey;

-Dr. Jalal Nafakh and Mr. Abdulrahman Al-Mesiened, from ADA, for providing me with spatial and attribute data for the pilot project;

-Mr. Stefan Befgstrom, Mr. Ali Al Tuwaijry, Mr. Abdul Aziz Al Salem, from MOC, for taking the time to fill out the GIS survey;

-Dr. Mustafa Al- Degaither, Mr. Adnan Al- Saati, from KACST, for discussions on GIS; and

-Mr. Mohammed Ben Mafouz, from MAW, for taking the time to fill out the GIS survey.

I would like also to thank my sponsors Imam Mohammed Ibn Saud Islamic University and Saudi Education Mission in Canada, for making my study possible.

My wife Modi and my children Monirah, Amel and Mohammed special thanks to you all for your patience, support, and understanding.

My friends Ali Al-Sha'ie, Khalid Al-Jufy and Abdullah Al-suwidani for their help and bearing with me.

There are others who I may have missed here, thank you all for whatever support and help you have provided me.

Table of Contents

Thesis Summary	iii
Acknowledgements	iv
Table of Contents	v
List of Tables	xi
List of Figures	xii
List of Maps	xiii
Abbreviations	xiv
1. Introduction	1
1.1. Background	1
1.2. Study Objectives	2
1.3. Importance of the Study	3
1.4. Research Hypothesis	4
1.5. Research Methodology	4
1.5.1. Approaches to GIS Development	5
1.5.1.1. The Hierarchical Approach	5
1.5.1.2. The Anarchical Approach	5
1.5.1.3. The Mutual Collaborative Approach	6
1.5.2. The Conceptual Framework of Implementation	6
1.5.3. Pilot Project	8
1.5.3.1. Study Area	8
1.5.3.2. System Resources	8
1.6. Sources of Information	9
1.6.1. Literature Review	9
1.6.2. GIS Survey	11
1.6.3. Interviews	12
1.7. Thesis Organization	13

2. GIS Technology: An Overview	15
2.1. Introduction	15
2.2. Definitions	16
2.3. A brief History of GIS	17
2.4. Hardware Development	19
2.4.1. Microcomputers	19
2.4.2. Workstations	20
2.4.3. Networks	21
2.5. Software	22
2.6. Functional Elements of GIS	24
2.6.1. Data Input	24
2.6.2. Data Processing and Organization	25
2.6.2.1. Infological Modelling	26
2.6.2.2. Datalogical Model	28
2.6.3. Data Management	28
2.6.4. Data Manipulation and Analysis	28
2.6.5. Data Output	29
2.7. Summary	29
3. GIS-Facilities	31
3.1. Introduction	31
3.2. Computer Graphic-Facility	31
3.2.1 Vector Data Structure	32
3.2.1.1. Spaghetti Model	33
3.2.1.2. The Topological Model	34
3.2.1.3. Hierarchical Vector Model	36
3.2.2. Raster Data Structure	38
3.2.2.1. Run-length Encoding	40
3.2.2.2. Quadtrees	40
3.3. Database Management-Facility	43
3.3.1. Traditional File Processing Approach (TFPA)	44
3.3.2. DBMS	46
3.3.3. Conventional DBMS	50
3.3.3.1. Relational DBMS	50
3.4. Analysis-Facility	51
3.4.1. Spatial and Attribute Analysis	52
3.4.1.1. Neighbourhood Analysis	55
3.4.1.2. Overlay Analysis	56
3.5. Summary	57

4. GIS and Government Agencies: Some General Relations	59
4.1. Introduction	59
4.2. Background	60
4.3. Requirement for Geographic Information	62
4.3.1. Agriculture and Water	63
4.3.2. Natural Resources	65
4.3.3. Municipality and Residential Development	66
4.3.4. Pilgrimage (Hajj)	68
4.3.5. Transportation	69
4.4. Source of Geographic Data	70
4.4.1. Statistical Data	70
4.4.2. Existing Maps	71
4.4.3. Ground Surveys	72
4.4.4. Aerial Survey	72
4.4.5. Remote Sensing	72
4.5. General Characteristics of Geographic Data	73
4.5.1. Data Sharing	73
4.5.2. Data Maintenance	74
4.5.3. Data Standardization	74
4.6. Some Suggested Solutions	74
4.7. Political Support	76
4.8. Managerial Support	76
4.8.1. Decision Making	77
4.8.2. R&D Activities and GIS	78
4.8.3. Coordination and Collaboration	78
4.8.4. Training	79
4.9. Example of GIS in the KSA	80
4.9.1. MIS Objectives	80
4.9.2. Phases of MIS Construction	81
4.9.3. Some Comments on MIS Development	84
4.9.3.1. Gradual Development	84
4.9.3.2. Digital Data Integration	84
4.9.3.3. The Experience	84
4.10. Summary	85

5. A Framework and Conceptual Guidelines for the Implementation of GIS	86
5.1. Introduction	86
5.2. Pre-automation Stage	86
5.2.1. Awareness of the Utility of GIS	88
5.2.1.1. Application Challenges	89
5.2.1.2. Capabilities and Limitations of GIS	89
5.2.2. Management Support	90
5.2.2.1. Recognizing the Need for GIS	90
5.2.2.2. Resources	91
5.2.2.3. Organizational Changes	92
5.2.2.4. Cooperation	92
5.2.2.5. Mandate	92
5.2.3. GIS Team	93
5.3. Planning Stage	94
5.3.1. GIS Objectives	95
5.3.2. Requirements Assessment	95
5.3.2.1. Functional (Users) Needs Analysis	96
5.3.2.2. Data Needs Analysis	97
5.3.2.3. HW/SW Specification	102
5.3.3. Approaches to GIS Development	102
5.3.4. Justification Analysis	103
5.3.4.1. Benefits Estimate	103
5.3.4.2. Costs Estimate	104
5.4. Design Stage	106
5.4.1. Implementation Plan	107
5.4.2. System Procurement	108
5.4.2.1. RFP	108
5.4.3. Database Design	110
5.4.4. Applications Design	111
5.5. Development Stage	111
5.5.1. System Acquisition	113
5.5.1.1. Evaluation and Vendor Selection	113
5.5.1.2. Installation	115
5.5.2. Database Development	115
5.5.3. Organizational Structure	116
5.5.3.1. The GIS Manager	117
5.5.3.2. The GIS Analyst	117
5.5.3.3. The Database Administrator	118
5.5.3.4. The Cartographer	118
5.5.3.5. GIS Operators	118
5.5.3.6. The System Manager	118

5.5.3.7. Programmers	119
5.5.3.8. The End User	119
5.6. Operational Stage	119
5.6.1. Pilot Project	120
5.6.2. Applications Development	121
5.6.3. Continuing Support	122
5.6.3.1. Managerial Support	122
5.6.3.2. Financial Support	122
5.6.3.3. Training Support	123
5.6.3.4. Technical Support	123
5.6.3.5. Legal Support	124
5.7. Summary	124
6. Transportation Applications: pilot project	125
6.1. Introduction	125
6.2. Objectives	126
6.3. User Needs Analysis	126
6.4. Benefits	127
6.5. Project Deliverables	127
6.6. Applications Development	128
6.5.1. Data collection	128
6.6.2. Data modelling	128
6.6.2.1. ERD	129
6.6.2.2. Data dictionary	130
6.7. Database Development	136
6.7.1. Spatial database	136
6.7.2. Attribute database	138
6.8. Spatial and attributes integration	141
6.9. Surface distress	141
6.10. Query design	144
6.10.1. Conditional symbology	145
6.10.2. Street network	146
6.10.3. Pavement distress	146
6.10.4. Auto volume projection	146
6.11. Summary	150

7. Conclusions and recommendations	152
7.1. Conclusions	152
7.2. Recommendations	157
Bibliography	158
Appendices	167

List of Tables

Table 1.6.2.1. Organizations identified for survey distribution and interviews . . .	12
Table 1.6.3.1. Organizations and individuals identified for interviews	12
Table 2.6.3.1. Data input systems	25
Table 2.6.5.1. Examples of output forms of land-related information	29
Table 2.6.5.2. Examples of different techniques and devices for output of land-information	29
Table 3.2.1. Advantages and drawbacks of using raster and vector models . . .	45
Table 3.3.2.1. Some of DBMS facilities	48
Table 3.4.1.1.1. Neighbourhood functions	56
Table 4.2.1. Dryland area of the KSA "Aridity"	62
Table 5.3.2.1.1. Geographic data management procedures	98
Table 5.3.2.1.2. Relationships between application areas and basic classes of geographic information	99
Table 5.3.2.1.3. Relationships between generic functions and applications	99
Table 5.3.2.1.4. Relationships between specific tasks and generic functions	100
Table 5.3.2.1.5. Relationships between specific tasks and GIS functions	100
Table 6.6.2.2.1. Data components description of street inventory data	131
Table 6.6.2.2.2. Data components description of subsection inventory data . .	131
Table 6.6.2.2.3. Data components description of surface distress data	133
Table 6.6.2.2.4. Data components description of planning data	135
Table 6.9.1. Severity rating code description	142
Table 6.9.2. Extent rating code description	142
Table 6.9.3. Distress type and relative weight	143

List of Figures

Figure 1.5.2.1. Conceptual framework of implementation	7
Figure 2.3.1. GIS family tree	18
Figure 2.4.3.1. GIS Division network configuration	23
Figure 2.6.1. Functional elements of GIS	24
Figure 2.6.2.1.1. Geographic phenomena and ERD	27
Figure 3.2.1.1.1. Spaghetti model	33
Figure 3.2.1.2.1. Topological data structure	35
Figure 3.2.1.3.1. Hierarchical structure	37
Figure 3.2.2.1.1. Raster data structure and run-length encoding	41
Figure 3.2.2.2.1. Quadtree data structure	43
Figure 3.3.3.1.1. Relational model	51
Figure 5.2.1. Pre-automation stage	87
Figure 5.2.1.1. Awareness of the utility of GIS	88
Figure 5.2.2.1. Management support	91
Figure 5.3.1. Planning stage	94
Figure 5.3.2.1.1. Information breakdown	96
Figure 5.4.1. Design stage	107
Figure 5.5.1. Development stage	112
Figure 5.6.1. Operational stage	120
Figure 6.6.2.1. ERD model	129

List of Maps

Map 6.10.2.1. Street network	147
Map 6.10.3.1. Overall street surface condition	148
Map 6.10.4.1. Number of trips projected on street network	149

Abbreviations

ACSM	American Congress on Surveying and Mapping
ADA	Arriyadh Development Authority
AM/FM	Automated Mapping/Facilities Management
ams	advanced mapping system
ASMD	Areal Survey and Mapping Department
AVHRR	Advanced Very High Resolution Radiometer
CAD	Computer Aided Design
CDS	Central Department of Statistics
CGIS	Canadian Geographic Information System
CIS	Cadastral Information System
CISM	Canadian Institute of Surveying and Mapping
COGO	Coordinate Geometry
CPU	Central Processing Unit
CRT	Cathode Ray Tube
DBA	Database Administrator
DBMS	Database Management Systems
DMMR	Deputy Ministry for Mineral Resources
DMTP	Deputy Ministry for Town Planning
DS	Distress Score
DXF	AutoCad's Drawing Interchange Format
EMR	Energy Mines and Resources
ERD	Entity Relationship Diagram
FDP	Fifth Development Plan
GBF/DIME	Geographic Base File/Dual Independent Map Encoding
GDP	Gross Domestic Product
GIS	Geographic Information System
GISD	GIS Division
HRV	High Resolution Visible
HW	Hardware
ICC	Information and Computer Centre
I/O	Input/Output
KACST	King Abdul Aziz City for Science and Technology
KSA	Kingdom of Saudi Arabia
LAN	Local Area Network
LIS	Land Inventory System
LMD	Land Management Department
MAW	Ministry of Agriculture and Water
MDB	Municipality Database
MFNE	Ministry of Finance and National Economy
MHPW	Ministry of Housing and Public Works

MIS	Municipality Information System
MOC	Ministry of Communications
MODA	Ministry of Defence and Aviation
MoMRA	Ministry of Municipality and Rural Affairs
MOU	Memorandum of Understanding
MPE	Ministry of Pilgrimage and Endowments
MPMR	Ministry of Petroleum and Mineral Resources
MSD	Military Survey Department
MSS	Multispectral Scanner
NDOT	New Brunswick Department of Transportation
NNP	Naming and Numbering Project
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OS	Operating Systems
PC	Personal Computer
RAM	Random Access Memory
R&D	Research and Development
REDF	Real Estate Development Fund
RFP	Request for Proposal
RIS	Rural Information System
SAFRS	Saudi Arabia Facility For Remote Sensing
SDS	Surface Distress Score
SIF	Intergraph's Standard Interchange Format
SNA	Standard Network Architecture
SPA	Sea Ports Authority
SPOT	Système Pour l' Observation de la Terre
SQL	Structured Query Language
SR	Saudi Riyal
SW	Software
TFPA	Traditional File Processing Approach
TM	Thematic Mapper
UAE	United Arab Emirates
URISA	Urban and Regional Information System Association
URPIS	Urban and Regional Planning Information System

Chapter one

1. Introduction

1.1. Background

A developmental process aims to improve social, economic, environmental, and technical aspects of society through policies and decision making. Planning as an instrument for effective development, requires integration between decision-making mechanisms and whatever practical means are available to achieve developmental goals. Planning for growth and other related activities, such as management of natural resources, municipal services and utilities, requires ready access to their geographic location and features. These activities also require the capability to process this information for analysis of dynamic change. This capability is important in countries or geographical areas experiencing relatively high growth rates and rapid modernization, and is particularly important in those countries where economic distress indicates a need to make more effective use of resources available.

At present, computer systems are being used extensively to process geographic information in many areas of interest such as: environmental monitoring, municipal services and utilities management, agriculture, geology, mining, and resource management. The object of these systems has been, and still is, to support management and to improve the decision-making processes.

Geographic Information Systems represent a computer-based information technology composed of hardware and software for the input, storage, manipulation,

and analysis of georeferenced digital data. Since one of its principal functions is to support decision-making processes, it is of particular importance in supporting the overall task of planning. With the accelerated development and the high profile use of this technology, it has become apparent that knowledgeable users are needed, and firm decisions from managers in both public and private organizations concerning GIS procurement and implementation, are being called for (Aronoff, 1989).

In the specific context of the KSA, in order to effectively implement and use this technology some basic requirements should be satisfied. These basic requirements are reviewed and discussed in several studies (Taylor, 1991, Dangermond, 1990, Harris, 1990, and Brail, 1990) concerning the effectiveness of GIS in developing countries, such as the KSA. In these studies, efforts have been directed towards providing a framework within which GIS could be of more significance in facilitating development of those countries. The findings indicate that there are still problems to be overcome. For example, Taylor (1991) has pointed out that, although GIS has the potential to be of much use in the struggle for development, it has not yet been fully realized and there are still many problems to be overcome.

1.2. Study Objectives

In developing a GIS, changes in institutional and organizational structures and the availability of data are the basic requirements to be considered for a successful implementation. In other words, organizations should plan carefully for

system implementation. Plans must be designed to accommodate long-term technological developments (Allam, 1991). In short, there should be extensive long-term planning prior to system implementation.

The specific objectives of this study are:

- to develop a conceptual framework and guidelines for GIS implementation in government agencies in the KSA; and
- to develop one study or a prototype GIS application using data from the KSA.

1.3. Importance of the Study

The importance of this study can be seen in light of the following considerations:

- there is no detailed study concerning GIS and its implementation in the KSA;
- the study depends, for the most part, on information gathered from the field. Data have been collected to serve two purposes: first, to examine the status of GIS in the KSA, and second, to support the pilot project objectives;
- it provides an insight and understanding about theoretical and technological aspects involved with GIS development; and
- it focuses on GIS implementation in a developing country (the KSA) where the need to make effective use of resources is apparent.

1.4. Research Hypothesis

The basic assumption of this study is that GIS is essential for the analysis of georeferenced data in the KSA; hence, a framework to pave the way for GIS development is critically needed. Further, GIS has potential to be utilized in the KSA and it is essential that planning precede system implementation. GIS cuts across organizational lines and requires cooperation by all concerned to make it work efficiently.

The goal then is to consider these assumptions and ultimately develop a plan for GIS implementation in the KSA.

1.5. Research Methodology

The basic methodology is to: develop a conceptual framework and general guidelines for GIS implementation in the KSA; apply the developed methodology to demonstrate application development through a pilot project. An important factor to take into consideration in this study is the institutional and organizational framework or approach under which the GIS development should take place. In short, in this thesis, the conceptual framework is where most of the information concerning GIS development in the KSA can be found, and the pilot project is a practical application of the methodology.

1.5.1. Approaches to GIS Development

Three approaches are being used by many agencies today for GIS implementation (PTI and ICMA 1991, and Bollens and Drummond, 1986):

1.5.1.1. The Hierarchical Approach

This top-down approach assumes that a single department within an agency develops a GIS with little or no input from other departments during the implementation stage. This approach has been used in the past within the mainframe computing environment.

In this model, a department controls GIS resources and makes most of the strategic decisions regarding the GIS implementation and application. Although access and service can be provided to other departments or agencies, a major limitation occurs when other users have different data needs and require different base maps.

1.5.1.2. The Anarchical Approach

In this bottom-up approach, a single user department, separated from other departments, creates and maintains its own database. This approach is often used when difficulties in cooperation with other departments are experienced during initial attempts to develop a GIS.

The major draw back of this approach is that a single department GIS means limited application and resources, without extended benefits to other departments when the system becomes operational.

1.5.1.3. The Mutual Collaborative Approach

This approach can be termed multi-participant GIS, and is used in many organizations. In this approach there is agreement and commitment by all potential user departments/agencies on common objectives, with full participation during the design and development of the system. Such a system is based on one set of strategic components, but can be used to develop diverse applications (PTI and ICMA 1991).

The system usually resides in and is managed by a separate unit (i.e. GIS division or planning agency) and guided by an interdepartmental/agency or other body to: ensure compliance with standards; protect the right of all users; and to enhance communications among users.

Although this approach maybe useful in overcoming the many problems the previous models are facing, its implementation and actual utilization may take a long time. In this thesis, this approach was evaluated and a conceptual model for system implementation was developed.

1.5.2. The Conceptual Framework of Implementatin

As shown in figure 1.5.2.1., implementation consists of five stages:

Pre-automation Stage: to increase awareness of the use of the technology and the advantages of shifting from a "manual practice tradition" to an "automated approach".

Planning Stage: to identify the objectives, assess user/technology requirements, i.e., Hardware (HW)/Software (SW) requirements, etc.

Design Stage: to formulate the implementation plan and design the database.

Development Stage: to acquire and install the system and database within a framework of organizational structure.

Operational stage: to develop GIS applications and to continue managerial, financial, training, technical, and legal supports.

1.5.3. Pilot Project

The objective of the pilot project is to construct a topologically coded street network for a transportation analysis in the "Malaz" area in the city of Riyadh.

1.5.3.1. Study Area

The project test site has been identified as the Malaz area in Riyadh City. The area covered is located in the middle of the city under the jurisdiction of the Malaz Municipality. The main criterion for selecting this site is that street names have already been assigned. While renaming of streets in other parts of the city is not yet completed.

1.5.3.2. System Resources

The following systems were used in the pilot project:

PAMAP micro-based system (from PAMAP Inc.).

GeoVision workstation-base system (from GeoVision Inc.).

Lotus 1-2-3 micro-based system (from Lotus Development Corporation).

dBase IV micro-based system from (Ashton-Tate Corporation).

Since PAMAP spatial-data input techniques are being investigated at both EMR and Carleton University, the PAMAP system at Carleton University was chosen for spatial data entry. This system has a powerful digitizing and editing module. The 2D string along with SNAP options available with this system allow creation of a line through the connection of a series of keypoints (intermediate) between two end points (nodes) with minimum error. Topologically structured databases are then converted to AutoCad's Drawing Interchange Format (DXF) format and transferred to the GeoVision system for further editing and analysis.

Lotus 1-2-3 and dBase IV are used to create attribute-database files. These files are then converted to ASCII format and transferred to GeoVision.

GeoVision, which is the main system used for spatial data editing, analysis and output, accepts spatial data in; DXF, Intergraph's Standard Exchange Format (SIF) and attribute-data in ASCII from any commercial database system or spread sheet. Direct spatial and attribute-data entry is also supported by GeoVision. However, it was found that it is more convenient to pre-process the data on other systems and then transfer it to GeoVision. Usually data translation to GINA format (GeoVision format) is a straightforward process associated with minimal difficulties.

1.6. Sources of Information

1.6.1. Literature Review

GIS technology and its applications are relatively new, and most of the work is published in scientific journals. Examples of these periodicals include *International*

Journal of Geographical Information Systems in the UK, *Urban and Regional Information Systems Association* (URISA), and *GIS World* in the US. In addition, annual conferences are considered to be excellent sources of gathered information which correlate theoretical and practical experiences of some of the professionals in this field. Some of the well known organizations that have contributed substantially to orchestrating such conferences are URISA, Automated Mapping/Facilities Management (AM/FM) International, American Congress on Surveying and Mapping (ACSM), and the Canadian Institute of Surveying and Mapping (CISM). A number of important books have been published about GIS. Among these books are:

- *Principles of Geographical Information Systems for Land Resources Assessment* by P. Burrough;
- *Geographic Information Systems: A Management Perspective*, by S. Aronoff;
- *Geographic Information Systems: An Introduction* by J. Star, and J. Estes;
- *Geographic Information Systems: The Microcomputer and Modern Cartography* edited by D.R.F. Taylor.; and
- *Geographical Information Systems: Principles and Applications* edited by D. Maguire, M. Goodchild, and D. Rhind.

These books provide an incomparable theoretical background to the state-of-the-art technology.

In the specific context of GIS in the KSA, little work has been done. Most of it is in the form of papers and reports prepared by individual organizations, such

as Ministry of Municipality and Rural Affairs (MoMRA) and Ministry of Communications (MOC).

Even though this research will be based on findings of previous research on GIS and their applications in the KSA, it will also use the results of the survey designed to identify the major issues that influence GIS implementation and utilization. These results will be considered as general indications rather than precise information. Also, the research will depend on the available literature, especially that which relates to the design and implementation issues of GIS in a country like the KSA.

1.6.2. GIS Survey

In order to identify the current and potential GIS users within government agencies in the KSA, a GIS survey was designed. The objective of this survey was to identify the major issues that influence GIS implementation and utilization in the KSA. Information collected from the questionnaire (as shown in Appendix A) included the following institutional and organizational issues as a means to identify user requirements, i.e., technical issues as a means to identify system specifications; and georeferenced data and database requirements.

The survey consists of two parts. Part one "Survey of Geographic Information System Needs in Saudi Arabia", requests specific information with reference to the issues described above. Part two, "Explanation of Questions and Terms Used in the Survey", provides the necessary explanation for most of the questions and terms in

part one. The questionnaire was distributed to the agencies listed in Table 1.6.2.1.

Table 1.6.2.1. Organizations identified for survey distribution and interviews.

Agency	Department	Individual
MoMRA	Information and Computer	Dr. Ahmed Al-sahaab
MAW	Land Management	Mr. Mohammed Ben Mahfouz
KACST	Research Institute of Natural Resources and Environment	Mr. Adnan Al-sa'ati
MOC	Design and Studies	Mr. Abdullah Al-mogbel
MPMR	Cartography	Mr. Ahmed Al-reshaid
MODA	MSD	Mr. Muhammed Al-Momen
ADA	Transportation Planning	Dr. Jalal Nafakh
SPA		Information

1.6.3. Interviews

In addition to the questionnaire, interviews were conducted with representatives of national agencies known to use spatial information. In addition to the individuals identified in table 1.6.2.1., persons identified in table 1.6.3.1. were interviewed to obtain additional data for the pilot project.

Table 1.6.3.1. Agencies and individuals identified for interviews.

Agency	Individual or department
MOC	Mr. Stefan Bergstrom
MODA	Major Abdullah Al-shahrani
MoMRA	Dept. of Maintenance

1.7. Thesis Organization

This study has been divided into seven chapters:

- chapter one **"Introduction"** is a general introduction;
- chapter two, **"GIS Technology: An Overview"**, presents a general overview of the state-of-the-art technology. The first part focuses on GIS definition, a brief history and HW/SW development. The second part discusses briefly issues related to GIS fundamentals such as data acquisition, organization and processing, manipulation and analysis, and output generation;
- chapter three, **"GIS Facilities"**, provides a detailed discussion of GIS facilities. Computer-graphic facility, management-facility, and analysis-facility are described. This chapter highlights issues related to spatial and attribute-data handling and processing by a computer. In discussing some of the models used to process geographic data, some general applications with each model are pointed out in order to increase awareness of the usefulness of this technology and to encourage its adoption in government agencies in the KSA;
- chapter four, **"GIS and Government Agencies: Some General Relations"**, examines potential political and managerial support required to introduce a new technology in general and GIS in particular. It also deals with problems related to spatial and attribute-data in terms of availability, accessability and sharing. In addition, a Municipality Information System (MIS) as an example

of a prototype GIS is presented;

- chapter five, **"A Framework and Conceptual Guidelines for the Implementation of GIS"**, is the core chapter of the thesis. It discusses in detail the conceptual implementation stages mentioned earlier, and describes the various stages of system development from pre-automation awareness to the operational system. It also details the steps to be accomplished in each stage, and concludes each stage with the description of the outcome. The intention in this chapter is to provide general guidelines for any organization that wishes to develop such a technology;
- chapter six, **"Transportation Applications: A Pilot Project"**, discusses issues related to building a topologically structured network to support transportation planning and analysis. It is an attempt to put into practice some of the issues related to GIS development presented in this study; and
- chapter seven, **"Conclusion and Recommendations"**, highlights briefly the findings of this study, and suggests some recommendations.

Chapter two

2. GIS Technology: An Overview

2.1. Introduction

GIS's are primarily designed to manage and manipulate spatial information. The spatial or geographic information is varied in quantity and quality as well as availability. As far as GIS's are concerned this information must be systematically gathered, spatially registered, stored, analyzed, generalized, retrieved, and displayed (Chrisman et al., 1989). The fundamental function of a GIS is to integrate these separate operations within the system.

Since the early 1960s, the evolution of GIS technology has paralleled advances in the field of computer science. It has followed development path to include the integration of other disciplines such as; management science, geography, cartography, geology, surveying, mathematics, and statistics. In simple terms, a GIS may be described as a set of computerized tools to be used for the input, storage, analysis, and output of spatial data and related attribute information.

GIS is now a multi-discipline, multi-user technology which is being applied in many fields and is emerging as a powerful tool to manage geographic information. However, if it is to be introduced or applied in a developing country such as the KSA, it is necessary to establish a conceptual framework to describe to new users what this technology is and how it works. It is appropriate to begin by exploring the various aspects and components of this technology.

This chapter is meant to provide a brief background to GIS, and to outline the HW/SW necessary to support its applications, followed by a brief discussion of GIS functional components.

2.2. Definitions

A GIS, as defined by the National Science Foundation (NSF), USA, is a computerized database management system used for the capture, storage, retrieval, analysis, and display of spatial (i.e., defined by location) data.

Maguire (1991) distinguishes between three views of GIS, namely, the map, database, and spatial analysis views.

The map view focuses on the cartographic aspects of GIS, and emphasizes the ability of GIS to produce high quality maps and charts, usually in vector format.

The database view emphasizes the importance of a well-designed and implemented database. An integral part of a GIS is a sophisticated Database Management System (DBMS).

The third view emphasizes the importance of the spatial analysis capability of a GIS. This view focuses on analysis and modelling and sees a GIS more as a spatial information science than a technology.

In Maguire's view, however, GIS is best described as an integrated collection of hardware, software, data, and liveware which operates in an institutional context.

2.3. A brief History of GIS

Geographic Information Systems were originally developed in Canada in the early 1960s as a result of research in digital mapping. GIS's were used at that time for the creation of Land Inventory Systems (LIS). The Canadian Geographic Information System (CGIS) is generally considered to be the first true GIS in the world. In the early days of development, GIS started out as a mainframe and/or minicomputer-based operation. Today, it is moving more into the less expensive microcomputer PC and workstation market (Yapa, 1991).

Over the last thirty years, several factors combined to produce today's GIS. Advances in computer technology (HW/SW) dominated its overall development. It may be that developments in HW technology will continue to outpace developments in software and applications for sometime to come (Taylor, 1991). But progress in cartography, photogrammetry, DBMS, and several other disciplines have also contributed to GIS development. Stars and Estes (1990) have stated that three important factors helped lead to the creation of digital geographic information systems in the 1960s:

- refinements in cartographic technique,
- rapid developments in digital computer systems, and
- the quantitative revolution in spatial analysis.

Figure 2.3.1. shows the sequence of GIS development.

Two recent trends in the evolution of GIS technology are the inclusion of artificial intelligence and expert systems into GIS design and operation.

Figure 2.3.1. GIS Family Tree
Source: McLaughlin et al., 1988

2.4. Hardware Development

HW for GIS applications or computational purposes has undergone a rapid pace of development in the last few years. It is the most rapidly growing business in the information era, and probably has the most promising future for data handling and display. Dataquest indicates that the use of GIS is growing at a rate of 35% a year (Walker et al., 1990).

Although mainframes and minicomputers were needed in the 1960s and 1970s, at the present time microcomputers and workstations dominate the field of GIS implementation.

2.4.1. Microcomputers

The most notable change in computer HW is the explosion of the use of personal computers (PC's) since the early 1980s.

The low cost and computational power of PC's has made them attractive to many potential users. In the area of GIS, the real advantage of microcomputers is their colour raster graphic capabilities (Slocum and Eghert, 1990), which permit displays of a wide variety of colours. This, in turn, facilitates the work of cartographers in colour selection and display.

The rapid rate of PC development is overcoming some of their limitations such as low computational power, speed and limited memory. Some high-end PC's are now surpassing minicomputers in processing speed and are available at much lower cost.

Characteristics of microcomputers may include some or all of the following characteristics (Walker et al., 1990):

- closely integrated CPU and storage devices;
- low cost CPU and software;
- graphics via integrated bitmap display;
- single user per system;
- huge volume of existing PC hardware; and
- fast CPUs (I/O and memory-bound performance).

2.4.2. Workstations

The introduction of workstations represents another improvement in HW for GIS applications. It is considered the second most rapidly growing area of GIS technology. Evolution to specialized workstations is expected to dominate workstations development in the 1990s. Dangermond (1990) has noted that,

In the 1990s, the power and flexibility of the modern workstation are likely to lead to the creation of a family of workstations specialized for various GIS-related functions. . . . The most important of these devices would be the development of a workstation specialized for the capture of geographic information from maps, images, and a like materials. . . . Such workstations would allow map compilation; permit interactive, computer-assisted adjustment of various aspects of the captured cartographic data; and help in solving edge matching, line correction, updating and related problems. . . . In time we can expect that whole rooms and eventually whole facilities will be designed as workstations working in particular fields or disciplines (Dangermond, 1990:3).

Characteristics of workstations may include the following (Walker, et al., 1990):

- networked single user stations;
- resources shared across the network;
- fast, powerful CPU's;
- possibly separated CPU and storage devices;
- "file server/client" configuration applications;
- a UNIX operating system;
- fast graphics via integrated bitmap display; and
- Window-based standards for menus and graphics.

2.4.3. Networks

The use of network hardware systems has rapidly been adopted for GIS applications. The network systems permit the interconnection of large databases with workstations, personal computers, file servers, various shared peripherals, and even mainframes where appropriate. These facilities can be shared, and exchange of data among many users can be distributed on the network (Dangermond, 1990). Thus, the organization of computer systems has changed with the emergence of communication networks. The concept of a computer centre, where users are required to bring their job to a central computer, has been rendered obsolete. Computer networking has also provided additional advantages to increase computational reliability: if a computer in the network fails, it is not catastrophic since the local users can draw on the computational power of any other computer in the network (Jenkins, 1987).

Part of the research for this thesis involved testing the many benefits of using a workstation and network environment. GIS operations can be performed on a network of workstations, PC's, and shared peripherals as shown in figure 2.4.3.1.

2.5. Software

A survey of GIS software packages was conducted in 1989 by the publication, "GIS World Inc". The survey aimed to evaluate general characteristics of GIS's (such as cost, support available, and ease of use), operating environment requirements (such as computer system, operating system, and specialized HW/SW requirements), and system functional capabilities (such as analytical capabilities, and data display) (see Appendix B). The major trend reflected by the survey is the clear move toward microcomputers and workstations as GIS platforms. More than half of the systems surveyed ran on micros of some type.

Capability of GIS software is related to: the size of GIS database, compatibility with other systems for data sharing and exchange, and the type of queries that could be performed. The types of applications to be performed by a GIS is the key factor that determines the type of GIS software.

GISD Network Configuration

Figure 2.4.3.1. GIS Division Network Configuration

2.6. Functional Elements of GIS

The five essential elements that a GIS must contain are data input, processing and organization, data management, manipulation and analysis, and product generation. These elements may be viewed as a sequential process for any application as shown in figure 2.6.1. A brief description of these elements will be provided in this section, and a detailed discussion of some of them will be presented in the next chapter.

Figure 2.6.1. Functional elements of GIS

2.6.1. Data Input

Data that can be input to a GIS are typically acquired from a variety of sources. This may include maps, remotely sensed data, conventional photographs, field survey data, statistics and others. The data may be either in conventional form (paper map) or in digital form (computer readable format).

Obtaining the relevant data that describes, as closely as possible, spatial characteristics in terms of data quality, accuracy, precision, and completeness will result in a highly reliable analysis and output. In simple terms, the data acquisition process means getting the relevant information into the computer. Table 2.6.3.1. provides a summary of commonly used data input systems.

Table: 2.6.3.1. Data input systems.

Entry system	Type of data
Keyboard	commonly attribute-data.
Manual digitizing	commonly spatial data.
Coordinate geometry	usually land record information
Scanning	automated method for spatial data.
Existing digital files	spatial and non-spatial data

Source: Aronoff, 1989

2.6.2. Data Processing and Organization

This involves processing and organizing data at hand in a systematic format so that they can be entered into a GIS. Depending on the type of application to be carried out, this information will require manual or automated pre-processing prior to the encoding process (Smith et al., 1987). This procedure will lead to the creation of the database which is the core of the system.

Modelling techniques are good, conceptual-design tools for the organization of the data set. Data structures are of two types: application-centered structures and database-centered structures (Morse, 1991).

In an application-centered approach, which is characteristic of a system designed without the benefit of a data model, each application has its own closed database (see chapter 3). If the requirements of an application change, an adverse effect may impact on the entire database.

The process of modelling a GIS database can be categorized as; infological and datalogical modelling techniques.

2.6.2.1. Infological Modelling

This modelling technique is related to human concepts of real world representation. There are two tools that could facilitate the creation of such a data model: an entity relationship model, and a data dictionary.

An entity relationship model is generally represented by an Entity Relationship Diagram (ERD). As shown in figure 2.6.2.1.1., the basic components of an ERD are entity, relationships, and attributes, described as follows:

- - An entity is an element (thing, object) of interest such as city, road, lot, etc.
An entity type is represented diagrammatically as a rectangle.
- A relationship is an association (or link) between entities. A relationship is graphically represented as a diamond. Relationship types may be: one to one (1:1), i.e., a road has one name and this name belongs to it; one to many (1:M), i.e., a country has many provinces, but a province is only one division of one country; many to many (M:M), i.e., each district may have many rock-types and each rock-type may occur in many districts.

- Attributes are associated or descriptive information of an entity or relationship. An attribute is graphically represented as a circle or ellipse.

The data dictionary as a means of data modelling provides a detailed description of the model components. It allows system users to identify the map features (entities) and associated attribute-data available for specific applications. It also establishes data standards and conventions for use.

2.6.2.2. Datalogical Model

A datalogical model is related to computer concepts and machine representation (Lodwick and Reuchtwanger, 1987). Computer representation of geographic phenomena will be discussed in detail in the following chapter.

2.6.3. Data Management

Data management means governing the database in terms of creation, data entry, access, updating, deletion, and retrieval. These functions should rank in priority with different kinds of access, which means, procedures must be set up to facilitate users with different kinds of access to the system and its database. A GIS usually includes integrated database management software typically referred to as DBMS.

2.6.4. Data Manipulation and Analysis

The information that can be generated from GIS will be determined by the function of data manipulation and analysis (Aronoff, 1989). It is not expected that GIS will automate all the functions that are required by users. GIS will, in fact, respond according to user orders. Therefore, it is important that users be capable of determining what and how data manipulation and analysis should be. In other words, "To anticipate the way in which the data in a GIS will be analyzed requires that users be involved in specifying the necessary functions and performance levels" (Aronoff, 1989:43). A list of GIS analysis functions is presented in the next chapter.

2.6.5. Data Output

The overall output of a GIS, which is usually called the reporting function, will depend on user demand. There are two broad forms of output, textual and graphic, and there are two types of output device, analog and digital. Table 2.6.5.1. and 2.6.5.2. give some examples of different output formats and techniques.

Table 2.6.5.1. Examples of output forms of land-related information.

	Analog	Digital
Graphic	Map sheet Photography	Digital map file Satellite image
Textual	Field sheet Paper field	Data logger cartridge Database segment

Table 2.6.5.2. Examples of different techniques and devices for output of Land-related information.

	Analog	Digital Transfer
Graphic	Plotters Photowriters Graphic display	Magnetic disk and tapes Electronic transmission
Textual	Printers Graphic display	"

Source: Lodwick and Feuchtwanger 1987:109

2.7. Summary

The National Science Foundation defines GIS as a computerized, database management system used for the capture, storage, retrieval, analysis, and display of

spatial data. GIS was developed in Canada in the early 1960s. Since then, especially in the 1980s, the technology has spread rapidly and has been adopted by many organizations worldwide.

The trend in the GIS computing environment is toward the new high-performance workstations. Much GIS SW with different capabilities and functions is available. The essential functions of a GIS are data acquisition, processing and organization, data management, manipulation and analysis, and output generation. Although all of these functions are essential for a successful GIS implementation, the most important functions are dependent on the type of application to be carried out by the system. Data processing and organization functions are related to concepts of how data should be constructed and developed in a computer environment. Data modelling techniques are being used in an attempt to enhance and formulate human perception of the real world. It is the human factor that will determine the applicability of such technology to be of use in assisting decision making mechanisms.

Chapter three

3. GIS-Facilities

3.1. Introduction

In the previous chapter, GIS technology and its basic functions were presented. To further provide an insight and understanding of this technology, it is appropriate, at this stage, to review the three major facilities that GIS can provide. Namely, the computer graphics, database management, and analysis facilities.

The computer-graphic facility is primarily concerned with spatial data handling. Vector and raster data models will be the focus of this section. Database management is concerned with storing, organizing, sorting, updating and retrieving large volumes of both spatial and attribute-data. The main focus will be on the database management sub-system of a GIS. Analysis is concerned with the systematic analytical functions of this technology.

3.2. Computer Graphic-Facility

A computer-graphic facility consists of HW/SW which enable operators to display cartographic features on a graphics terminal and also to create, add, delete, edit, and manipulate these features interactively. For example, an operator can extract and combine map features from maps of different scales, or analyze the results of two map overlays.

Geographic data represented by points, lines and areas or polygons on either hardcopy (map) or displayed on a CRT is an abstraction or model of the real world. Point data may represent geographic elements related to a single geographic location such as a well, village, etc. Line data portrays the data-string of a continuous geographic entity such as a river or a road. Polygon data represents areas enclosed by lines, such as: vegetation limits, administrative jurisdictions, etc. Cartographic data may be collected in two or three dimensions. It is important to note that point and line data at one map scale may be represented as areas on larger scale maps. For example, city location on a map with a scale of 1:1,000,000 would be depicted as a point entity whereas this location would be represented as an area entity on a map or chart at a scale of 1:10,000.

To construct a spatial database in a computer environment, spatial data must be structured in a readable format for the machine, because computers are not organized like the human mind (Burrough, 1986). In reducing spatial data to points, lines, and polygons for the computer, it is essential to specify the feature, its geographic location and its relationship to other features on the map.

All GIS systems operate on geographic data encoded in either vector or raster format, or a combination of both. The following sections discuss these encoding schemas and the models they represent.

3.2.1 Vector Data Structure

Vector format or coordinate system is the classical approach of representing

or coding spatial data. A data point is represented by a single xy coordinate pair, a line is encoded by a series of xy coordinates, and an area is recorded by a closed loop of xy coordinates.

3.2.1.1. Spaghetti Model

The Spaghetti model is very simple and easy to understand. It is basically a translation, line-for-line, of map features as shown in figure 3.2.1.1.1. In simple terms, the data file is the data structure (Peuquet, 1991 and Aronoff, 1989), which means spatial data is recorded as a list of xy coordinates.

Source: Aronoff, 1989:174

This model is inefficient and not suitable for spatial analysis, because spatial relationships are not retained. For example, in order to determine whether or not two polygons are adjacent, a searching process through the data file is required. This model type could be however, used for reproducing existing maps or graphs if analysis of the data is not required.

3.2.1.2. The Topological Model

The concept of topology is a mathematical method to define spatial relationships. In a GIS context, map topology refers to the spatial relationships between mapped features. In a polygon a line segment is the main logical unit in this model (Peuquet, 1991). A line segment begins and ends at a node where two lines meet. Each line segment is recorded with the coordinates of its two endpoints. In addition, each polygon in this model has an identifier in each side of the line segment as shown in figure 3.2.1.2.1. Moreover, unlike the Spaghetti model, each line segment shared between two polygons is recorded only once. This will reduce data redundancy in the database while retaining spatial relationships.

This model can be used for spatial analysis purposes, since spatial relationships are explicitly encoded and retained. Analysis applications of this model include automated error detection, windowing for analysis and graphic presentation, network applications, determining whether a point falls in a specific polygon, proximity operations, polygon overlay, and other intersection procedures (Peucker and Chrisman, 1975 as quoted in Star and Estes, 1990).

Link #	R_Polygon	L_Polygon	Node 1	Node 2
1	1	0	3	1
2	2	0	4	3
3	2	1	3	2
4	1	0	1	2
5	3	2	4	2
6	3	0	2	5
7	3	5	5	6
8	3	4	6	4
9	5	4	7	6
10	4	0	7	4
11	5	0	5	7

Topologically Coded Network & Polygon File

Node #	X Coordinate	Y Coordinate
1	23	6
2	17	17
3	29	15
4	26	21
5	8	26
6	22	30
7	24	38

X, Y Coordinate Node File

Figure 3.2.1.2.1. Topological Data Structure

Source: Peuquet, 1990:80

In general terms, data structure for topological modelling is more difficult than a simple list of xy coordinates as in the Spaghetti model. Searching for a spatial object in the topological database will depend on how carefully the database has been developed and what model has been used. Yet, there are two general methods in which spatial relationships can be determined (Feuchtwanger and Poiker 1987):

Explicit relationships are included as part of the data structure/model as attribute values or pointers to the related items. They can be further distinguished as being:

- directly explicit where there is a direct link, in the model to the related item; and
- indirectly explicit where the link to the related item is via other items in the model.

Derived relationships are not given but have to be calculated using coordinate geometry. For instance, the relationships between points in an unorganized point data set have to be determined by computing the distances between each point.

3.2.1.3. Hierarchical Vector Model

The Hierarchical data model or 'tree structure' is based on one-to-many or one-to-one relations. In this model, as shown in figure 3.2.1.3.1., data are structured as being subsets of a larger group which is a subset of another larger group. For example, soil information could be grouped as a soil series within a soil family. The

top of the hierarchy is termed the root, which is comprised of one entity. In a lower level from the root, every branch has one higher branch related to it, usually termed parent. Each parent in the hierarchy would have one or more subordinate branches, commonly termed children.

Hence, it is possible to store geographical data, i.e., point, line and polygon data in a logical manner. As well, spatial relationships could be, but not necessarily, established, since there is a direct linkage between one feature and another. Moreover, data retrieval could be done very quickly by searching down through branches. There is a direct link between, i.e., soil series 1 and soil family 1. On the other hand however, searching for data in the same level, i.e., series 1 and 2 is tedious, since one must travel through the hierarchy to find data in series 1. After

that, to find data in series 2, another searching process all the way back down again in another route is required. Consequently, if the structure of all possible queries can be known before hand, data retrieval in the hierarchical structure would be more convenient.

For geographical analyses, hierarchical data structure might not be appropriate because of many reasons including the following:

- not all spatial relations in the real world are based on hierarchical structure;
- data searches are often exploratory and cannot be predicted in advance; and
- data relationships (data structure) are difficult to modify.

3.2.2. Raster Data Structure

Raster, or cellular organization, is the other form of spatial data representation. Raster structure consists of a regular grid of cells. The location of each cell or pixel (picture elements) is defined by its row and column numbers. Each cell has a value indicates the value of attribute it represents (Aronoff, 1989).

In raster structure, a data point is represented by a single grid cell; line data are recorded by a number of neighbouring cells strung out in the direction of the line data; area data are represented by an agglomeration of neighbouring cells. Consequently, all spatial entities are coded in the same manner, but the relationships are not modelled explicitly. These relationships would then be coded at a "higher level" by means of modelling (Lodwick and Feuchtwanger 1987). As each cell in a raster file consists of only one value, different attributes are thus

stored in separate files. For example, road classes and land cover would be stored as separate roads and land cover data files. They would be combined however by means of overlay.

There are three possible types of regular grid cells. These are square, triangular and hexagonal meshes. The regular square cell has been widely used in GIS for many reasons (Peuquet 1990 and Aronoff, 1989). For example:

- compatibility with a number of hardware devices for data input and output;
- ease of handling as a numerical array by more common programming languages; and
- it is compatible with cartesian coordinate systems.

The resolution, or scale of the raster data depends on the relation between the cell size in the database and the size of the cell on the ground. For example, if the cell size is designated as a 200 m x 200 m area on the ground, then a distance of 1 Km would be recorded by 5 cells. A 1 Km x 1 Km area would be recorded by 25 cells. On the other hand, if the size of the cell is designated as a 100 m x 100 m, then 1 Km distance would be represented by 10 cells. An area of 1 Km x 1 Km would be encoded by 100 cells. As the number of variables increases, the number of cells accumulates with the gradual development of the raster data file. In this case, raster files could contain several million of cells. Despite this huge number of cells, many of them however could have the same value as they represent the same phenomena.

Data redundancy and large storage requirements are the main barriers in raster models. Nonetheless, it is possible to compress the size of raster data files to achieve storage efficiency. Among the methods could be used for data compression are run-length encoding and quadtrees.

3.2.2.1. Run-length Encoding

Run-length encoding system is based on scanning each row, from left to the right, and grouping neighbouring cells with the same value together. Their values would be then stored only once instead of storing each value for each cell.

In figure 3.2.2.1.1., a significant reduction in the size of raster file has been achieved. The number of cell coding has been reduced from 100 to 57. Although, this model is more compact than conventional raster grid file, whenever there is a many-to-one relationship, data processing becomes complex. Data processing in a complex and large run-length raster file would be time-consuming as nil cells would be processed.

3.2.2.2. Quadtrees

Quadrees are another form of raster data file compression technique. This technique is based on successive division of the 2x2 array into quadrants. Conceptually, quadtree structure can be thought of as a process of continuously subdividing a map. The map is broken into groups of blocks of squares. The block structure can be described by a tree of degree $n=4$. Figure 3.2.2.2.1. represents a simple quadtree structure.

COLUMNS										R O W S	COLUMNS									
0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
0	A	A	A	A	A	A	A	A	A	A
										1	A	A	A	A	A	A	A	A	A	A
										2	A	A	A	B	B	C	C	C	C	C
										3	B	B	B	B	B	C	C	C	C	C
										4	B	B	B	B	B	B	C	C	C	C
										5	B	B	B	B	B	B	C	C	C	C
										6	B	B	B	B	B	B	C	C	C	C
										7	B	B	B	B	B	B	C	C	C	C
										8	B	B	B	B	B	B	B	C	C	C
										9	B	B	B	B	B	B	B	B	C	C

Map

Raster Encoding
(100 Values)Run-Length Encoding
(57 Values)

VALUE	LENGTH	ROW
A	10	0
A	10	1
A	3	2
B	2	2
C	5	2
B	5	3
C	5	3
B	6	4
C	4	4
B	6	5
C	4	5
B	6	6
C	4	6
B	6	7
C	4	7
B	7	8
C	3	8
B	8	9
C	2	9

Figure 3.2.2.1.1. Raster data structure and run-length encoding

The entire map is the root node of the tree. The array then is subdivided into four squares (sons) represented by nodes, NW, NE, SW, SE. Each square of a map can be subdivided into square-square, which in turn may be subdivided into square-square-squares and so on until a fully homogeneous sub-square is identified. The key that links spatial data to attribute-data is the node number.

Quadtree models can be useful in carrying out certain spatial analysis functions. Set operations and point-in-polygon searches could be made more efficient than when a conventional raster data structure is used (Aronoff, 1989). The notable advantage of quadtree structure is when data are fairly homogenous and do not require frequent updates. Otherwise, this advantage could be diminished, if a considerable variability of data exists, where updates are frequently performed and the quadtree structure becomes complex.

To point out some advantages and drawbacks of vector and raster digital data models, one can say that, it depends highly on the type of applications to be carried out and represented in GIS systems. As vector models tend to be a translation of line by line of the paper map, this model is more suitable for network analysis and cartographic production. However, for some other applications and analysis such as overlay analysis, a raster format might be appropriate as all spatial entities are coded in the same manner. Table 3.2.1. provides a summary of some of the advantages and drawbacks of vector and raster models.

3.3. Database Management-Facility

Database technology emerged in the late 1960s as a result of development in two areas. First, the rapid improvement in computer technology and the increased

storage medium to handle information. Disc-based computer systems, among other things, became economically feasible and gave rise to a move away from magnetic tape to disc (recently optical disk) as the main file medium (Oxborrow, 1986). Second, the growing volume of information seem to be unmanageable without an innovative approach to handle them. There are two approaches of data management: 1) traditional file processing system and 2) database management systems.

3.3.1. Traditional File Processing Approach (TFPA)

TFPA is commonly designed for specific purpose in a specific program. Basically, there is one or more files for each application program. Also, it is the application program which has to link data between files as relevant and when necessary (Oxborrow, 1986).

Oxborrow (1986) Lokwick and Feuchtwanger (1987) Aronoff (1989) among others, summarize some of the disadvantages of the file management approach as follows:

Query inflexibility: If the data are stored in separate files, and if the system should answer questions from these files, a special program has to be written to access each file and search and retrieve the relevant data. In addition, if the data is modified in the data file, instructions in each application program have also to be modified.

Table 3.2.1. Advantages and drawbacks of using raster and vector models.

<i>Vector Models:</i>	<i>Raster Models:</i>
<p>Advantages:</p> <ul style="list-style-type: none"> - more compact data structure; - accurate graphic representation; - topology can be effectively encoded, thus implementation of topologically required information such as network analysis, can be done effectively; and - retrieval, updating and generalization of graphics and attributes are possible. 	<p>Advantages:</p> <ul style="list-style-type: none"> - simple data structure and easy to handle by computer; - overlay process can be easily implemented; - the technology is cheap and energetically developed; and - it is compatible with high speed graphic input and output devices.
<p>Drawbacks:</p> <ul style="list-style-type: none"> - complex data structure; - spatial analysis and filtering within polygons is difficult; - combination of several polygons maps, or polygon and raster maps through overlay create difficulties; and - technology involved with vector format display and plotting can be expensive especially for high quality representation. 	<p>Drawbacks:</p> <ul style="list-style-type: none"> - large storage need for data enhancement; - topological relationships are difficult to represent; and - raster output is less pleasant because of blocky appearance of lines rather than fine lines in hard-copy map.

Data protection: data accessed by different application programs and by different users could easily be destroyed. Data reliability, security and integrity cannot be maintained efficiently due to decentralized control over the database.

Data redundancy: in a filing system, the same item of data can appear in a number of master files. Data redundancy means more space is used in the storage medium and data inconsistency may occur as a result of updating error.

3.3.2. DBMS

DBMS of a GIS provides the facilities necessary to store, organize, sort, update, and retrieve large volumes of both spatial and attribute-data. A GIS database is specially designed to facilitate spatial searches utilizing either graphical queries or text-search queries. The computer-graphic facility allows a user to visually identify map features on the screen in order to define the spatial limits of the search within the database. For example, by highlighting a city block on the graphic screen (and introducing certain additional search criteria), the operator can obtain a list of all property-owner names contained within the selected city block.

The DBMS component of a GIS permits users to access the database efficiently. At the same time, it offers a degree of protection to the physical data depending on the degree of user authority. It is by all means the mechanism for access control to the highly structured database. Not all users in a large organization should have the authority to access the database. For example, only after a control authority has verified that the change is both appropriate and correct, database

update may be permitted (Star and Estes, 1990).

As shown in table 3.3.2.1., the basic facilities of DBMS to the database which might be considered as advantages over TFPA include (Date, 1990):

Data redundancy: Data redundancy can be reduced or controlled. However, it cannot be eliminated completely either for technical or application reasons.

Data consistency: Consistency of the data depends, to some degree, on data redundancy in the way that, if redundancy exists, data inconsistency may occur. However, if the redundancy controlled by making it known to the system, then it could be guaranteed that the database is never inconsistent (Date, 1990). The process of *propagating updates* (automatic update to related data) which include insertion, deletion and modification is not supported by all available commercial DBMS. If this facility is not available in the system, the database could be in a state of inconsistency.

Data sharing: In most DBMS, the database can be shared by many applications by means of controlled access. The applications, in fact, do not directly access the database, instead they pass requests to the database management system to retrieve or store data. In addition, new applications could be developed from the same database without having to create additional data. This means that data independency from potential applications exists.

Data standardization: The central control of DBMS provides the opportunity to enforce data standards.

Table 3.3.2.1. Some of DBMS facilities

Facility	Comments
1. Data Description Record/ relation/etc.description Structured data description View (sub-schema) description	Not relational systems Not always provided
2. Data Input/ Edit/ Update File-based Interactive/form-based	Important for large database Important for micro DBMS users
3. Data Retrieval Interactive query language Other data retrieval/ manipulation languages	Generally non-procedural and at various levels May be record -at-a-time/ may be extension of non-procedural query language
4. General Purpose Data Manipulation Application programming facilities via host language or self-contained language	
5. Data Presentation Tabular display of results Report facilities Graphic display	Generally quite sophisticated in mainframe DBMSs
6. Data Protection Passwords/ authorization rules & Backup copy/ transaction logs Validation rules & concurrent access locks and rules	For access authorization For recovery after a failure of some sort For database integrity assurance
7. Data Administration Integrated data dictionary Usage monitoring Physical organization facilities (indexing/ hashing /sorting/ file characteristics/ etc.)	Not always provided for database tuning (micro DBMSs generally only provide sorting and indexing).

Source: Oxborrow, 1986:145.

Security: The database Administrator (DBA) can control the means of access by:

- ensuring the access to the database is through specified channels; and
- defining a security check whenever access such as add, modify, deletion is attempted to the database.

Integrity: Data integrity is checked by authorised DBA whenever an update operation is attempted.

DBMS still have some disadvantages. Among them are: (Aronoff, 1989).

Cost: Database systems software and supported hardware can be expensive.

Complexity: A DBMS is more complex than a simple TFPA.

Centralized risk: The centralized nature of the database may generate potential risk as a result of any kind of failure or corruption while the system is running. However, the backup and recovery facilities of some DBMS's, especially in a mainframe environment could minimize the risk.

Data in a DBMS are generally organized by means of records, fields and keys. A set of data items related to each other is stored in a record. A record could be perceived as a row on a table (Aronoff, 1989). The record is divided into fields, in which an item of data record is stored. A field could be specified as a key in which data could be analyzed and retrieved. In other words, the key determines how the data can be accessed.

3.3.3. Conventional DBMS

There are three general purpose DBMS which are usually used to handle attribute-data. Namely, relational, hierarchical and network data models. The emphasis of the following section is on the relational approach as it is being adopted as a sub-system of most of GIS's.

3.3.3.1. Relational DBMS

The first relational products made their appearance in the late 1970s and early 1980s. Example of such products that are being used as a sub-system of GIS include: DB2 (developed by IBM), ORACLE (developed by Oracle Corporation), and INGRES (developed by Ingres Corporation).

Data structure in a relational model is easy to construct and understand. Data are organized by means of relation. In figure 3.3.3.1.1., the entire table is called a relation. Data are stored in a form of simple record, termed tuples, which correspond to a complete set of information about a single road. Each column or field is called an attribute. For example, 'width which corresponds to width of roads is an attribute'.

Access to a relational database is available through either the database programmer or query language. Structured Query Language (SQL) developed by IBM is widely used to formulate relation operations.

3.4. Analysis-Facility

The key feature of a GIS is the analysis of data to produce new information. In a GIS that uses topologically structured data, logical linkages between the various graphic elements in the database are established, allowing the system to "know" if, for example, a polygon exists to the left or to the right of a line segment. The following examples are a few types of analysis facilities that should be made available in a topologically structured spatial database:

- determination of inter-visibility of two points;
- identification of map features occurring within a specific distance from other features;
- determination of the shortest linear route between specified points;
- identification of common areas or node features;
- identification of points or areas connected to others by linear feature; and
- conduction of temporal comparison of map features.

Categorization of GIS analysis facilities is a difficult task since it is not clear what degree of analytic functionality is necessary to identify a system as a GIS (Goodchild, 1987). Data modelling and structure, and type of application are also effectual factors that will determine the type of analytical functions required by the system. The objective in this section is to discuss briefly some of the issues concerning GIS analysis function regardless of how the data are stored, i.e., in a vector or raster format. The discussion will focus on spatial and attribute-data analysis. Neighbouring and overlay analysis will be presented with details as examples of GIS analytical functions.

3.4.1. Spatial and Attribute Analysis

Goodchild (1987) identified two levels of GIS analytical operations. The lower level is concerned with the type of objects; point, line, and polygon, to be processed in each class. At the highest level, operations are classified according to whether they:

- analyze the attributes of a single class of objects (statistical analysis). An

example of this is Boolean analysis, where the selection of a subset of objects from a class based on their attributes is possible:

- analyze one class of objects using both locational and attribute information.

An example of this is nearest neighbour analysis, where various nearest neighbour statistics can be computed for a point object class by processing their locational information:

- analyze the attributes of object-pairs. An example of this is distance measurement between point-point object-pairs;
 - analyze more than one class of objects. An Example of this is calculation of spatial auto-correlation for a class of areas. An Example of this operation is the finding of the shortest path through a network from an origin node to a destination node, as it requires access to both point and line objects representing nodes and links respectively;
 - create new object-pairs for one or two existing classes of objects; and
 - create a new class of objects from one or more existing classes of objects.
- An example of this is polygon overlay (will be discussed in the next sections).

The following nine classes of analytical functions were identified in the 1989 GIS survey report (see Appendix B).

1. Distance/area measurement

- Straight distance measurement
- Curved distance measurement
- Proximity distance

- Area measurement

2. Buffering

- Buffer around points
- Buffer around polygons
- Buffer along straight lines
- Buffer along curved lines
- Weighted buffer

3. Map algebra

- Add/subtract maps
- Multiply/divide maps
- Exponentiate maps
- Trigonometric functions
- Differentiate map values

4. Boolean operations

- Multiple maps
- Multiple themes

5. COGO computations

6. Network tracing

7. Remote sensing image analysis

8. Terrain analysis

- Compute terrain slope
- Compute compass aspect
- Interpolate elevation
- Line-of-sight viewshed
- Generate elevation contours
- Model drainage work

- Generate terrain cross-sections
- Cut and fill computations

9. Polygon operations

- Nearest neighbour search
- Analysis within corridor
- Compute shortest path
- Polygon overlay
- Point-in-polygon operation
- Line-in-polygon operation

3.4.1.1. Neighbourhood Analysis

Neighbouring analysis is a process that allows users to examine the various elements surrounding a specified location. For example, evaluating a residential area surrounding a school or examining the farm land around a city would be types of neighbouring analysis function of a GIS.

Three elements should be specified in this operation: target locations (i.e., a school and a city, neighbouring area specification, (i.e., 2 km² of residential area), and analysis function to be performed (Aronoff, 1989).

This function is usually executed by means of *search function*. There are two types of search functions. One is a numerical type function and the other is a thematic type function (Aronoff, 1989). The first usually achieved by means of average, diversity, maximum, minimum and total. In addition to these operators, thematic function type uses a majority operator also termed the mode. Neighbouring

functions are shown in table 3.4.1.1.1.

Table 3.4.1.1.1. Neighbourhood functions

Function	Description
Average	The average of the values in the neighbourhood.
Diversity	A measure of diversity of values in the neighbourhood is calculated such as the variance or standard deviation.
Majority	The number of occurrences of each value in the neighbourhood is evaluated. The value occurring most frequently is the calculated result.
Maximum, Minimum	The values of each element in the neighbourhood are evaluated and the maximum or minimum value is returned.
Total	The total of the values in the neighbourhood.

Source: Aronoff, 1989:212.

3.4.1.2. Overlay Analysis

Overlay operation in a GIS could be described as a creation of a new class of area objects from two (or more) existing classes (Goodchild, 1987). Overlay operation is considered the most powerful set of techniques in handling geographic information and will support a wide range of information retrieval, analysis, and display functions.

Spatial analysis often requires the overlay of different layers of spatial information. Map overlay simply refers to placing one (or more) maps over another one to view them simultaneously. A GIS allows the user to combine many layers of data, in any number of combinations, in order to analyze the relationship of different data levels with one another. GIS systems support the overlay operation function by means arithmetic and logical overlays.

Arithmetic overlay includes such operations as addition, subtraction, multiplication and division of each value in a data layer by the value in the corresponding location in a second data layer. Whereas logical overlay involves finding those areas where a specific set of conditions occur (or do not occur) together.

An example of an application of overlay could be an agricultural soil study requiring the overlay of soil type, slope, elevation, agricultural land use and climate data. Rather than having to flip through five different maps, often at different scales, the information can be overlaid, the user could query and class the map based on the combination of all required data.

Performance of overlay operations in GIS vary widely. One of the major factors affecting the performance of these functions is the data model being used. Raster and vector models differ significantly in the arithmetic and logical operations implemented. Overlay operations are usually performed more efficiently in raster-based systems.

3.5. Summary

Computer graphic-facility, database management-facility, and analysis-facility are major modules of a true GIS. It has been discussed that, geographic data basically consists of points, lines, and polygons or areas. Their representation in a computer environment can be achieved through two major models, namely, vector and raster spatial data models. Vector is based on coordinate system (X,Y).

Topological data structure of the vector model is widely used with a GIS. Spatial relationships between map features are retained with minimum data redundancy. Since these relationships are retained, topologically required information such as network analysis can be achieved with high resolution output effectively. The drawbacks of this model are: the complexity of data structure and; the limited spatial analytical capabilities such as filtering within polygons. Raster on the other hand, is based on a cellular system (picture elements). Data structure with this model is simple and easy to handle by computer. It facilitates overlay analysis very efficiently. The large storage need and difficulties associated with topological relationships are the major drawbacks of this model.

A sub-system of a GIS is DBMS. They provide the facilities necessary to store, organize, sort, update and retrieve large volume of data. Unlike TFPA, where the data files are accessed through application program, DBMS permits access with a degree of protection. Users do not directly access the database, instead they pass requests to the database system to retrieve or sort data.

The main attraction of a GIS is its analytical capabilities. Analytical functions of this technology include distance/area measurement, buffering, map algebra, boolean operations, COGO computation, network analysis, terrain analysis, and polygon operations.

Chapter Four

4. GIS and Government Agencies: Some General Relations

4.1. Introduction

Institutional and organizational factors influence the adoption of information technology to a greater degree than technological capabilities (Lurnecke, 1987, Fox, 1991, Taylor, 1991, Allam, 1991, and others). In developing countries, (the KSA is no exception), institutional and organizational factors include a wide range of elements such as: financing and staffing; nonstandardized and overlapping jurisdictions; lack of integrated information systems, and lack of effective decision-making mechanisms (Fox, 1991). It is possible to add functional applicability; lack of effective policies; socio-economic weaknesses and more importantly lack of coordination and networking between potential GIS users.

Although, the influence of these issues on the adoption of this technology is applicable to both developed and developing countries; in developing countries they are of more concern and would have greater influence than in the developed world. The reason for this is that GIS technology is still in the emergent stage and a number of factors could alter the use of such systems. Despite the fact that the effectiveness of this technology is limited by many factors, its adoption and the exploitation of its capabilities should not be discouraged or slowed (Edralin, 1990). It is necessary therefore, to eliminate and remove such factors in order to maximize the use and benefits of this technology.

The aim of this chapter is to discuss the use of GIS in some government agencies in the KSA. It examines some of the institutional and organizational issues that have an impact on GIS development, and provides solutions to the most pressing problems. By assessing the status of GIS in the KSA, along with information about the technology presented in chapters two and three, a conceptual framework for the implementation of this technology in the Kingdom will be presented in the next chapter.

4.2. Background

Saudi Arabia is located in south west Asia, between longitudes 35 and 56 degree East and between latitudes 16 and 32 degree North. It occupies approximately 80 percent of the Arabian Peninsula, an area of about 2,250,000 Km². It is bounded to the north by Jordan, Iraq, and Kuwait, to the south by Yemen and Oman, to the east by Arabian Gulf, Qatar, and U.A.E., and to the west by the Red Sea.

The population is estimated to be 13 million in 1990 (75% in urban areas, 22% in rural areas and 3% nomadic groups). People in urban areas live in 99 urban centres and people in rural areas occupied 10,000 registered villages (Al-Ankary 1991).

The KSA in general is a desert or semi desert land as shown in table 4.2.1. Along the coast of the Red Sea rises the mountains in the west region, down almost to sea level in the east region. In the south is the largest sand area in the world

(Rub' al Khali). In the hinterland, a sandy plateau slopes downward to the Gulf, broken up by wadis, broad valleys carved out by the rainfall of a time perhaps 15,000 years ago.

The dominant climatic feature in the country is aridity. Its weather is linked to the Eastern Mediterranean and adjacent lands, in that it has a long, hot, and almost dry summer, with a short cool winter, in which a little rainfall occurs. In interior areas in the summer season the temperature reaches 48° C, whereas in the winter sub-freezing temperatures often occur at night. In fact, the weather conditions in the KSA, which affect every aspect of life, have played a major role in distributing the population in scattered centres.

The KSA with its past conditions prior to 1932, could be one of the least developed countries in the Arab World. The traditional tribal system was dominant where each tribe has its own leadership, its own land with no formal education or disciplinary work. Modern KSA however, has gone through a rapid pace of development from which conditions of poverty, deprivation, illiteracy and poor health have been largely ameliorated. In fact, there were two major factors that have led the country to be modernized. First, the unification of the KSA in 1932 under the leadership of king Abd al Aziz Ibn Saud (1902-1953). Indeed, this factor has integrated the various tribes into the new national political structure of the Kingdom. Second, the discovery of oil in 1938 and the increased revenue from exporting it has been, and still is the major capital supply for development programs.

Table 4.2.1. Dryland area of the KSA Aridity

Desertification risk	Hyperarid km ²	Arid km ²	Semiarid km ²	Aridity totals km ²
High		1,087,200	36,000	1,123,200
Moderate		12,000		12,000
Desertification totals		1,099,200	36,000	1,135,200
No desertification	1,264,800			1,264,800
Total drylands	1,264,800	1,099,200	36,000	2,400,000

Source: Hopkins and Jones 1983:179

4.3. Requirement for Geographic Information

The KSA has undergone a rapid pace of development in which most of the difficulties affecting the society have been minimized. Nonetheless, the major challenge is to diversify the economic base and to lessen dependence on the export of crude oil. Efficient and effective processing and analysis of geographic information in other areas may point the way to more effective decisions and alternative solutions to the nation's development problems.

The growing complexity of social and economic life is a normal consequence of rapid development and calls for an ever increasing flow of objective information upon which decisions can be based (Ministry of planning, 1990). The collection, publication and widespread dissemination of accurate information and statistics has become an issue of fundamental importance for policy formulation and investment decisions in both public and private sectors. With regard to data that are referenced by location, most government organizations in the KSA require this information to

effectively perform their activities. Geographic information in areas such as natural resources, infrastructure management, land use and cover, demography etc., all is needed by all government agencies.

Although geographic information is important in all areas, this study identifies the following areas of interest as deserving of special attention.

4.3.1. Agriculture and Water

The Ministry of Agriculture and Water (MAW) is the government agency which is primarily responsible for agricultural and water development in the country. The main functions of MAW are: to prepare and implement plans and programs for balanced agricultural development; provide technical and financial assistance to promote agricultural investment, and to design policies and regulations in order to control and optimize the use of water and agricultural resources. In addition to the Central Administration in Riyadh, MAW consists of 18 regional Directorates, 78 Agricultural Branches distributed in the major agricultural areas, and 13 research stations (Ministry of Agriculture, 1984).

Agricultural development in the KSA aims to expand and diversify the agricultural base in order to reduce the country's dependence on food imports. Agricultural development is critical because of its role and influence on balanced development. The more diversified the economy, the more potential for securing national income and high employment opportunities. The basic role of agricultural development is to solve special problems related to spatial differences, climate

conditions, food production, agronomic technology, market, manpower, management and other services. Most of all however, is to understand the nature of agricultural problems, examine alternatives and provide best solutions.

One of the major challenges of the KSA agricultural development is the availability of water. The potential for renewable surface water supply is very limited. Underground water supplies, which provide 80 percent of the agricultural sector's water requirements are non renewable therefore, the need for more effective water resource management is required.

In the area of geographic information, most difficulties which have to be faced in this sector are that information in agriculture is either simply not available, inaccurate, or outdated. Most of all, the information is not precise enough or not collected at a sufficiently accurate level. Geographic information capable of being captured at both macro and micro levels, would permit planners and developers to take the necessary actions for changes or adjustments. Of course, close observation to obtain valuable and accurate information would provide the most needed data for effective measurements.

The Land Management Department (LMD) is already utilizing Arc/Info and AORTAS PC-based GIS's for training purposes. Based on our GIS survey results, it is estimated that by the year 1995, this department will have completed the conversion of its spatial and attribute-data into digital form.

4.3.2. Natural Resources

The Ministry of Petroleum and Mineral Resources (MPMR) is the government body responsible for the administration, development and exploitation of the kingdom's oil, gas and mineral resources. In discharging its wide responsibilities, it works in conjunction with Petromin. This State Petroleum company is responsible for the development of the entire natural resource sector and harnesses it to the service of overall development.

As oil and its related industries such as hydrocarbon are very well developed, mineral resources represent a real opportunity and challenge to lessen the country's dependence on oil. The territory of the kingdom contains abundant minerals and metals, as well as hydrocarbon mineral resources. The Deputy Ministry for Mineral Resources (DMMR) was established to develop economically promising natural resources, such as the exploration of mineral and sea resources, the mapping of their location, their further development and utilization, and the processing of available natural gas to the maximum extent possible (Ministry of Planning, 1990). This organization has conducted a number of studies revealing the existence of different kinds of metal and minerals in various parts of the country. Therefore, the need to process geographic data in this area is critical. Geological maps and remotely sensed data along with knowledge and the information technology to process them would be the right tools to perform an analysis and ultimately arrive at suitable decisions. These decisions would thus achieve the desired objectives in this sector.

4.3.3. Municipality and Residential Development

MoMRA, Ministry of Housing and Public Works (MHPW), and Real Estate Development Fund (REDF) play an important role in regional development. MoMRA is charged with the overall responsibility of: provision of essential sanitation services; planning and pavement of streets; construction of parks; and many other municipal services including the allocation of housing plots for low and middle income families. MHPW helps several government agencies plan and construct their buildings and housing programs for households of limited incomes. REDF is responsible for private sector housing construction through the provision of interest free loans to individuals and real estate companies (Ministry of Planning, 1980).

Because of the rapid pace of development, priority in the past was concentrated on the major economic growth centres. At the present time, it is the objective of the Fifth Development Plan that this trend be shifted to provide appropriate levels of municipal services to a maximum number of households in all provinces of the Kingdom.

Geographic information in the municipal sector is the heart of its functional activities. Town planning and services management require ready access to their geographic information. Improvement of this information is a prerequisite for effective management practices associated with challenges in this sector.

Challenges which arise as negative consequences of rapid development, include the following (Ministry of Planning, 1990):

- inter-regional imbalances as well as urban-rural disparities;
- locational mismatch between the urban infrastructure and newly built houses;
- lack of sufficient standardization and institutionalization of preparation, approval, and most importantly, of enforcement procedures;
- lack of coordination of responsibilities between MoMRA and other government agencies, especially with regard to water and traffic planning and organization;
- greater delegation of administrative, technical and financial responsibilities to medium and small municipalities still controlled by MoMRA;
- revenues from municipal services below production costs due to problems of urban development control;
- valuable cultural heritage, in the form of old town and village centres, are abandoned and allowed to decay, while new settlement structures, intended to replace them, remain incomplete; and
- the stability of buildings and public utilities in low lying areas of cities is affected by rising ground-water tables as a result of some water and sewerage network losses and intensive irrigation.

MoMRA has fully recognized the critical need for GIS to handle and analyze geographic data. It is probably one of the first organizations to embark on a large-scale GIS. MoMRA's project will be presented as an example of GIS technology in the KSA later in this chapter.

4.3.4. Pilgrimage (Hajj)

The Ministry of Pilgrimage and Endowments (MPE) is responsible for the provision of facilities for the visits of pilgrims to the Holy Cities of Makkah and Madinah and to the other holy places in the country. It is also responsible for the building and maintenance of mosques throughout the Kingdom, as well as the administration of land held by religious trusts (Al-Farsy, 1990).

Each year over two million pilgrims come to Makkah and Madinah to perform hajj. These visitors come for a very short periods of time to perform their religious duty. Thus, their safety and provision of services to them are essentially the responsibility of the Saudi government. In fact, this gives a unique characteristic to the Kingdom as the holy shrines gives a unique characteristic to Makkah and Madinah.

One of the major challenges in this area is the huge movement of pilgrims and vehicles between the holy sites on certain days. As a consequence of this massive mobility, routing and rerouting of their movement is required almost on a daily basis during the Hajj season. Most of the activities and operations related to the pilgrimage are handled manually by the police and traffic directorates.

Therefore, GIS technology could be of use to facilitate planning for the movement of pilgrims in this holy season.

4.3.5. Transportation

MOC is the government agency whose mandate is to operate and regulate transportation functions. Its function is to undertake the design, construction and maintenance of the country's network of roads. In particular, this ministry is responsible for the coordination of all surface transportation, including bus services and railways.

The paved road network has expanded from about 8,000 kilometres in length in 1970 to more than 32,000 kilometres in 1989. The transportation network satisfies two fundamental needs of the Kingdom. First, it is an important facility upon which the continued development of other sectors such as agriculture, industry, and mining, in particular, depends. Second, the transportation system provides accessibility to the population and fosters an equitable distribution of government services (Ministry of Planning, 1980).

Along with the need to expand the highway network to areas and villages with economic and regional development potential, the movement of people and goods on this network requires enhancement of highway safety and the elimination of bottlenecks in the road network. This represents a real challenge to MOC to regularly maintain this network and keep it in sound condition.

MOC has already realized the need to employ information technology to process and analyze their geographic information. At least 90% of their spatial data has already been converted into digital form. Road data has been collected over a six year period and stored in a data bank. An Arc/Info PC-based GIS along with other road information systems are already in-house. The Maintenance Department is already pressing management to embark on a full-scale Arc/Info system (Bergstorm, 1991).

4.4. Source of Geographic Data

Most of the geographic data available in the KSA such as maps, records, photographs, and remotely-sensed data is still in conventional form. Only a few of them have been converted to a digital format. The following sections discuss some of the recognized sources of information in the country.

4.4.1. Statistical Data

Almost every government agency has some form of statistical department that periodically collects statistical data related to its activities. In addition to these sources, the Central Department of Statistics (CDS) of the Ministry of Finance and National Economy (MFNE) is a major source of statistics in the Kingdom. For over 25 years this department has regularly published a statistical year book which covers a wide range of statistics including those of: physical features, education, health, social services, prices and indexes, petroleum, industry, and public utilities, transportation, and communications, trade, financial and economic affairs,

agriculture, and private establishments.

Statistics in this year book are mostly at the national and regional levels and are not spatially referenced. In a GIS context, and for this information to be of use to the decision-making process, they have to be referenced to smaller spatial divisions. Another constraint related to statistics is, that the national population census, although repeated regularly, entails long and irregular intervals between censuses and inconsistent spatial division for data collection and aggregation (Al-Ankary, 1991).

4.4.2. Existing Maps

Various agencies such as the MoMRA, Military Survey Department (MSD), and MPMR are major sources of maps, not all of which are taken into consideration in the planning process, either because of limited access to them, or because they are outdated (Al-Ankary, 1991).

MoMRA for example as a major source of medium and large scale maps 1:500 to 1:10,000 has already started a conversion process of these maps from a conventional format to a digital format. These maps are to be used for the agency's planning projects.

Until recently, the Aerial Surveys and Mapping Department (ASMD) at the MPMR was considered a primary source of mapping services for the Kingdom. Its mapping production includes, topographic maps for the entire country, hydrographic maps for marine navigational purposes, thematic maps from data furnished by

government agencies, and large-scale maps for use in town planning, road design, and other purposes. That role has now been taken over by the Military Survey Department (MSD) which under its mandate, is required to take over map production and services for both military and civilian applications, at scales from 1:25,000, 1:50,000 and 1:250,000. MSD is actively collecting digital data for map production and other related activities.

4.4.3. Ground Surveys

Ground surveys provide the basic control for high-precision mapping. It is used where precise locational data is required. It is however a time consuming and labour intensive method. Ground surveys are the principal source of data for municipal GIS's and could be used to update existing maps.

4.4.4. Aerial Survey

MoMRA was one of the active organizations in the field of aerial survey. Urban cities and large villages have been covered by aerial photographs at scales of 1:5000 - 1:50000. Aerial photographs can be used to generate photo mosaics, digital map data, conventional maps and to update existing maps. At the present time, MSD is responsible for all aerial surveys in the Kingdom.

4.4.5. Remote Sensing

The KSA has its own receiving station for satellite data. The Saudi Arabia Facility for Remote Sensing (SAFRS) is a complete system capable of receiving and processing data from LANDSAT TM and MSS, the SPOT HRV sensor and the

NOAA/TIROS AVHRR sensors (Al-Ankary, 1991). Remotely sensed data which can be interpreted and processed by information technology, are becoming an important source of geographic data.

4.5. General Characteristics of Geographic Data

Lack of geographic data is one of the major restraints facing the implementation of GIS technology. With the emergence of information technology, a multipurpose geographic reference framework is needed. Most geographic information available remains in hard-copy form, such as records, photography, and maps. The general characteristics of this information are briefly discussed in the following sections.

4.5.1. Data Sharing

Each agency has its own data and not all agencies know what data may be available from others. All government agencies i.e. municipal, transportation, planning, agriculture, etc., use different base maps. At times, they may without knowledge of each other, collect duplicate data in the same geographic area at different times. For example, MoMRA may collect data within an area for municipal services, i.e., land management, and the same data may be collected by the ADA for planning at the traffic analysis level. There is no easy or effective way to integrate or exchange data among the government agencies as some geographic data are not accessible because of considerations of national security or for the simple fact that they do not exist. There is also a fear that information if shared, may be

misused or changed either within the same agency or by others. Thus, without coordination of agency efforts the duplication of resources such as unnecessary additional data storage or redundant data collection may occur.

4.5.2. Data Maintenance

Official sources of information such as maps and statistics are usually outdated (Al-Ankary, 1991). In addition, infrequent updates to the base maps occur. If the updating is made, it might not be a true representation of the actual changes made in the area. This may largely depend on the overall importance of this area.

4.5.3. Data Standardization

Standards of geographic information are not satisfactory nor adequate. In other words, attribute data, i.e., census, data on land use, utilities, etc. are not adequate and do not meet the high standards needed for effective decision-making. For example, land use coding is not standardized among all departments and each department uses different categorizations. Also, these codes do not match or fit the needs of the planning process which might need different categorization. This results in the inability to exchange data collected by other departments.

4.6. Some Suggested Solutions

Precise and systematic information is regarded as a pre-requisite for successful decision-making, not to mention creating better methodologies to analyze them is required. Information other than solely technical, must also be considered and developed as a key resource like personnel and capital in the "emerging society"

(Warkecle, 1987). Since MSD is responsible for mapping the Kingdom, and is now the main supplier of maps for other government agencies, the need for an information master plan is required. This master plan should consider all aspects of the functional requirements of a national database. It is also important to keep all other government and non-government agencies informed of progress made during the process of improving geographic information. Keeping them informed and involved is a major factor for the success of the final outcome. The objectives of this master plan would be to:

- reduce data redundancy and improve decision making to make the most effective use of resources;
- improve quality and timeliness of information;
- establish a national administrative boundaries with acceptable resolution that satisfy user needs;
- establish a national standards for geographic information;
- allow sharing of data between different users by improving communications;
- develop a national, regional, and county-base maps that can display data on various overlays and to any scale;
- determine data collection mechanisms;
- determine an update cycle for data; and
- formulate laws, rules, costs, and like matters.

Efforts should be thus directed to provide a common file structure in order to facilitate the exchange of digital files between all agencies. In contrast, developed countries such as USA, Canada, UK, and Australia, focus largely on efforts to provide common files which may allow multi-user access to the services of a GIS in order to pass information on to other associated organizations.

4.7. Political Support

Political support is a vital factor obtaining the resources needed for GIS implementation. Needless to say, that building political support for GIS will not only help generate financial resources to start up the system, but will lessen the chances of funding cut-backs in the future (Bollens and Drummond, 1986). To examine GIS potential development in the KSA, it is necessary to investigate whether the adoption of new technology is acceptable.

4.8. Managerial Support

The motivating factor to exploit this technology in some organizations is its potential usefulness. For example, responses to questions 1.2.1 and 1.2.2 in the GIS survey reflect that authorities with top management positions are aware, or at least recognize, the potential benefits of this technology. Mr. Mahfoz who acts as a Director General for LMD at the MAW stated that:

The land management department is carrying out assessment of land resources of the kingdom. Automated databases are being prepared for soils, water, climate, land use and vegetation. The data on these attributes would be integrated into land resources units, which would be presented on a map. This integrated map would be prepared, at

first, by conventional cartography. But later it is planned to be digitized for computer storage and retrieval of the spatial information.

Dr. Al-Degaither, who is a Director of Research Institute of Natural Resources and Environment at KACST sees the employment of GIS as being of assistant to conducting research related to natural resources management and environmental planning. Furthermore, he recognizes the possibility of integrating GIS with remotely-sensed images for some selected applications.

Mr. AL-Momen, a GIS Study Coordinator at the MSD, remarked that GIS could be used to assist in analysis, planning and decision-making for various military applications. For the long term, he mentioned that the scope of GIS's could be extended to the national level covering civilian applications within MSD

It is clear that most participants are looking forward to GIS technology to perform functions previously not considered feasible. On the other hand however, the majority are not fully aware of the limitations that can still be encountered in this technology since their systems are still at the development stage and not yet operational.

4.8.1. Decision Making

Managerial practice and style in the KSA are influenced by culture and the existing political situation. For example, consultative style decision-making is the dominant style in the KSA. The GIS survey sample indicated that approximately 60% of the executive managers use this style. If a technology is introduced to an

organization just because it has proven to be useful elsewhere; its contribution to the development process in that organization will remain marginal because it has not been integrated with the organization's decision-making process to any extent (Taylor, 1991). Or in other words, it is not a manifestation based on their perceived needs. Therefore, early awareness of the potential use of GIS technology must be stressed prior to its implementation, which is crucial to the planning and decision-making processes at both national and organizational levels.

4.8.2. R&D Activities and GIS

In the area of R&D activities related to GIS, the focus of most participants tend to be on feasibility studies. Cost/benefit assessments of GIS hardware and software seem to be of major concern. MOC's response to question (1.2.3) indicated that feasibility studies were being conducted to cover the following areas:

- conduct survey of GIS market;
- investigation of road related requirements of GIS; and
- pending: a full scale study including:
 - investigation and evaluation of GIS market;
 - determination of all related organizations and training requirements; and
 - development of terms of reference for the implementation.

4.8.3. Coordination and Collaboration

When asked to describe the degree of coordination (question 1.2.10) within organizations other than government, private or foreign agencies, 40% of the respondents stated that coordination efforts in regard to GIS development, were

limited to within their own agency. Another 40% indicated that they were willing to participate at any coordinating level that will ensure successful GIS implementation. The remaining 20% did not response to this question.

4.8.4. Training

Knowing that training plays a crucial role in the development of GIS technology, the subject was given a great attention in the GIS survey. In response to the number of staff they intend to involve with GIS, (question 1.3.1) 40% of participants indicated that they have, or plan to have, at least 5 GIS specialists in their department or organization. An equivalent percentage (40%) plan to acquire 10 persons to work with their systems. The remaining 20% did not respond.

In the area of training policy, an overwhelming response of (80%) chose to retrain their existing staff and hire additional GIS specialists. Whereas only 20% are interested in retraining their existing staff rather than hiring new GIS specialists. One of the major of drawbacks of hiring new staff is that they still need to be trained to adapt to the new working environment and carry out sound and useful applications for an organization.

System administration, management, data entry, analysis and applications development are all areas of training programs identified in question 1.3.3. In response to this question, only 20% are interested in training their employees in all of the above training areas, while the remaining 80% have made a varied selection of the training subjects to suit their own programs.

2

PM-1 3 1/2" x 4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

PIONEERS IN METHYLENE BLUE TESTING SINCE 1974

TEL: 812 426 7007 FAX: 812 426 7007 TLA: 9100000000

4.9. Example of GIS in the KSA

Although GIS technology was first developed in Canada in the 1960s, the visible reliability of these systems became evident in the early 1980s. In North America in particular, the year 1988 has come to be regarded as the cross-over point in which GIS technology proved to be useful (Taylor 1991 after Tomlinson 1989). In the developing countries prior to 1980, GIS did not signify. Exploitation of GIS's started in the second half of 1980s (Taylor, 1991). Edralin (1991) has argued that, in the developing countries, most GIS projects are in an emergent stage and are not yet developed in a full-blown context. GIS development in the KSA, being no different from the rest of the Third World countries, has its own challenges and opportunities, and is in its first stages. An example of GIS development in this country is MIS, which has been under development by MoMRA since 1983 (Al-Ankary, 1991).

4.9.1. MIS Objectives

This project is developed mainly to assist planning and decision making mechanisms at three levels; local, regional and national levels. Specifically, it aims to assist in achieving a just and equitable distribution of municipal services, and to plan and control urban and regional growth in several areas of interest including; water and sewage, urban roads, landscaping, parks and planning studies. In addition to this, it aims to automate the conventional processes of; data acquisition, storage, manipulation and analysis, retrieval and updating of geo-related data.

An incremental approach to MIS development has been chosen for many reasons. It has been argued that this method is useful in the case of shortage of financial, human, or technical resources (Al-Ankary, 1991). Also, for developing countries, most of the problems lie in institutional and organizational constraints rather than the technology. Furthermore, the incremental approach is often the cheapest to implement because it does not require reworking old information and produces the least disruption at the institutional level. The problem with large scale incremental projects such as MIS however, is that it may take a long time for the system to return completely to fully operational standing.

4.9.2. Phases of MIS Construction

MIS is evolving through four phases. These are:

Phase 1: Establishing the Central Sub-system

According to Al-Ankary (1991), the development of the central subsystem started in 1983 in association with the establishment of the Information and Computer Centre (ICC). The main objective of MIS during this stage is to create the basic parts of the database subsystems which include the following:

- Municipality Databases (MDB)

Two types of MDB have been developed at the national level. The first MDB, which was completed in 1987, comprises a wide range of information ranging from general physical and human attributes to detailed statistics about each municipal service. The second MDB is

a comprehensive information subsystem which was designed to be the main information source for most of the technical, planning and financial activities of MoMRA. Data has been composed to embody information at the local (municipality level). This entails information on population, finance, personnel, physical features (soil, topography, climate), buildings, networks, services and utilities.

- Urban and Regional Planning Information Systems (URPIS)

URPIS's are being designed and developed independently by the Deputy Ministry for Town Planning (DMTP) at MoMRA. The purpose of this subsystem is to collect data in order to characterize the spatial growth sectors of each municipality for the next two decades. It is supposed that this enterprise has been completed, since it was a two year project which was started in 1987.

- Cadastral Information Systems (CIS)

DMTP is responsible for the development of the CIS. Manual digitizing of all available maps, especially those which are used for cadastral purposes, is the main instrument for CIS development. This project is still under development and hardware and software to support its potential applications are being tested.

- The Rural Information System (RIS)

A survey project was initiated in 1983 to collect information on

services and utilities in 10,000 villages. This information is available in a computer readable form. Since this information is now somewhat old, an updating project is being considered (Al-Ankary, 1991 following Dakkak, 1987).

Phase 2: Regional Networking

The following steps connect regional municipalities with the central database subsystems at MoMRA. There are fourteen Regional Branches throughout the Kingdom. Two central subsystems, namely MDB and URPIS, are being inspected to be connected to the regional branches. In order to minimize cost and need for technical experience the focus will be on direct application of this technology with more remote connection to the central main systems. It was expected that this project would be completed in 1990.

In the future MoMRA is contemplating the expansion of its network to encompass local municipalities given the financial, human and technical resources. Some of the larger municipalities such as, Riyadh, Jeddah, and Dammam may have the ability to develop their own GIS. These municipalities can be connected instantly to the main system. As for the smaller municipalities too weak to develop their own GIS, they may connected to the nearby regional branch. Regional branches will be given the responsibility for providing the small municipalities in their region with the necessary information for their applications. Updating and modifications of their data will be performed at regional branches as often as needed. Connecting the local municipalities, whether large and small, will be the third phase of MIS

implementation.

The fourth phase will be data integration at all three levels. Considerable attention to planning procedures will be given to achieving standardized data files throughout the MIS network. This phase will be gradual and expected to be completed at about the same time as the third phase.

4.9.3. Some Comments on MIS Development

By reviewing the implementation of MIS, it is possible to provide some general comment regarding its broad scope and the policy involved.

4.9.3.1. Gradual Development

This approach in MIS development has proven, to some extent, to be useful in overcoming financial, technical, institutional and data constraints. However its actual utilization may be a long time in coming.

4.9.3.2. Digital Data Integration

Digital data integration and exchange with other government and non-government agencies may prove to be difficult unless the agencies adopt the same or similar standards and procedures in hardware and software configurations.

4.9.3.3. The Experience

MoMRA with the development of the large scale MIS has definitely accumulated enough experience in GIS development and could play a major role as a consultant for other government agencies who may wish to develop similar projects.

4.10. Summary

The KSA is a developing country and needs to make the most effective use of its resources. It is evident that in the sectors of agriculture, natural resources, municipal and residential development, pilgrimage services and transportation etc., that geographic information processing systems are essential in achieving that goal.

Geographic information is available in a wide variety of formats for daily processing, in government and other agencies, including, statistics, maps, aerial photographs and remotely sensed data. Most of this data, however are still in conventional format. In order to convert this data into digital formats and to ensure efficient data standards, sharing, maintenance, etc. there is a need for a comprehensive information master-plan to remove such barriers.

In the context of GIS; political and managerial support is a vital factor for GIS implementation. This view has been accepted at the executive levels of many organizations. Yet further effective policies and improvements in managerial practice, R&D, coordination and training are sorely needed. Furthermore, a parallel need for formal guidelines and directions to implement this technology is evident.

MIS as an example of a large-scale GIS, on-going project developed by MoMRA, and is apparently a step towards taking advantage of this geographic information technology. After its completion, it will play an important role in improving municipal services at the national, regional and local levels. The extended benefits to other organizations may be limited until, databases are integrated, standards achieved and cooperative procedures approved and put in place.

Chapter five

5. A Framework and Conceptual Guidelines for the Implementation of GIS

5.1. Introduction

The last three chapters have outlined some of the issues related to the technology of GIS, and the status of GIS in the KSA. It is apparent from the discussion provided, that for successful implementation several issues must be dealt with. Organizational and institutional, technological and database development are among these aspects to be carefully examined. Further, the process of GIS development requires good planning prior to its implementation.

In the case of the KSA, where GIS is still marginal to decision-making mechanisms, the need for a conceptual framework and guidelines for GIS development are evident. The discussion in this chapter assumes that a single agency is interested in developing a GIS to handle its geographic information in order to provide of more efficient services. This chapter is an attempt to draw such a conceptual framework and implementation plan for GIS in government agencies in the KSA. Five stages of GIS development are discussed in this chapter. Namely, pre-automation, planning, design, development, and operational stage.

5.2. Pre-automation Stage

This stage is important in any GIS project development in the KSA, and it might be the greatest impediment to its success. In the KSA there are many agencies with a long tradition of handling geographic information manually. By embarking

on a full-scale GIS development without preparing staff, the adoption of an automated approach as a means of handling geographic information may cause frustration, attitude problems, and a reluctance to accept the system. As shown in figure 5.2.1., this stage starts with increasing the awareness of staff to the benefits of GIS technology in order to gain management support, and ends by appointing members of a GIS team.

5.2.1. Awareness of the Utility of GIS

GIS implementation models often do not include steps to ensure that staff are fully aware of the utility of GIS. Most models assume, sometimes without foundation that awareness and acceptance of GIS is high. Increasing staff awareness is a means of encouraging their support and acceptance through greater knowledge of the new technology. As shown in figure 5.2.1.1, application challenges and capabilities and limitations of GIS technology are the two areas to be carefully evaluated.

Figure 5.2.1.1. Awareness of the utility of GIS

5.2.1.1. Application Challenges

Challenges facing staff are to be identified and dealt with. Also, it is necessary to investigate constraints that limit performance in the key areas of the organization in order to determine how a "GIS solution" can either remove or relieve them (Lodwick et al. 1987), and to evaluate whether "GIS solution" could form part of the organization's long-term information master plan.

5.2.1.2. Capabilities and Limitations of GIS

PTI and ICMA (1991) have identified many reasons for considering a GIS, which can be categorized into internal and external operations. Internal management and productivity gains include the following improvements:

- reduction or elimination of redundant activities;
- better data management;
- rapid, shared access to more data and comprehensive information analysis;
- productivity improvements;
- capacity for storage and manipulation is increased;
- regional planning and intergovernmental communication are improved; and
- charges for new products or services can bring in new revenues.

External operations provide the following improvements:

- responses to queries are quicker, more accurate, and more consistent; and
- new products and services are available (maps, reports, 24-hour on-line access, etc.).

Meetings, seminars and workshops are the appropriate instruments to increase awareness of technology and identify the need for a GIS. The outcome of this stage is a document outlining areas that will benefit most from GIS and its possible applications. This will serve as a tool to obtain management support.

5.2.2. Management Support

The greatest risk of GIS project development is the lack of strong and continuing management support (Seaborn, 1991). It is highly recommended that planning and implementation should not proceed, if it is not supported by management (Allam, 1991).

As shown in figure 5.2.2.1., GIS requires a powerful combination of significant funding, multi-department or multi-agency cooperation, and long-term organizational commitment, all of which demand official involvement and support. Only with a firm policy guidance and support, can GIS team members go forward with an effective assessment and implementation. Further, support must be sustained throughout the complex and sometimes lengthy process of system development.

5.2.2.1. Recognizing the Need for GIS

To obtain sustainable top management support, the executive level must first recognize the need for this technology. Questions such as 'why do we need a GIS' from executive managers could have been answered in the GIS awareness sessions mentioned earlier. If the decision to implement a GIS is made, at the executive level, managers are committed to persevere in their support and recognize their

crucial role in making GIS project a 'success story'.

Figure 5.2.2.1. Management support

5.2.2.2. Resources

A GIS is a significant investment for many organizations. Resources, financial and human, must be secured by top management throughout system development. Gaining management support, in fact, will not only generate resources to start up the system, but will also lessen chances of funding cut-backs in the future.

5.2.2.3. Organizational Changes

With the installation of a GIS, there is the inevitable shift from a "manual" to an "automated" system consequently, the way people work, interact and communicate through long-time working with paper maps and records (i.e. hardcopy) will be changed significantly. The balance of power i.e., who owns the information, who maintains it, will be changed also, which will affect management structure and processes (Seaborn, 1991).

5.2.2.4. Cooperation

A corporate technology such as GIS requires cooperative efforts between diverse users. Saudi local and national organizations are highly individual in character therefore, the adoption and implementation of a GIS can not simply be embedded within the individual characteristics of each department without considerable preparation. Cooperative efforts and commitments from potential user departments are therefore essential for successful installation. Data sharing is the most vital reason for cooperation among GIS participants thus, the role of management is to establish appropriate channels for cooperation.

5.2.2.5. Mandate

It is significantly important for management to assign responsibilities for system and application development to a GIS team.

5.2.3. GIS Team

A team approach has proven to be useful in implementing GIS projects (Allam, 1991). It encourages exhaustive solutions and supports cooperation and sharing among potential user departments.

The GIS team will have the responsibility to plan, implement, monitor and probably manage the operation of the GIS enterprise. The team leader (GIS manager) must have a good experience with GIS and access to top management. Further, the leader should understand policy and technical issues of the project and convey them to his group. If such a person is not available, the use of a consultant in GIS information master planning is a wise choice.

PTI and ICMA (1991), have pointed out some of the important issues in selecting the members of a GIS team:

- time commitment;
- qualifications mix;
- user department knowledge of key applications;
- awareness of overall management objectives; and
- knowledge of information systems and existing computing environment.

The team must meet regularly to establish a common perspective and to minimize conflicts that may arise during system implementation.

The outcome of this stage is a GIS policy recognizing the role of this technology to improve internal and external operations of the organization. It should

also emphasize the full support and provide general guidelines, directions and authorization to the GIS team to proceed with system development. It should also emphasize the organization broad objectives and how GIS could fit within their aspirations.

5.3. Planning Stage

As shown in figure 5.3.1., the planning stage is composed of four tasks, i.e., setting GIS objectives, user requirements assessment, evaluating approaches to GIS development, and finally undertaking justification analysis.

5.3.1. GIS Objectives

The first task is to decide upon GIS objectives. It is important to state specific objectives, rather than to issue vague statements. The following should be taken into consideration when identifying these goals:

- review the overall objectives of the organization;
- evaluate the potential benefits to the agency of using GIS technology;
- evaluate the implications of adopting GIS technology;
- examine how GIS could improve accessibility of information to users;
- examine the issues around sharing digital data among diverse users; and
- measure potential applications.

The scope of the project should be clearly defined. In addition, the objectives should be supported from both management and users perspectives. The objectives could be redefined at any further stage.

5.3.2. Requirements Assessment

Requirements assessment is a general term used to identify user needs and functional requirements of the GIS. Requirement assessments could be divided into functional (user) needs analysis, data needs analysis and hardware and software specifications. These are the most important issues in GIS development. It should be clear that the purpose of the analysis process is to replace the existing manual procedures in handling and exchanging geographic data, as well as to assess future applications.

Several techniques are used during requirement analysis process, including interviews, workshops, questionnaires, and modelling. The Survey of Geographic Information System Needs in Saudi Arabia (see Appendix A), could be used as a good technique to assess the GIS team in this process. It covers most of the issues that will be described briefly in the following sections.

5.3.2.1. Functional (Users) Needs Analysis

Functional (user) requirement analysis process involves identifying the "users" departments or groups within an organization that may benefit from the GIS. It is important to divide them into functional areas and level of significance that are applicable to the overall functions of the organization. This process can most likely, start by interviewing users and potential user departments. The next step is to review documentation followed by break-down of information in order to specify the

relationships between data items and general categories as shown in figure 5.3.2.1.1.

The next step is to identify the relationships between generic functions, special tasks, and GIS functions. Allam (1991) has pointed out that it is important to specify the relationships between geographic data management procedures and generic functions as shown in table 5.3.2.1.1. Further, in this step, the relationships between applications and basic classes of geographic information and the relationships between generic functions and applications, as shown in tables 5.3.2.1.2. and 5.3.2.1.3. are defined. Next, is to define the relationships between specific tasks and GIS functions, as shown in table 5.3.2.1.4. and 5.3.2.1.5. The purpose of analysis is to describe and specify present and future requirements of the GIS, based on users needs.

This task is normally conducted by means of group interviews or workshops (Antenucci et al. 1991). This approach will allow user representatives a comprehensive understanding of GIS and its functional needs. As well, it will encourage and facilitate departments to cooperate with GIS project team.

5.3.2.2. Data Needs Analysis

This step will occur in parallel with the previous one, and may even overlap it. It aims to evaluate and categorize existing data sets (spatial and attributes) and specify the need for new data. To accomplish this task questionnaires may be the appropriate form to gather, evaluate and classify data (see Appendix A). The following issues should be evaluated during the data-needs analyses (Plunkett and

BASIC CLASSES OF GEOGRAPHIC INFORMATION			APPLICATIONS					
			TRAFFIC ANALYSIS	EMERGENCY RESPONSE	GROUND WATER MANAGEMENT	LAND USE PLANNING	DRAWING MANAGEMENT	
1	BASE/PARCEL MAP		●	●	●		●	
2	ENGINEERING / ROAD NETWORK		●	●		●	●	
3	LAND USE / ENVIRONMENTAL				●	●		
4	ADMINISTRATIVE				●	●		
5								
6								

Table 5.3.2.1.2. Relationships between application areas and basic classes of geographic information

APPLICATIONS			GENERIC FUNCTIONS					
			SITE INSPECTION	EVENT RECORDING	VEHICLE DISPATCH	MANAGE FACILITIES	CONDUCT DESIGN	
1	TRAFFIC ANALYSIS		●	●			●	
2	EMERGENCY PREPAREDNESS			●	●	●		
3	GROUND WATER MANAGEMENT		●			●		
4								
5								
6								

Table 5.3.2.1.3. Relationships between generic functions and applications

		GENERIC FUNCTIONS				
		SITE INSPECTION	EVENT RECORDING	VEHICLE DISPATCH	MANAGE FACILITIES	CONDUCT DESIGN
1	PROJECT MANAGEMENT	●	●			●
2	HIGHWAY DESIGN		●	●	●	
3	TRAFFIC SIGNAL MAINTENANCE	●			●	
4						
5						
6						

Table 5.3.2.1.4. Relationships between specific tasks and generic functions

		GIS FUNCTIONS				
		POLYGON OVERLAY	CONTOURING	PROXIMAL ANALYSIS	OPTIMAL PATH	AREA DISTRICTING
1	PROJECT MANAGEMENT	●				●
2	HIGHWAY DESIGN		●	●		
3	TRAFFIC SIGNAL MAINTENANCE	●			●	●
4						
5						
6						

Table 5.3.2.1.5. Relationships between specific tasks and GIS functions

1991):

data set description:

- data set category or theme, i.e., land use, agriculture, etc.
- data contents, i.e., principle elements of the thematic classification.
- data type, i.e., digital, analog, combination.
- source of base map, i.e., agency.
- source of value added thematic data, i.e., remote sensing, field measurement, etc.
- source of data set, i.e., agency.
- coverage, i.e., local, provincial, etc.
- geographic referencing, i.e., map projection, coordinate system, etc.

data availability:

- access policy.
- cost of data or access to data.
- data procurement selection, i.e., map sheet, lat/long coordinates, etc.
- data supply media, i.e., conventional types, and or digital types.

database structure:

- spatial data file structure(s), i.e., raster, vector, etc.
- attributes data file structure(s), i.e., lists, relational, etc.
- feature coding standard(s).
- digital data interchange format(s), i.e., DXF, SIF, etc.

data set application:

- existing applications, i.e., land management, maintenance, etc.
- potential applications.

future plans:

- adding new data, i.e., increasing accuracy, precision, coverage, etc.
- future updates, i.e., update cycle, etc.

5.3.2.3. HW/SW Specification

The step thereafter is to specify HW/SW requirements based on the initial functional (user) and data analysis. It is necessary to specify and evaluate HW/SW components that can store, process, analyze, retrieve, and display georeferenced data. Evaluation process should take into consideration in-house HW/SW and examine how GIS requirements can be incorporated into the existing system. The analysis should be driven by applications rather than processes. The final products of the GIS are the issue against which GIS development will be tested.

HW/SW requirements that should be assessed in the analysis are:

- software functionality;
- hardware devices and capacities; and
- communication facilities.

The outcome of requirement assessment process is a document to describe data input, processing function, and output product needs, and a list of HW/SW required. This document will be used in subsequent steps as an information source for design, application development, and operation.

5.3.3. Approaches to GIS Development

As indicated before in chapter one, the collaborative method is the most appropriate approach for GIS implementation. Data sharing and cooperation are the most distinct characteristics of this approach.

5.3.4. Justification Analysis

The step thereafter is to conduct justification analysis. The attempt here is not to answer whether a GIS is worth its cost, but rather to highlight some aspects that an organization should be aware of in undertaking such analysis. There is no standard justification process (Reeve, et al. 1986, PTI and ICMA, 1991). Although some organizations performed different analyses to justify their GIS purchase such as savings projections, at the root of all the analyses were some type of cost/benefit comparison (Reeve et al., 1986). Cost/benefit analysis with GIS is not an easy task. Where there are some measurable costs and benefits of developing a GIS, there are intangibles and effectiveness that cannot be easily measured or quantified, such as the impact of GIS on the organization, staff and operations, which cannot fit the conventional cost/benefit models (Reeve et al., 1986, Aronoff, 1989, PTI and ICMA, 1991, Clarke, 1991 and others). Thus, GIS team have no alternative, but to act on estimates.

5.3.4.1. Benefits Estimate

Antenucci et al. (1991) have identified five types of benefits which are either quantifiable or not. Also, they can be either direct or indirect, predictable or sporadic. These benefits are:

- type 1- quantifiable efficiencies in current practices, or benefits that reflect improvements to existing practices; improvements of automating geographic data handling; cost savings through the

reduction of redundant activities, and productivity improvement.

- type 2- quantifiable expanded capabilities, or benefits that offers added capabilities. Example of this type is that GIS offer expanded capabilities to some ineffective manually performed tasks, such as bus routing.
- type 3- quantifiable benefits that result from unpredictable events. An example of this type is the applications that could be developed based on unpredictable events with operational system such as, response to a natural disaster.
- type 4- intangible benefits which are diverse, but should not be underestimated in the system development evaluation process. Improved decision making, improved service to customers are but a few potential benefits to an organization.
- type 5- quantifiable benefits that result from the sale of information services such as sale of information to a construction company from a utility department.

5.3.4.2. Costs Estimate

Costs associated with GIS development can be categorize as follows:

- **database**

Costs associated with the database development account for more than

50% of the total system cost. These costs include one or more of the following:

- initial cost to obtain the data set, i.e., ground survey, aerial photographs, field work, etc.
 - mapping process, i.e., labour, and production of digital and hardcopy maps.
 - data conversion, i.e., digitizing, scanning, editing, etc.
 - data modelling costs, i.e., database structure for both spatial and non-spatial data.
 - database development costs, usually involves labour efforts.
- **HW/SW costs**

HW costs:

Costs associated with typical HW for GIS may include the following:

- computer(s) (workstation).
- file servers and other processors.
- data storage devices.
- terminals.
- printers and plotters.
- data communication equipment (networking).
- structural modifications, and environmental control.
- annual maintenance cost.

SW costs:

Costs associated with SW needed for GIS may include the following:

- operating system software.
 - core GIS software.
 - application software i.e specialized package for specific analysis.
 - device software i.e. communication software.
 - annual maintenance cost.
- Other costs

Costs may include training cost and expenses resulting from planning through implementation.

The outcome of this stage is a finalized document, to be presented for approval by top management. It may summarize the objectives and scope of the project, requirements assessment, proposed implementation approach, and cost/benefit analysis report. It should include project team recommendations and outline, encountered problems and proposed solutions.

5.4. Design Stage

The aim of design stage as shown in figure 5.4.1., is to formulate the implementation plan and other related activities such as system, database, and application design.

5.4.1. Implementation Plan

This plan should accommodate the long-term objectives of the organization as well as short term delivery of applications with a budget limit. It should address issues of system acquisition and provide participants with an understanding of individual roles and responsibilities. It should identify functions and priorities and be guided by the findings of previous stages such as objectives, requirements assessment and the overall approach to develop a GIS including system specifications.

The following activities are key components of the implementation planning process:

- identification and description of individual tasks and their relationships;
- assigning responsibilities for each task;
- identification of resources committed;
- adopting a procedure for system evaluation at various stages;
- identification of products and milestones; and
- establishing a schedule.

5.4.2. System Procurement

Selecting the type of system required depends on system specifications and needs. One way to acquire a GIS system is through a procedure based on a Request For Proposal (RFP).

5.4.2.1. RFP

An RFP is a document that is released to vendors to solicit bids for a GIS. An RFP emphasizes either the desired functions, specifications or combination of both, (PTI and ICMA, 1991). However, each model may have advantages and drawbacks as follows:

- desired functions when included in an RFP minimizes the list of hard technical specifications that vendors have to meet. On one hand, it gives vendors a chance to make their case and provide solutions to the problem since details are avoided. On the other hand, however, a functional RFP

requires more time from the GIS team to prepare and evaluate. The team thus, is faced with complex technical issues to evaluate and some mandatory criteria must be identified to eliminate less responsive bids.

- RFP's that emphasize specifications tend to have lengthy lists of features, mandatory or desirable, to be provided by the vendors. Such a proposal reduces the amount of work vendors must put into the response. They also simplify the process of bid evaluation, since there are fewer alternatives to evaluate. These RFPs are very effective when the product to be purchased can be very tightly defined. See Appendix C as an example of technical specifications for a GIS.

The content of an RFP typically covers a wide range of issues. This include products and services, HW/SW. In addition, it can cover spatial data conversion services, database design, application design and development, and a wide range of consulting services. PTI and ICMA (1991) have provided an excellent detailed study of RFP preparation, contents and evaluation.

Typical activities involved in preparing RFP may include (Clarke, 1991):

- specification of contractual requirements; and
- specification of evaluation methods.

After RFP preparation, it should be released to vendors. Enough time must be given to vendors to respond to the proposal. It is important to open a channel of understanding and negotiation with interested vendors.

5.4.3. Database Design

Database design addresses the specifications to develop and maintain the database. It should be built on the findings of a data analysis study. This process may involve a requirement to:

- evaluate information gathered during data needs analysis and specify exact data;
- determine database structure i.e. relational, hierarchical or network data structure;
- design database modelling schema related to entities and their relationships;
- design data quality control such as positional and attribute accuracy, resolution, consistency, completeness, etc.;
- determine data set conversion procedures;
- address database administration related issues such as, access, security, update, ownership, etc.;
- design database linkage to internal and external systems to ensure compatibility and flexibility for digital data sharing and exchange; and
- allocate resources (financial, human) and a time-schedule for database development.

5.4.4. Applications Design

The GIS team determines the priority of applications to be developed, based on criteria such as overall importance, greatest need for automation, degree of impact and visibility, cost of development and buy-in by participants (PTI and ICMA, 1991). Applications design needs; realistic planning; staged development; adherence to priorities; resources, schedule, and the continuing involvement of end-users.

The following examples are some of the applications most frequently needed by local governments:

- map productions and maintenance applications;
- infrastructure maps, inventories and related operations management systems;
- public safety and emergency preparedness;
- environment impact assessment; and
- planning, land use, and economic development analysis applications.

The outcome of this stage is a detailed document containing the implementation plan, system, database and application design. The next stage is a translation of design stage.

5.5. Development Stage

As shown in figure 5.5.1., the development stage is concerned with system acquisition and database development within a framework of organizational

structure. System acquisition focuses on: evaluating proposals; selecting the GIS system and supplier, and system installation. The database development process emphasizes spatial and attribute data structure. Finally, organizational structure focuses on where the system is to be located and what qualifications are required to make it operational. It is important to note that these steps are most likely to occur in parallel.

Figure 5.5.1. Development Stage

5.5.1. System Acquisition

5.5.1.1. Evaluation and Vendor Selection

The step hereafter, is to evaluate proposals received. The evaluation process is most likely to start with a general review to eliminate unacceptable offers. For those offers who responded thoroughly to the RFP, a selection criteria must be developed. Once the final four or five high scored proposals have been determined, vendors may be subjected to interviews, presentations, benchmark tests or site visits.

The purpose of interviews and presentation is to verify system capabilities and limitations and any other associated aspects. In this case, the GIS team will acquire a wealth of information that could enable them to prepare a benchmark test or site visit for further verification.

A benchmark test is a practical experiment with real automated data, which will be provided to the short list of vendors to be tested. In the past, the focus of a benchmark test was on SW/HW functionality. At present since SW/HW basic functions have proven to be reliable, the focus shifted to the testing of system utilities for specific applications. When conducting such a test, timing, performance, and functionality of the various components of the system such as data entry, retrieval and analysis, database management and output should be observed and carefully recorded.

Another alternative, is a visit to a currently operating customer site. In this case, there is no need for any type of test. Instead, GIS team will have the

opportunity to verify system functionality and utility through real and practical applications in a comparable organization.

If a decision is made and the final two or three vendors have been selected, another scenario of negotiations and contracting process will begin. Up to this point there is no obligation on either side. The negotiating team, if negotiations fail for any reason, should reserve the right to discontinue negotiations. In this case, the alternative is still open to chose other vendors.

Negotiation is a critical issue, and it can not be stressed enough that negotiation should cover the key aspects of GIS implementation. Practically, anything is negotiable. HW/SW, documentations, installation, maintenance, services, support, applications software development, consulting and training, price and terms of payment all are subject to negotiations.

If negotiations are successfully completed and the system and vendor selected, contracting and procurement logically follow. The various reviews required in preparing a contract for GIS procurement include (PTI ICMA, 1991):

- review necessary adjustments to the implementation plan;
- review the deliverables as described in the proposed contract;
- review cost associated with deliverables and legal aspects; and
- review legal aspects such as data right, copy right, cost or revenue sharing, or royalties and fees.

5.5.1.2. Installation

The system installation process will be guided by system design, acquisition and specification, and terms of agreement in the contract document. The vendor is expected to deliver, install and configure the system HW/SW and network if any. When all system components are installed, the vendor usually conducts a series of tests to verify successful installation and operation. Vendor obligations do not end by installing the system. Staff training, support and services, and maintenance are all continuing processes for many years between vendors and the organization.

Pilot projects and applications development are two logical steps after system installation. These aspects will be dealt with in the operational stage.

5.5.2. Database Development

As discussed earlier, it is assumed at this stage that database design has been completed. The issue here is to capture the data either in-house or by contracting to a private company. As the database creation is a labour and time consuming process, some organizations will contract their database development phase. If this is the case, database creation may start before purchasing the system. However, there is a trade-off to this approach. First, staff will not gain the experience of data conversion. Second, transferring data to the eventually selected GIS, may be associated with some difficulties.

The other alternative is to create the database after system installation. In this approach, staff will be trained and will gain the experience necessary to create

the database. The disadvantage of this is that, the initial investment will appear to be under utilized until staff are trained and data are entered (Aronoff, 1989). Furthermore, by the time the database is developed, there will very likely be more advanced GIS systems in the marketplace.

5.5.3. Organizational Structure

The implementation plan is assumed to identify the group that will be responsible for the implementation and operation of the GIS, for example through the GIS team. This committee must ensure an effective integration and cooperation between user departments, as it has representatives from those departments. In addition, if the system development process proves to be successful, the GIS team may in the future gain the management support necessary to operate the system. Finally, continuing technical support will be sustained with technical member(s) of the committee being fully aware of any progress, modifications, changes, and maintenance on the technical side. In organizing the team to operate the GIS, members may be added or excluded as needed.

There are two options in which GIS can be operated. First, assign responsibilities of operating the system to an existing body or department in the organization usually information services department. Although this approach will avoid creating an additional administrative layer to the organization, it will not assure full utility of the GIS.

The second option, which is gaining wide acceptance especially in the developed world, is to create a separate unit or division to operate the system. Although this may add an additional workload to the parent organization, it has long-term benefits. It should not however, function in isolation from other units, of the parent organization since it will be the main supplier of data and be responsible for updating and maintaining the database.

The last point in discussing organizational structure is staff functions and qualifications.

5.5.3.1. The GIS Manager

GIS manager acts as an executive link between the GIS unit and other user departments or organizations. The first priority of the manager is to keep within budget and organizational limits, while motivating staff to obtain maximum benefits from the system. This position requires a person with a broad knowledge of GIS applications, capabilities, and database requirements in the organization.

5.5.3.2. The GIS Analyst

The person occupying this position must have specific experience with GIS and its applications. A GIS analyst plans, develops, implements, and analyzes databases. In addition, the analyst must have the ability to translate user requests into procedures and methods for generating reliable products. In short, the analyst is the educator about GIS (Brown, 1986).

5.5.3.3. The Database Administrator

Database administrators must have adequate knowledge of spatial and attribute data, their use in GIS, and the methods of organizing them into layers and descriptive records. Database managers, in addition, have the authority to control access to and the updating of the database.

5.5.3.4. The Cartographer

The person in this position must be experienced in map making. Experience in spatial data entry and display operations of GIS are also necessary. The cartographer must also be qualified to compile and integrate data from many sources for automation, as well as the design of output maps to be produced by the system. This will ensure high quality GIS products.

5.5.3.5. GIS Operators

A data entry operator is responsible for data entry to the system. An operator must have knowledge of accurate digitizing, scanning, vectorizing, and keyboard entry of spatial and attribute data. A general knowledge of computer HW/SW is preferred for this position.

5.5.3.6. The System Manager

System maintenance including HW/SW peripherals, and supplies are the basic responsibilities of system manager.

5.5.3.7. Programmers

Qualifications for a programmer to work with a GIS includes experience with scientific programming languages such as for example C or C++, and a good knowledge of computer graphics. The basic responsibility of a programmer is to ensure compatibility of input, output formats to accommodate end-users.

5.5.3.8. The End User

End users are people with differing backgrounds and needs. Their jobs may require the use of GIS without having to learn the entire system. By training they will acquire the knowledge of the functions and capabilities of GIS and how can it be applied to meet their needs.

End users either from within the organization or outside, will make requests of the GIS facility to produce a specific set of products. Thus, every efforts should be made to meet their needs. A GIS may be judged by satisfaction expressed.

An assembled staff with all of the above-mentioned qualifications would form a theoretically best GIS team to achieve the overall long-term GIS objectives of an organization. The number of this team and their qualifications will vary from one agency to another depending on the overall functions to be automated by a GIS.

5.6. Operational Stage

The operational stage is where the pay-off of significant investments in the system's development will begin and cost increases diminish. On the other hand it

is the stage that will reflect how well the previous stages were planned and executed. It is at this stage that one can say the agency has an operational system that could be of benefit. As shown in figure 5.6.1., this stage consists of a pilot project, applications development, and continuing support.

Figure 5.6.1. Operational Stage

5.6.1. Pilot Project

A pilot project is an excellent way to verify and test the many unidentified elements related to system installation and configuration, software development, and

database design. It saves time and money that may otherwise be spent on methods unsuitable or inefficient in the proposed work procedures and applications development.

To perform a typical pilot project, the following steps should be carried out:

- define clearly the objectives of the pilot project;
- choose a study area that is representative of the area to be addressed in future operation;
- select the database for this area. It should exhibit a full range of complexity to be anticipated in later processing;
- enter the data into the system, manipulate, analyze and generate products; and
- demonstrate the analysis to potential users.

This test requires adequate planning to define the objectives, etc., and evaluate the project. Cost, speed, and accuracy should be reviewed in detail and recommendations to overcome encountered difficulties should be made.

5.6.2. Applications Development

Applications are special programs that are produced using software and macros language tools provided with the system to perform specific tasks (Antenucci et al. 1991). These tasks could range from a very simple computation process to more complex tasks such as data entry, retrieval, computation, analysis, and other processes. The type of application to be developed is highly dependent on

the initial need analysis and database design. Applications development is a process that will continue for many years. Indeed, it provides extra benefits to the organization which were invisible, or unquantifiable, prior to their development.

5.6.3. Continuing Support

In order for GIS to successfully and continuously advance the agency's functions, a number of issues related to system operations must be considered. This includes managerial, financial, training, technical and logistical supports. Although, most of these issues have been dealt with elsewhere in this chapter, it is appropriate to briefly re-emphasize these here to highlight their importance.

5.6.3.1. Managerial Support

System expansion, changes in user needs, and necessary modifications to databases are but a few examples that need continuing management support. For example; new high resolution data capture devices may be developed, which may lead to a revision of data collection and development methods. This may lead in turn to dramatic modifications which will need management support.

5.6.3.2. Financial Support

The experience of some funding agencies suggests that through the careful and thoughtful attention of finance, it is possible to promote effective use of geographic information (UNISIST, 1984). Stable and sustainable funding will ensure and enable long-term, well planned activities.

5.6.3.3. Training Support

Training in depth should be considered of extreme importance from the very beginning of system development. Training programs have to be established on a continuing basis and should not be restricted to just short periods during or after, system installation. The shortage of highly skilled, qualified personnel in the KSA could limit the implementation, development and use of the GIS, unless firm training policy and programs are considered in the early stages of system development.

The following are some types of training programs that should be considered as part of the implementation plan:

- vendor training; usually as part of system procurement that covers the basic fundamentals of GIS,
- In-house training usually on a continuing basis,
- workshops and seminars, and
- short courses; undergraduate or graduate programs by academic institutions.

5.6.3.4. Technical Support

Technical support in terms of HW/SW maintenance and upgrading, and database maintenance and update are a prerequisite. Availability of spare parts and routine maintenance of HW peripherals and communication equipment must be ensured. Routine backup of software and database files must be established. Database related issues such as confidentiality, maintenance and update should be

considered. Allocation of enough funds to cover these areas are fundamental.

5.6.3.5. Legal Support

Issues such as data ownership, copyright, value, control, standards, and access represent real challenges within legal and institutional frameworks (Antenucci et al. 1991, Allam, 1991). Those issues are gaining more and more attention and should become part of GIS development and planning process. Conflicts on those areas should be resolved and appropriate laws must be introduced.

5.7. Summary

The five stages of GIS development and implementation in the KSA have been examined and discussed. The findings, believed to be universal to any GIS project, indicate that GIS development is a complex lengthy process and requires extensive planning and participation prior to its implementation. In addition, they enforce the notion that, the most pressing problems in GIS projects are organizational rather than technical in nature. Last but not least, is that staged development is the most appropriate approach to GIS development which leads to flexible and less disruptive methods, alternatives and strategies, to replace existing manual functions and practices. It allows users to evolve in parallel with the technology and also improves the chance of success.

Chapter six

6. Transportation Applications: Pilot Project

6.1. Introduction

Rapid urbanization is the main characteristic of Saudi Arabia in the second half of the twentieth century. The percentage of urban population has increased dramatically from 30% in 1960 to 76% in 1988 and is expected to reach 82% in the year 2000. Riyadh (the capital city) has a population of approximately 2 million inhabitants; 15% of the total population, and occupies 1600 km².

The total area of paved roads in Riyadh is approximately 180 million m². The movement of people and goods within the city in association with rapid urban growth, requires extensive and continuous transportation planning and road maintenance.

A part of sound transportation planning is to maintain roads and streets in good conditions to facilitate traffic flow and to improve the overall transportation planning process. To do this, the need for up-to-date information concerning roads condition becomes apparent. Gradually, traditional storage media, i.e., road maps, charts etc. have become out-dated and less relevant. Finding new and faster means of providing up-to-date information in 'near real time', has become imperative. The current state-of-the-art GIS technology offers the best-solution to the problem.

The ability of GIS technology to provide innovative approaches to manage and integrate transportation related information, especially those related to road maintenance, will be portrayed in this project. The Malaz area in Riyadh city has been selected as a test site for this project. All stages of applications development have one major role; to ensure that automation of the workplace proceeds in a manner that will generate suitable software, while maintaining cost-effectiveness, stability, flexibility, and be open to widest possible access within a parent agency.

6.2. Objectives

The primary objective of this project is to construct a topological street network for the Malaz area to support the following applications:

- road inventory;
- infrastructure management; and
- planning "what if analysis".

The above stated applications are described in the data components and potential applications section of this chapter.

6.3. User Needs Analysis

This project aims to demonstrate the ability of GIS to manage and analyze some aspects of road related information. This project can play an important role in many areas such as maintenance prioritization and transportation planning. The agencies most likely to benefit from this project are:

- Department of maintenance at MoMRA.
- Transportation planning at ADA.

It could also provide a foundation base for a road information system which could be further enhanced to develop other applications such as accident analysis, traffic operations and emergency services.

6.4. Benefits

This project provides standard procedures for locational data and attribute data, for specified applications. In this project data is integrated from various sources, such as: scales and dates to provide overall management and decision making. Furthermore, it illustrates to Saudi critics, the potential of GIS technology in managing road-related information to speed the advance of transportation development in the Kingdom.

6.5. Project Deliverables

Final products of this project include:

- A project report; and
- A GIS database.

Upon completion of this project, the project report and the GIS database will be available for demonstration at the GIS technology centre, GISD, EMR.

6.6. Applications Development

The development of applications specified in this project may be divided into six steps as follow:

- data collection;
- data modelling;
- database construction;
- graphic and attribute data integration;
- queries design; and
- output generation.

6.5.1. Data Collection

Between July 1 and August 31, 1991, spatial and attribute data for the study area were collected from Riyadh Municipality, ADA and NNP. Despite efforts to obtain authentic values for the attributes, they were not available to demonstrate the potential of GIS in transportation planning. Accurate street names and trip generation data was obtained. The remaining attributes are fictitious.

6.6.2. Data Modelling

This step is a preparation process for data entry to the GeoVision GIS. Conceptual modelling (infological modelling) is the main theme of this task. It forms the foundation of the database. In this step, all the basic facts and constraints under which the database will have to operate, are being considered to satisfy query

requirements. Two modelling techniques are then used for database development.

6.6.2.1. ERD

ERD is used to model spatial and attribute data. As shown in figure 6.6.2.1.1., roads and road segments are considered entities. Each entity has differing attributes to support the initial applications. In this model there are three types of entities and their relationships and attributes.

Figure 6.6.2.1.1. Street network ERD

6.6.2.2. Data Dictionary

(A) Spatial data

Base map

The base map is composed of control data and topographic, elevation contours. It provides a framework to which all other overlays and tabular data can be referenced.

Supplier: Municipality of Riyadh, Department of Urban Planning and Studies.

Scale: 1:10,000

Source: Map compiled from aerial photography taken during 1982.

Projection and basic data:

Map projection: (U.T.M.)

International Spheroid

Horizontal datum: National Geodetic Net (Ayn al Abd 1970).

Vertical datum: Mean Sea Level (Jeddah 1969).

(B) Attribute data:

1. Street inventory data

Table 6.6.2.2.1. is a description of street inventory data in the Malaz area. It contains general information of the street network.

Table 6.6.2.2.1. Data components description of street inventory data.

Data item	Description	Source	Unit
ID	unique identification	user defined	
ST_Name	street name	NNP	
From_ST	from street name	NNP	
To_ST	to street name	NNP	

Potential applications of data in this file may include:

- assigning street names; and
- street name control checks.

2. Subsection inventory data

Table 6.6.2.2.2. is a description of inventory data at the subsection level of the street network.

Table 6.6.2.2.2. Data components description of subsection inventory data.

Data item	Description	Source	Unit
ID	unique identification	user defined	
SEC_ID	Section identification	user defined	
FROM_ST	from street name	NNP	
TO_ST	to street name	NNP	
CLASS	functional class 1- Major road 2- Secondary road 3- Residential street		
WID_TOTAL	total width for both directions of a street from side walk to side walk	as measured by road engineer	Meter

SPEED	maximum speed limit	as assigned by road engineer	Km/h
MAT_TYPE	material type asphalt		
PRIORITY	maintenance priority base on importance, class...etc. 1- High priority 2- Medium priority 3- Low priority	as measured by traffic engineer	
INSP_FREQ	inspection frequency	as measured by road engineer	year
CONS_DATE	construction date		
LANE_NO	total number of lanes in both street directions		
SURV_YEAR	date when this information collected or last date of inspection		

Potential applications of this file may include:

- street mapping;
- vehicle routing/dispatching; and
- inspection updates.

3. Surface distress data

Table 6.6.2.2.3. contains distress severity and extent values at subsection level of major street network.

Table 6.6.2.2.3. Data components description of surface distress data.

Data item	Description	Source	Unit
ID	unique identification	user defined	
SEC_ID	unique identification for subsections	user defined	
RCAL_SEV	Severity of Ravelling and Coarse Aggregate Loss distress type	as measured by road engineer	
RCAL_EXT	Extent of Ravelling and Coarse Aggregate Loss distress type	as measured by road engineer	
RCAL_DV	Distress value of Ravelling and Coarse Aggregate Loss distress type	as calculated by the system	
EX_A_SEV	Severity of Excess Asphalt distress type	as measured by road engineer	
EX_A_EXT	Extent of Excess Asphalt distress type	as measured by road engineer	
Ex_A_DV	Distress value of Excess Asphalt distress type	as calculated by the system	
PO_SEV	Severity of Potholes distress type	as measured by road engineer	
PO_EXT	Extent of Potholes distress type	as measured by road engineer	
PO_DV	Distress value of Potholes distress type	as calculated by the system	
RU_SEV	Severity of Rutting distress type	as measured by road engineer	
RU_EXT	Extent of Rutting distress type	as measured by road engineer	
RU_DV	Distress value of Rutting distress type	as calculated by the system	
DI_SEV	Severity of Distortion distress type	as measured by road engineer	
DI_EXT	Extent of Distortion distress type	as measured by road engineer	

DI_DV	Distress value of Distortion distress type	as calculated by the system	
AL_C_SEV	Severity of Alligator cracking distress type	as measured by road engineer	
AL_C_EXT	Extent of Alligator cracking distress type	as measured by road engineer	
AL_C_DV	Distress value of Alligator cracking distress type	as calculated by the system	
LM_C_SEV	Severity of Longitudinal and meandering cracking distress type	as measured by road engineer	
LM_C_EXT	Extent of Longitudinal and meandering cracking distress type	as measured by road engineer	
LM_C_DV	Distress value of Longitudinal and meandering cracking distress type	as calculated by the system	
TC_SEV	Severity of Transverse cracking distress type	as measured by road engineer	
TC_EXT	Extent of Transverse cracking distress type	as measured by road engineer	
TC_DV	Distress value of Transverse cracking distress type	as calculated by the system	
PA_SEV	Severity of Patching distress type	as measured by road engineer	
PA_EXT	Extent of Patching distress type	as measured by road engineer	
PA_DV	Distress value of Patching distress type	as calculated by the system	
SEC_DV	the overall distress value for street section	as calculated by the system	
SURV_YEAR	date when this data were collected or last inspection date		

Potential applications of data in this file may include:

- road maintenance scheduling;
- inspection frequency scheduling; and
- road condition reporting.

4. Planning data

Table 6.6.2.2.4. contains information obtained from Riyadh Transportation study. It is a result of analysis done by the EMME2 system. The inclusion of auto-volume in this project is to illustrate the cartographic capabilities of GIS over other systems. EMME2 displays the analysis results as numbers for each travel direction. This information is displayed cartographically using conditional symbology in the GeoVision system (see map 6.10.4.1.).

Table 6.6.2.2.4. Data components description of Planning data.

Data item	Description	Source	Unit
ID	Unique identification	user defined	
SEC_ID	Unique identification for subsections	user defined	
UNIQ_ID	Unique identification	user defined	
AUTO_VOL	Auto volume	as calculated by EMME2	Car/24hr
EMME_LANE	Total lanes number	as calculated by EMME2	

Potential applications of this data include:

- transportation planning.

6.7. Database Development

This step involves converting organized data into a digital format and entering data into the GIS.

6.7.1. Spatial Database

Street segments on the base map are digitized using PAMAP PC-based GIS. Major and secondary roads are digitized into different levels or layers. After that, the data was converted into DXF format using the PAMAP conversion utility. Data was then transferred to the GeoVision system. The spatial database schema was developed in GeoVision system and is as follow:

Layer number:	10
Layer name:	major_rd
Layer description:	major roads

Layer number:	20
Layer name:	second_rd
Layer description:	secondary roads

Layer number:	30
Layer name:	landmark
Layer description:	land marks

Layer number:	50
Layer name:	expanded
Layer description:	expanded symbology from layer 10

Network number: 11
Network name: major_rd
Network description: major road network
Network type: linear
Network layer: 10

Network number: 21
Network name: second_rd
Network description: secondary road network
Network type: linear
Network layer: 20

Network number: 31
Network name: landmark_nt
Network description: land mark network
Network type: polygon
Network layer: 30

Network number: 51
Network name: expanded_nt
Network description: expanded meager road network
Network type: linear
Network layer: 50

Layer 50 and network 51 are created using expanded symbology in advanced mapping system (ams) module. The feature expansion capability allows the user to expand the symbology into actual features. For example, a street centreline was symbolized as a set of parallel lines. This symbology was expanded to generate new road edges features.

6.7.2. Attribute Database

The attribute database schema is as follow:

1- Inventory data file:

Structure for database: INVENTORY data file

Number of data records: 22

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	ID	Character	3		Y
2	ST_NAME	Character	40		N
3	FROM_ST	Character	40		N
4	TO_ST	Character	40		N
**	Total **		123		

2. Inventory subsection data file

Structure for database: INVENTORY SUBSECTION data file

Number of data records: 78

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	ID	Character	3		Y
2	SEC_ID	Character	2		Y
3	FROM_ST	Character	40		N
4	TO_ST	Character	40		N
5	CLASS	Numeric	1		N
6	WID_TOTAL	Numeric	2		N
7	SPEED	Numeric	2		N
8	MAT_TYPE	Character	7		N
9	PRIORITY	Numeric	1		N
10	CONS_DATE	Date	4		N
11	INSP_FREQ	Numeric	1		N
12	LANE_NO	Numeric	1		N
13	SURV_YEAR	Date	4		N
**	Total **		108		

3- Distress data file

Structure for database: DISTRESS TYPE data file

Number of data records: 78

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	ID	Character	3		Y
2	SEC_ID	Character	2		Y
3	RCAL_SEV	Numeric	1		N
4	RCAL_EXT	Numeric	1		N
5	RCAL_DV	Numeric	2		N
6	EX_SEV	Numeric	1		N
7	EX_EXT	Numeric	1		N
8	EX_DV	Numeric	2		N
9	PO_SEV	Numeric	1		N
10	PO_EXT	Numeric	1		N
11	PO_DV	Numeric	2		N
12	RU_SEV	Numeric	1		N
13	RU_EXT	Numeric	1		N
14	RU_DV	Numeric	2		N
15	DI_SEV	Numeric	1		N
16	DI_EXT	Numeric	1		N
17	DI_DV	Numeric	2		N
18	AC_SEV	Numeric	1		N
19	AC_EXT	Numeric	1		N
20	AC_DV	Numeric	2		N
21	LM_C_SEV	Numeric	1		N
22	LM_C_EXT	Numeric	1		N
23	LM_C_DV	Numeric	2		N
24	TC_SEV	Numeric	1		N
25	TC_EXT	Numeric	1		N
26	TC_DV	Numeric	2		N
27	AP_SEV	Numeric	1		N
28	PA_EXT	Numeric	1		N
29	PA_DV	Numeric	2		N
30	SEC_DV	Numeric	2		N
31	SERV_YEA	Date	4		N
** Total **			48		

4- Distress score matrix

Structure for database: DISTRESS SCORE MATRIX data file

Number of data records: 20

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	SEVERITY	Numeric	1		N
2	EXTENT	Numeric	1		N
3	SCORE	Numeric	2		N
** Total **			4		

This file contains a distress score matrix used to calculate distress score for each distress type in the previous file.

5- Relative weight

Structure for database: RELATIVE WEIGHT data file

Number of data records: 9

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	DIS_TYPE	Character	4		N
2	R_WEIGHT	Numeric	5	3	N
** Total **			9		

Data in this file, which is based on distress type and its relative weight, is used to calculate the overall distress value for subsections of street network.

6- Planning data file

Structure for database: PLANNING data file

Number of data records: 78

Date of last update : 02/26/92

Field	Field Name	Type	Width	Dec	Index
1	ID	Character	3		N
2	SEC_ID	Character	2		N

3	UNIQ_ID	Character	2	N
4	AUTO_VOL	Numeric	5	N
6	EMME_LANE	Numeric	1	N
** Total **			18	

6.8. Spatial and Attribute Data Integration

In this step, various elements of spatial and attribute data are linked to satisfy the initial applications identified in the objective section. An analysis is undertaken to define an acceptable procedure for assigning a unique index key for street sections. This allows the road inventory GIS spatial database to be linked to road inventory attribute database. Tables invensub and planning in the database are used as a primary tables which are directly related to spatial features in the database. The other tables are used as look up tables to perform calculations and queries. They are linked through ID and SEC_ID index keys which are used as a key fields in the database.

6.9. Surface Distress

Surface distress is the degree of damage to a pavement surface caused by traffic and environment. Determining the condition of a pavement is useful to determine what are the appropriate maintenance and rehabilitative treatments, and probably best timing for their application.

This study adopts the same procedure developed and used by the New Brunswick Department of Transportation (NDOT) to produce a surface distress score value. The surface distress manifestations are in a coded form ranging from

-8.0 (very severe, throughout) to 10.0 (no distress). The Surface Distress Score (SDS) calculation is based on severity and extent of distress type (1-9) in a given section of a road. Table 6.9.1. and 6.9.2. present severity and extent rating codes used by NDOT.

Table 6.9.1. Severity Rating Code Description.

Severity Code	Severity Description
0	None
1	Slight
2	Moderate
3	Severe

Table 6.9.2. Extent Rating Code Description.

Extent code	Extent description
0	None
1	Rare
2	Intermittent
3	Frequent
4	Extensive

The objective is to automatically calculate the surface distress values based on control section in spatial database. There are 9 distress types and their relative weight (see table 6.9.3.) to be considered as an attribute data for any given segment of a road in the topological network.

Table 6.9.3. Distress type and relative weight.

I	Distress type	Relative weight
1	RCAL	0.044
2	Ex	0.022
3	Po	0.078
4	Ru	0.167
5	Di	0.156
6	AC	0.200
7	LM_C	0.133
8	TC	0.111
9	Pa	0.089

2. Procedure to determine distress value (DV)

To determine DV, it is necessary to calculate the Distress Score (DS) first.

3. DS calculation

DS calculation is based on assigning a number from the following matrix to the distress type. This matrix is based on the severity and extent of distress type. The values in this matrix are constants.

Distress Score Matrix					
Extent					
Severity	0	1	2	3	4
0	10	10	10	10	10
1	10	9	7	5	4
2	10	7	5	3	-2
3	10	6	3	-2	-8

For example, if severity of RCAL distress type = 1 and extent = 2, DS will be 7 (see matrix).

4. DV calculation:

The DV at each section of a road is then calculated using the following equation:

$$DV = \sum_{i=1}^{i=9} DIWT_i \times DS_i$$

Where,

$DIWT_i$ = relative weighting factor for distress type i.

DS_i = distress score for distress type i.

Example,

$$= .044DS_1 + .022DS_2 + .078DS_3 + .167DS_4 + .156DS_5 + .200DS_6 + .133DS_7 \\ + .111DS_8 + .089DS_9$$

$$DV = .044(3) + .022(10) + .078(6) + .167(3) + .156(7) + .200(7) + .133(-2) \\ + .111(7) + .089(10) \\ = 5.2$$

The overall distress value of a section of a road is assigned to the database. SQL was used to perform the calculation and to store the results.

6.10. Query design

Spatial and attribute queries are developed using SQL, and GeoVision macros and menus to automate street network database queries, and product generation.

6.10.1. Conditional symbology

Conditional symbology allows the user to display the same feature in many different ways. It allows the display of a limited number of features with an unlimited number of symbology choices.

One of the basic tasks required by this project is to display the overall status of the street network in the Malaz area. The condition rating, as an attribute in the database, is an overall index of the segment's condition, based on its surface condition. For example, a segment in perfect condition has a rating of 10, while a poor one will rate less than 0. (see map 6.10.3.1.).

The following example is one of the conditional symbology macros used to represent auto-volume on the street network.

```
set scale: 15000
if @auto_vol >= 18000;
set color: "red";
set line thickness_r: 4;
elseif @auto_vol >= 13000 and @auto_vol <= 17999;
set color: "orange";
set line thickness_r: 2;
elseif @auto_vol >= 5000 and @auto_vol <= 12999;
set color: "yellow";
set line thickness_r: 1;
elseif @auto_vol >= 0 and @auto_vol <= 4999;
set color: "white";
set line thickness_r: 0.5;
endif;
```

Number of maps may be generated from a spatial and attribute database based on different queries and macros. The following are examples of maps that can be generated from this pilot project.

6.10.2. Street network

Map 6.10.2.1 is a street network map of Malaz area. It shows the street network and land marks.

6.10.3. Pavement distress

Map 6.10.3.1. portrays the overall condition of each segment of a street in terms of distress value rating from -8 to 10. The overall condition of a road section has been classified into four categories.

Where the distress value is greater than 4, the street section is in a good condition, and there is no need for restoration. Distress values between 1.5 and 4, mean that the street section is in satisfactory condition, but probably needs inspection. Distress values between 0 and 1.5, mean that the street section is in unsatisfactory condition and the need for restoration is required. Distress values less than 0, mean the street section is probably unusable.

6.10.4. Auto-volume projection

Map 6.10.4.1. illustrates the number of trips from Saturday to Wednesday projected by the EMME2 modelling package. The number of trips are classified into four categories:

More than 18000 trips per day;

13000 to 18000 trips per day;

5000 to 13000 trips per day; and

Less than 5000 trips per day.

Map 6.10.3.1. Overall Street Surface Condition

Map 6.10.4.1. Number of Trips Projected on Street Network

If auto-volumes and surface distresses were authentic values, important GIS correlations between them could be generated indicating state of road related to road condition. This type of application could be very important in prioritizing pavement maintenance requirements.

6.11. Summary

During the course of the pilot project, it became evident that planning for GIS application development requires a great deal of time. In this case, approximately 50% of the pilot project development efforts.

The various steps of application development from spatial data collection to product generation are described. Data analysis and output are satisfactory in the relational database by using appropriate procedures according to user requirements.

This project could be of use as an example for road maintenance and transportation planning departments in the KSA. It also could form the foundation base for other GIS projects in the country. However, it is recommended that careful planning prior to application development must be considered, and that end users get involved in prototype application development.

Chapter seven

7. Conclusions and recommendations

GIS represents a set of information technology composed of hardware and software for the input, storage, manipulation and analysis, and output of georeferenced data. The general assumption of this study is that this technology could be of use to government agencies in the KSA, if basic requirements are satisfied and proper channels for its implementation are established. While the discussion has been centred around this general assumption, this study concludes with the following:

7.1. Conclusions

GIS has evolved since early 1960s as a multi-user and multi-discipline technology as a result of research and development in computer science, management science, cartography, geography, geology, surveying, engineering, mathematics and statistics. The multi-standard characteristics of this technology has increased its potential usage to cover many areas such as environmental monitoring, municipal applications, agriculture, geology, resource management, etc. On the other hand however, there is a dilemma around its associated definitions and terminologies. For example, there is no universal definition of GIS. Another example, is the use of several terms such as spatial, cartographic, locational, and georeferenced data, all of which can/may be used interchangeably.

One of the significant trends in GIS computing environment is toward the high performance workstations and the PC as GIS platforms. Mainframe and minicomputer systems seem to have been superseded by the new high-speed, desktop technology. Networks represent another significant improvement in HW/SW technology which permits the interconnection of large databases with workstations, personal computers, file servers and various shared peripherals. Despite these desirable general trends, the type of HW/SW to support any geographic information processing system depends always on the size of an organization, its budget limitations and its perceived functional requirements.

Data acquisition and input, processing and organization, management, manipulation and analysis, and output, are all fundamentals of a GIS. This continual process illustrates human and machine concepts of data representation. It has been illustrated in this study by the means of modelling techniques. ERD and data dictionary modelling methods refer to human concepts, which is usually called infological models. Whereas datalogical models refer to machine representation of spatial and attribute data. Vector or coordinate systems and Raster or cellular systems are the two major models used to represent spatial data by computers. Topological vector data structures are commonly used by GIS. It is a mathematical coding process that defines spatial relationships and establishes a direct linkage between spatial entities. Raster data structure on the other hand, is simple and easy to handle by computer as all spatial entities are coded in the same manner. Despite the large storage needs, it facilitates the overlay analysis process efficiently. In short, each data

model has its advantages and drawbacks in reference to data representation and analysis. Data and applications are the driving forces of vector or raster usage.

DBMS as a subsystem of a GIS, provides the facilities necessary to store, organize, sort, update and retrieve large volumes of data. It permits access with a degree of protection to the physical structure of the database. Relational, hierarchical, and network database systems are the three general purpose data models commonly used with a GIS. In particular, relational database sub-systems such as DB2, ORACLE, and INGRES are widely used with a GIS. Analytical capability is the most distinct feature of a GIS which distinguishes it from other systems such as CAD. Analytical functions of this technology include distance/area measurement, buffering, map algebra, boolean operations, COGO computation, network analysis, terrain analysis, and polygon operations. Although, the performance of this technology is mostly straightforward, uncertainties of GIS analysis, can at times, not only affect the accuracy of spatial and attribute data, but can also produce vagueness, ambiguity, imprecision, and inexactness, which has not yet been resolved completely.

In the context of GIS in government agencies, the survey showed the following:

- in some agencies canvassed, the decision-making process has not been influenced by consideration of GIS simply because installation of GIS has not been considered;

- GIS is desirable and its usefulness is being recognized by top management level;
- most organizations are determined to utilize GIS, but they lack knowledge and directions;
- some agencies have already purchased GIS's without full knowledge of their potential employment. The result is, that in the absence of proper training program and qualified training instructors, the system may be abandoned;
- there is a shortage in GIS personnel and the need for strong training policies is apparent; and
- improvement in data sets are necessary. This requires adopting an information master plan.

The need for formal planning and conceptual guidelines for GIS development is apparent as has been reflected in this study by means of staged GIS development. Five major stages are suggested:

- the pre-automation stage states that; increased awareness of the use of GIS technology and management support, are of particular importance prior to embarking on a full-scale GIS development. It also suggests that for effective system development a team must be appointed which consists of both management and user department representatives. This team should be headed by a manager with experience knowledge of GIS's.

- the planning stage is the foundation stage of a GIS. The needs assessment, GIS objectives, approaches to the technological development, the justification analysis are all working tasks of this stage. The GIS team is thus faced with a number of challenging issues to be dealt with carefully in order to establish a solid and reliable foundation for this technology.
- the design stage suggests that, once documentation of previous stages has been approved by both management and users, a design process for system configuration, and database and applications design will take place, and a design framework formalized. This is reflected in an implementation plan which considers individual tasks and responsibilities, products and milestones, resources, and schedules. Consultation with experts is suggested at this stage.
- the development stage, which is a practical translation of former stages, aims to set proper procedures for system acquisition and database development. Organizational structure to operate the GIS enterprise, is also of particular importance in this stage. Creation of a GIS unit which can be operated by a GIS team is recommended.
- the operational stage is definitely not the final development stage, but rather a stage requiring a sustainable and continuing support for system development and utilization. It is sometimes at this stage where the pay-off of the large investments will begin and costs gradually decrease. Managerial, financial, technical, legal, supports must be sustained to ensure that this technology will function effectively.

7.2. Recommendations

This study concludes with the following recommendations:

- Recommendation to proceed

It is recommended that government agencies in the KSA proceed with GIS development according to the guidelines provided in this study. There is convincing evidence of the critical role GIS plays in geographic information management. It is also clear that the integrity and timeliness of geographic information resources will become a significant factor in utilizing this technology in the future.

- Recommendation for management support

The implementation process of this technology should receive human, financial and technical support from top management level. The findings support the view that significant returns on large investment may be realized although it may be a multi-year process to fully integrate a GIS into an agency's working and management environment. Without full support, it is unlikely that the returns on investment can be completely realized. It is recommended that senior management stress the importance of transition to an 'automated approach', so proper channels of coordination, sharing of digital data and ultimately, improvement of the decision-making mechanisms can be established.

- Recommendation regarding geographic information:

Improvement of geographic information is necessary. This study recommends that availability and reliability of geographic information is to be a mandatory matter. It should be regarded as a valuable resource. It cannot be emphasized enough that data accuracy, completeness, timeliness, lineage, standards, and accessibility are extremely important for reliable use of this technology. This study also recommends that geographic data requirements must be accommodated at both national and sub-national levels.

- Recommendation for GIS education:

To improve the level of use of a GIS to its maximum potential, it is recommended that, in order to bring about adequate knowledge of GIS culture, GIS education should be introduced in academic institutions throughout the country. Further, it is recommended that government agencies should involve and organize conferences related to all aspects of GIS.

—

Bibliography

- Allam, M. and Templin, A. (1991) **Mapping Sector Charts a New Field**. In: *Geos*, A Quarterly about the Earth's Resources, EMR, Vol.20 No.1 Winter 1991:1-5.
- Allam, M. (1991) **Preparing Your Organization for a GIS: Avoiding Surprises when Hardware/Software Arrives**. Proceedings of Conference of Commonwealth Surveyors, Paper No. G-1, Cambridge, UK:514-521.
- Al-Ankary, K. (1991) **An Incremental Approach for Establishing A Geographical Information system in a Developing Country: Saudi Arabia**. *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:85-94.
- Al-Farsy, F. (1991) **Modernity and Tradition: The Saudi Equation**. Kegan Paul International.
- Anderson, K. (1987) **Pavement Surface Condition Rating Systems**. Roads and Transportation Association of Canada.
- Antenucci, J. C., Brown, K., Croswell, P., Kevany, M., and Archer, H. (1991) **Geographic Information Systems: A Guide to the Technology**. New York: Van Nostrand Reinhold.
- Aronoff, S. (1989) **Geographic Information Systems: A Management Perspective**. Ottawa, WDL Publications.
- Baser, R. (1991) **Inter-Agency Committee on Geomatics Data Dissemination and Government Data Bases Sub-Committee Summary Report on Activities**. *Proceedings of the Canadian Conference on GIS-91*, Ottawa:CISM:216-38.
- Beidler, A. and Williams, R. (1986) **A Local Government Geographic Information System Evaluation Process**. *Proceedings of the URISA '86 Conference*. Urban and Regional Information Systems Association. Washington D.C. Vol. 2:168-76.
- Bergstrom, S. (1991) **GIS for Road Related Systems**. A Study Report by MOC/SweRoad.
- Bollens, S. and Drummond, W. (eds.) (1986) **Land Data Systems: Defining a Research and Dissemination Program**. Lincoln Institute of Land Policy.
- Bracken, I., and Webster, C. (1990) **Information Technology in Geography and Planning**. London:Routledge.

- Brail, R. (1990) **Integrating GIS into Urban and Regional Planning Alternate Approaches for Developing Countries.** *Regional Development Dialogue*, UNCRD, Vol.11 No.3 Autumn 1990:63-77.
- Brown, B. and Friedley, D. (1988) **Assessing Organizational Preparedness for a Comprehensive, Distributed LIS/GIS.** *URISA-'88 Mapping the Future*, The 26 Annual Conference of the Urban and Regional Information Systems Association, Los Angeles, California: Vol.III:22-36.
- Brown, C. (1986) **Implementing a Geographic Information System What Makes a New Site a Success?.** *Proceedings of Geographic Information Systems Workshop*, American Society for Photogrammetry and Remote Sensing, Atlanta, Georgia, April 1-4, 1986:12-19.
- Burrough, P. (1986) **Principles of Geographical Information Systems for Land Resources Assessment.** Oxford: Oxford University Press.
- Chambers, D. (1989) **Overview of GIS Database Design.** *ARC News*, Vol. 11, No. 2.
- Champhell, H. (1991) **Organisational Issues and the Utilisation of Geographic Information Systems** *Regional Research Laboratory Initiative*. Discussion Paper No. 9, March 1991.
- Clarke, A. (1991) **GIS Specification, Evaluation, and Implementation.** D. Maguire, M. Goodchild, and D. Rhind (eds.) *Geographical Information Systems Principles and Applications*, Longman Scientific Technical, Vol.1:477-88.
- Chris, C. (1989) **Parcel User Driven Approach to GIS Database Design.** *Symposium Proceedings Geomatics II A Future in the Making*, Montreal: CISM, November 9-10:43-52.
- Chrisman, N., Cowen, D., Fisher, P., Goodchild, M., and Mark, D. (1989) **Geographic Information Systems.** G. Gaile, and C. Willmott (eds.) *Geography in America*. Ohio:Merrill Publishing Company:776-96.
- Chunga, F. (1989) **National GIS Issues in Zimbabwe.** *Challenge for The 1990s GIS, Proceedings for National Conference*. Ottawa, CISM: 415-416.
- Coll, D. (1990) **Development of Equipment and Techniques: Microcomputer Graphics Environments.** D.R.F. Taylor (ed.) *Geographic Information Systems: The Microcomputer and Modern Cartography*, Pergamon Press:39-59.

- Congalton, R. (1986) **Geographic Information Systems Specialist: A New Breed.** *Proceedings of Geographic Information Systems Workshop*, American Society for Photogrammetry and Remote Sensing, Atlanta, Georgia, April 1-4, 1986:37-42.
- Crane, R.D. (1978) **Planning The Future of Saudi Arabia.** New York: Praeger Publishers.
- Dangermond, J., Derrenbacher, B. and Harnden, E. (1982) **Description of Techniques for Automation of Regional Natural Resources Inventories.** R. William (ed.) *Geographic Information Systems For Resource Management: A Compendium*, American Society for Photogrammetry and Remote Sensing and American Congress on Surveying and Mapping:9-33.
- Dangermond, J. (1990) **Geographic Information System Technology and Development Planning.** *Regional Development Dialogue*, UNCRD, Vol.11 No.3 Autumn 1990:1-16.
- Dangermond, J. (1991) **The Commercial Setting of GIS.** D. Maguire, M. Goodchild, and D. Rhind (eds.) *Geographical Information Systems Principles and Applications*, Longman Scientific Technical: 55-65.
- Dangermond, J. (1990) **The Organizational Impact of GIS Technology.** *Geographic Information Systems: An Assessment of Technology, Applications, and Products*, S.E.A.I Technical Publications, Vol.2:340-58.
- Date, C. (1990) **An Introduction to Database Systems.** Addison-Wesley Publishing Company, Inc. Vol.1, Fifth Edition.
- Davis, W. (1989) **The Impact of Computer Trends on Geoprocessing.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM :571-75.
- Edralin, J. (1991) **Conference Report: International Conference on Geographic Information Systems Applications for Urban and Regional Planning.** *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:147-54.
- Ezigbalike, I., Cleman, D., Cooper, R. and McLaughlin, J. (1988) **Managing a Multi-User Land Information System.** *URISA-'88 Mapping the Future*, The 26 Annual Conference of the Urban and Regional Information Systems Association, Los Angeles, California: Vol.III:55-64.

- Faig, W. and McLaughlin, J. (1989) **Spatial Analysis and Information Management: A Surveying Engineering Perspective. Challenge for The 1990s GIS, Proceedings for National Conference.** Ottawa, CISM :576-86.
- Feutchwanger, M., and Poiker, T. (1987) **Infological and Datalogical Spatial Models.** J. Blais (ed.) *Lecture Notes in Digital Mapping and Land Information.* CISM:146-67.
- Fox, J. (1991) **Spatial Information for Resource Management in Asia: A Review of Institutional and Organizational Issues.** *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:59-72.
- Frank, A. (1987) **Towards a Spatial Theory.** *Proceedings of International Geographic Information Systems (IGIS) Symposium: The Research Agenda*, November 15-18,1987 Vol.II:215-28.
- GIS World (1989) **The 1989 Software Survey.** *The GIS Sourcebook*, GIS World, Inc.:32-46.
- Goodchild, M. (1991) **The Technical Setting of GIS.** D. Maguire, M. Goodchild, and D. Rhind (eds.) *Geographical Information Systems Principles and Applications*, Longman Scientific Technical:45-54
- Goodchild, M. (1987) **Towards an Enumeration and Classification of GIS Functions.** *Proceedings of International Geographic Information Systems (IGIS) Symposium: The Research Agenda.* Technical Issues and the Research Agenda, November 15-18,1987 Vol.II:67-77.
- Hallen, S. (1991) **Finding, Evaluating and Using Existing Data Sources.** *GIS World*, November 1991, Vol.4:60-63.
- Harris, B. (1990) **Urban and Regional Planning in the Third World with Geographic Information System Support.** *Regional Development Dialogue*, UNCRD, Vol.11 No.3 Autumn 1990:17-62.
- Hopkins, S., and Jones, D. (1983) **Research Guide to the Arid Lands of the World.** Oryx Press.
- Joffe, B. (1987) **Evaluating and Selecting a GIS System.** *GIS '87 -San Francisco.* Second Annual International Conference, Exhibits and Workshops on Geographic Information Systems, October 26-30, 1987:138-47.

- Johnston, D. (1989) **GIS and Regional Government - From the Underground UP. Challenge for The 1990s GIS, Proceedings for National Conference.** Ottawa, CISM: 537-47.
- Kingdom of Saudi Arabia, Arriyadh Development Authority (1991) **Riyadh Transportation Study Phase 2, Final Technical Report.**
- Kingdom of Saudi Arabia, Ministry of Agriculture and Water (1984) **A Guide to Agricultural Investment in Saudi Arabia.** Riyadh:Dar Alhela!
- Kingdom of Saudi Arabia, Ministry of Planning (1990) **Fifth Development Plan 1990-95.** Riyadh:Ministry of Planning Press.
- Kingdom of Saudi Arabia, Ministry of Planning (1985) **Fourth Development Plan 1985-90.** Riyadh:Ministry of Planning Press.
- Kingdom of Saudi Arabia, Ministry of Planning (1980) **Third Five Year Development Plan 1975-1980.** Riyadh:Ministry of Planning Press.
- Kubo, S. (1986) **The Development of Geographic Information Systems in Japan. Proceedings of the URISA '86 Conference,** Urban and Regional Information Systems Association. Washington D.C. Vol.2:75-84.
- Lee, J. (1988) **Integrating Attribute Data and Graphic Data: A Case Study of a Successful GIS Project for Dover, NH. URISA-'88 Mapping the Future,** The 26 Annual Conference of the Urban and Regional Information Systems Association, Los Angeles, California: Vol.III:109-116.
- Lodwick, G. and Feuchtwanger, M. (1987) **Land-Related Information Systems.** UCSE Report No. 10010, Calgary: The University of Calgary.
- Maguire, D. (1991) **An Overview and Definition of GIS.** D. Maguire, M. Goodchild, and D. Rhind (eds.) *Geographical Information Systems Principles and Applications*, Longman Scientific Technical:9-20.
- Mark, D., Svorou, S. and Zubin, D. (1987) **Spatial Terms and Spatial Concepts: Geographic, Cognitive, and Linguistics perspectives. Proceedings of International Geographic Information Systems (IGIS) Symposium: The Research Agenda,** November 15-18,1987 Vol.II:101-12.
- McLaughlin, J. (1988) **Land Information Management, An Introduction with Special Reference to Cadastral Problems in Third World Countries.** Oxford, Calrendon Press.

- McLaughlin, J. and Coleman, D. (1989) **Land Information Management into the 1990s.** *Fourth United Nations Regional Cartographic Conference for the Americas.*
- Meyere, J. (1989) **Training of the GIS Professional.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM: 872-79.
- Molenaar, M. (1989) **Five Central Questions for A Geoinformation Theory.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM :578-600.
- Montgomery, G. (1990) **Funding and Financial Strategies for Multiparticipant GIS Projects.** *GIS World*, Vol.3 No.4 August 1990:79-81.
- Montgomery, G. (1990) **GIS Projects: Formulas for Success.** *GIS World*, Vol.3 No.6 December 1990:105-06.
- Montgomery, G. (1990) **Multiparticipant Project Management.** *GIS World*, Vol.3 No.5 October 1990:105-06.
- Montgomery, G. (1990) **Organizing a GIS Multiparticipant Project - Getting Started.** *GIS World*, Vol.3 No.3 June 1990:62-64.
- Morrison, J. (1989) **GIS: United State Government Agency Perspective.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM:410-14.
- Morse, B. (1991) **What to Consider in Land Information Sytem Data.** *1991-1992 International GIS Sourcebook*, GIS World, Inc.:401-04. _
- Openshaw, S. and Brunsdon, C. (1991) **An Introduction to Spatial Analysis in GIS.** *1991-1992 International GIS Sourcebook*, GIS World, Inc.:378-79.
- Oxborrow, E. (1986) **Database and Database Systems**, Chartwell-Bratt. Lund.
- Palmer, D., Petersohn, F., and Coleman, D. (1988) **Priorities in the Land Information Systems/Networks Development Process.** *URISA- '88 Mapping the Future*, The 26 Annual Conference of the Urban and Regional Information Systems Association, Los Angeles, California: Vol.III:108-15.
- Parker, H. (1989) **GIS Concepts.** *The GIS Sourcebook*, GIS World, Inc.:1-9
- Peuquet, D. (1990) **Method for Structuring Digital Cartographic Data in A Personal Computer Environment.** D.R.F. Taylor (ed.) *Geographic Information Systems: The Microcomputer and Modern Cartography*, Pergamon Press:68-95.

- Peters, G. (1984) **Construction Project Management Using Small Computers.** London: The Architectural Press.
- Plunkett, G. (1991) **Inter-Agency Committee on Geomatics Data Dissemination and Government Data Bases Sub-Committee Summary Report on Activities.** *Proceedings of the Canadian Conference on GIS-91*, Ottawa:CISM:216-238.
- PTI and ICMA (1991) **The Local Government Guide to Geographic Information Systems: Planning and Implementation.** PTI (Public Technology Inc.).
- Ralston, B. (1991) **GIS Key In Transportation Network Analysis.** *1991-1992 International GIS Sourcebook*, GIS World, Inc.:405-06.
- Reeve, C. and Smith, J. (1986) **The Varied Viewpoints of GIS Justification: A Survey of Vendors and Users.** *Proceedings of Geographic Information Systems Workshop*, American Society for Photogrammetry and Remote Sensing, Atlanta, Georgia, April 1-4, 1986:396-403.
- Rhind, D. (1991) **Breakthroughs in GIS? A British Perspective.** *Proceedings of the Canadian Conference on GIS-91*, Ottawa:CISM:284-99.
- Rix, D. (1989) **First footsteps in GIS.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM: 846-850.
- Robertson, W. (1989) **National GIS Issues in New Zealand.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM: 406-09.
- Sahab, A., and Abd-Elwahed, M. (no date) **The design of an Integrated Information System that Supports Different Management Levels.** A Report by MoMRA.
- Slocum, T., and Egbert, S. (1991) **Cartographic Data Display.** D.R.F. Taylor (ed.) *Geographic Information Systems: The Microcomputer and Modern Cartography*, Pergamon Press:168-99.
- Star, J. and Estes, J. (1990) **Geographic Information Systems: An Introduction.** Prentice-Hall, Inc.
- Seaborn, D. (1991) **Enterprise GIS: The Management Challenge.** *Proceedings of AM/FM/GIS Navigating the Future, Conference XIV.* San Diego, California: March 24-27, 1991:134-42.
- Smith, E. (1991) **Creating Digital Road Inventory Maps for the New Brunswick Department of Transportation.** *Proceedings of the Canadian Conference on*

GIS-91, Ottawa:CISM:473-80.

- Smith, G. and Honeycutt, D. (1987) **Geographic Data Uncertainty, Decision Making and the Value of Information.** *GIS '87 -San Francisco*. Second Annual International Conference, Exhibits and Workshops on Geographic Information Systems. October 26-30, 1987:300-12.
- Somers, R. (1990) **GIS in Local Government, Where Do You Place the GIS?.** In: *GIS World*, Vol.3 No. 2 April 1990:40-41.
- Taylor, D.R.F. (1989) **Cartography and the Developing Nations: Some New Challenges.** D. Rhind, and D.R.F. Taylor (eds.) *Cartography Past, Present and Future.* England: Elsevier Science Publishers Ltd.
- Taylor, D.R.F. (1990) **Geographic Information Systems: The Microcomputer and Modern Cartography.** D.R.F. Taylor (ed.) *Geographic Information Systems: The Microcomputer and Modern Cartography*, Pergamon Press:1-20.
- Taylor, D.R.F. (1991) **GIS and Developing Nations** D. Maguire, M. Goodchild, and D. Rhind (eds.) *Geographical Information Systems Principles and Applications*, Longman Scientific Technical, Vol.2:76-84.
- Taylor, D.R.F. (1980) **The Computer in Contemporary Cartography: Introduction.** D.R.F. Taylor (ed.) *The Computer in Contemporary Cartography*. John Wiley & Sons, Ltd:1-5.
- Taylor, D.R.F. (1991) **GIS in Developing Nations.** *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:1-2.
- Thomas, D. (1987) **Evaluation on Graphic Workstations and Their Relationship to Micro, Mini, and Mainframe Systems.** *Proceedings of International Geographic Information Systems (IGIS) Symposium: The Research Agenda*, November 15-18,1987 Vol.II:397-404.
- Thomas, E. (1988) **A Countrywide Land Use Data Base: Maintained and Mapped By Computer.** *URISA-'88 Mapping the Future*, The 26 Annual Conference of the Urban and Regional Information Systems Association, Los Angeles, California: Vol.III:117-124.
- Tihama (1976) **Summary of Saudi Arabia Five Year Development Plan 1975-80.** Jeddah, Tihama Publications.
- Tihama (1981) **Summary of Third Development Plan for Saudi Arabia 1980-85.** Jeddah, Tihama Publications.

- Unesco (1978) **Essential parts of a Geographic Information System. Computer Handling of Geographic Data.** The Unesco Press:15-19.
- UNDP (1990) **Human Development Report 1990.** Oxford University Press.
- Unesco (1984) **Conceptual Framework and Guidelines for Establishing Geographic Information Systems (Preliminary version),** Paris:Unesco, August 1984.
- Unwin,T. (1989) **The Urban-rural Context of Agrarian Change in the Arabian Peninsula.** R. Potter and T. Unwin (eds.) *The geography of Urban-rural Interaction in Developing Countries*, London: Routledge: 169-203.
- Vanstone, N. and Ogilvie, M. (1989) **The Interdepartmental Committee - an Efficient Means for Developing GIS policy.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa, CISM: 858-64.
- Walker, T. and Miller, R. (1990) **The Technology of GIS.** *Geographic Information Systems: An Assessment of Technology, Applications, and Products*, S.E.A.I Technical Publications, Vol.1:31-76.
- Walker, T. and Miller, R. (1990) **Implementing GIS.** *Geographic Information Systems: An Assessment of Technology, Applications, and Products*, S.E.A.I Technical Publications, Vol.2:359-78.
- Warnecke, L. (1987) **Institutional Research Needs to Maximize Geographic Information Development.** *Proceedings of International Geographic Information Systems (IGIS) Symposium: The Research Agenda.* Technical Issues and the Research Agenda, November 15-18,1987 Vol.1:165-176.
- Wellar, B. (1989) **Emerging Trends In Structuring and Directing GIS Research.** *Challenge for The 1990s GIS, Proceedings for National Conference.* Ottawa: CISM :601-08.
- Yapa, L. (1991) **Is GIS an Appropriate Technology?.** *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:41-58.
- Yeh, A. (1991) **The Development and Application of Geographic Information Systems for Urban and Regional Planning in the Developing Countries.** *International Journal of Geographical Information Systems*, Vol.5, No.1, 1991:5-27.
- Zillmer, G. (1991) **Implementing GIS Technology: A Management Perspective.** *Proceedings of the Canadian Conference on GIS-91*, Ottawa:CISM:271-83.

Appendices

Appendix A

Survey of Geographic Information Needs in Saudia Arabia

Survey of Geographic Information System Needs in Saudi Arabia

Prepared by:
Saleh Alsawydani

Ottawa
June 1991.

TABLE OF CONTENTS

PART ONE: GIS SURVEY

INTRODUCTION:	1
SECTION ONE: INSTITUTIONAL AND ORGANIZATIONAL ISSUES	1
1.1.0 IDENTIFICATION INFORMATION	2
1.2.0 MANAGEMENT SECTION	3
1.3.0 TRAINING ISSUES	8
SECTION TWO: TECHNICAL ISSUES	10
2.1.0 IDENTIFICATION INFORMATION SECTION	11
2.2.0 PRESENT GIS INSTALLATION	12
2.3.0 HARDWARE REQUIREMENTS	13
2.4.0 SOFTWARE	15
SECTION THREE: GEOREFERENCED DATA	17
3.1.0 IDENTIFICATION INFORMATION SECTION	19
3.2.0 DATA SET DESCRIPTION SECTION	20
3.3.0 DATA AVAILABILITY	24
3.4.0 DATABASE STRUCTURE SECTION	25
3.5.0 DATA SET APPLICATION SECTION	26
3.6.0 FUTURE PLANS	27
7.0 THE FORMAT DESCRIPTION SECTION	28

PART TWO: EXPLANATION OF QUESTIONS AND TERMS

SECTION ONE: INSTITUTIONAL AND ORGANIZATIONAL ISSUES	1
SECTION TWO: TECHNICAL ISSUES	5
SECTION THREE: GEOREFERENCED DATA	8

PART ONE

GIS SURVEY

Introduction

SECTION ONE: Institutional and Organizational Issues

SECTION TWO: Technical Issues

SECTION THREE: Georeferenced Data

THIS IS A SURVEY TO IDENTIFY SOME ISSUES CONCERNING GIS IMPLEMENTATION IN SAUDI ARABIA

Introduction:

The **objective** of this survey is to identify the major issues that influence GIS implementation and utilization in Saudi Arabia. Among those issues are: institutional and organizational considerations, technical support, training, and georeferenced data. The questions in this survey should be answered by any government agency or department who has GIS in operation or planning to implement it in the future.

To avoid misunderstanding or confusion of the survey contents, it has been divided into three major sections as follow:

First: Institutional and organizational issues.

Second: Technical issues.

Third: Georeferenced data.

Each section contains, in addition to the questions, some instructions at the beginning. **Explanation of questions and terms** used in this survey is included in the second part. Please refer to this part whenever you need an explanation of question or term.

Although this survey may appear to be lengthy; 28 pages, it has been designed in **answered question format**. In other words, beneath most of the questions is a list of items or codes. Your task is to pick the code(s) that correspond to your situation. However, some of the questions need to be answered in written format. If you refer to the second part of this survey (**Explanation of Questions and Terms**), you would find some information that might help you to answer such questions. Since there were no alternatives to avoid such questions, you are required only, to answer in 100 words or less.

Your **completion** of this survey will be of great help to finish my study. In addition to this, **your organization might benefit** as well. The final results of this study will define and identify the common issues concerning GIS implementation in Saudi Arabia. Possible results may include:

- Introduction to GIS technology and its benefits.
- It will yield suggested solutions to overcome some of the organizational and institutional barriers.
- It will provide a fair and reasonable evaluation of GIS technology (hardware and software), which might assist in developing this technology.
- Most importantly, it has unlimited benefits in the area of georeferenced data i.e. data availability, sharing, exchange, format and so forth.

NOTE: If you require a copy of the final results of this study, please check here _____

NOTE: Institutional and organizational issues, technical issues, and georeferenced data are different areas of interest to GIS. Therefore, this survey could be filled out by many persons and or different departments.

THANK YOU VERY MUCH

SECTION ONE: INSTITUTIONAL AND ORGANIZATIONAL ISSUES: AN IDENTIFICATION OF GIS WORKING ENVIRONMENT

The **objective** of this section is to identify GIS working environment. It is designed to examine the institutional and organizational issues such as system management, training and financial related matters.

This section may be filled out by a person who is directly involved with GIS planning and implementation, since most of the questions are related to management aspects of GIS.

NOTE: Please refer to the second part (**Explanation of Questions and Terms**) whenever you need an explanation of a question or term.

1.1.0 IDENTIFICATION INFORMATION

1.1.1 PERSONAL INFORMATION (it may be completed by a GIS manager or by a person with similar position)

Name _____
Title _____
Department _____
Organization _____
Address _____

Phone #: _____
FAX #: _____
Other #: (TELEX, etc.): _____

1.2.0 MANAGEMENT SECTION

1.2.1 IMMEDIATE REASONS FOR UTILIZING GIS TECHNOLOGY (Describe briefly-100 words max.)

1.2.2 LONG TERM OBJECTIVES OF GIS IMPLEMENTATION (Describe briefly-100 words max.)

3000 COUNTY ROAD 3, ELIZABETH, NJ 07208
TEL 912 436 2002 FAX 912 436 2007 TLE 912 436 2008

1.2.3 FEASIBILITY STUDIES PRECEDED GIS IMPLEMENTATION (Describe briefly-
100 words max.)

1.2.4 DECISION MAKING STYLE

- Enter all code(s) that apply: _____

- A. Delegation style
- B. Consultative Style
- C. Centralized Style
- D. Other (specify): _____

1.2.5 MAJOR PROBLEMS WITH GIS PROJECT

- Enter all code(s) that apply: _____

- A. Financial
- B. Technical
- C. Organizational
- D. Managerial
- E. Insufficient staff
- F. Training
- G. Other (specify): _____

1.2.6 MAJOR FUNCTIONS PERFORMED OR WILL BE BY GIS (Describe briefly-100 words max.)

1.2.7 AREAS WHERE AUTOMATION HAS OR WILL BE MOST BENEFICIAL (Describe briefly-100 words max.)

1.2.8 AREAS WHERE AUTOMATION HAS OR WILL BE LEAST BENEFICIAL (Describe briefly-100 word max.)

1.2.9 GIS RESEARCH AND DEVELOPMENT ACTIVITIES (Describe briefly-100 words max.)

1.2.10 COORDINATION AND COLLABORATION WITH OTHER AGENCIES (or departments) (describe briefly-100 words max.)

1.2.11 TECHNOLOGY TRANSFER (including challenges and opportunities) (describe briefly-100 max.)

1.3.0 TRAINING ISSUES

1.3.1 NUMBER OF STAFF INVOLVED WITH GIS (including managers, supervisors, DBA, operators, engineers, technicians, etc.)

- Enter the corresponding code:_____

- A. 5
- B. 10
- C. 15
- D. Other (specify):_____

1.3.2 TRAINING POLICY

- Enter all code(s) that apply:_____

- A. Retraining existing staff
- B. Hiring GIS specialists/engineers
- C. Other (specify):_____

1.3.3 MAJOR AREAS OF TRAINING PROGRAMS

- Enter all code(s) that apply:_____

- A. DB managers/administrators
- B. Data entry
- C. Data analyst
- D. System interaction
- E. Computer science
- F. System administration (GIS management)
- G. GIS application development and design
- H. Other (specify):_____

1.3.4 TRAINING PROGRAM DURATION

- Enter all code(s) that apply:_____

- A. Long term
- B. Short term
- C. Other (specify):_____

1.3.5 TRAINING PROGRAM TYPES

- Enter all code(s) that apply:_____

- A. Vendor training
- B. Customized courses
- C. In-house training
- E. Workshops and seminars
- F. Short courses offered by universities and colleges
- G. Abroad training programs
- H. Other (specify):_____

1.3.6 SKILLS, KNOWLEDGE, ABILITIES AND QUALIFICATIONS IN HIRING NEW STAFF (Describe briefly-100 words max.)

1.3.7 AREAS WHERE STUDENTS MIGHT HELP (including thesis study, joint research projects, etc.)

**SECTION TWO: TECHNICAL ISSUES:
AN IDENTIFICATION OF THE AVAILABILITY OR POTENTIAL
AVAILABILITY OF TECHNICAL SUPPORT FOR GIS**

The **objective** of this section is to identify GIS technology that is already installed or to be installed in the future.

GIS technology includes computer hardware and software used in the retrieval, storage, conversion, analysis, display, output and distribution of geographic information.

This part is to be completed by any agency that has GIS technology now or is **planning** to install in the future.

NOTE: please refer to the second part (**Explanation of Questions and Terms**) whenever you need an explanation of question or term.

2.1.0 IDENTIFICATION INFORMATION SECTION

2.1.1 DEPARTMENT/AGENCY NAME (where the technology currently resides e.g. division)

2.1.2 TECHNOLOGICAL SUPPORT CONTACT (for further information regarding technological support)

Name _____
Title _____
Department _____
Organization _____
Address _____

Phone #: _____
FAX #: _____
Other #: (TELEX, etc.): _____

2.1.3 TECHNOLOGICAL SUPPORT DETAILS CONTACT (If the person completing this form is other than the person identified in 2.1.2 above, please enter information in this section. Otherwise, skip to section 2.2.0)

Name _____
Title _____
Department _____
Organization _____
Address _____

Phone #: _____
FAX #: _____
Other #: (TELEX, etc.): _____

2.2.0 PRESENT GIS INSTALLATION

2.2.1 FAMILIARITY WITH GIS TECHNOLOGY (at the agency or department)

Enter A, B, or C: _____

- A. Good
- B. Fair
- C. Inadequate

2.2.2 GIS STATUS

- Enter A, B, C, or D: _____

- A. In-house (operational)
- B. Installed but not operational (testing stage)
- C. To be installed in the future (feasibility study completed, implementation next stage)
- D. To be determined (i.e. feasibility study)
- E. No plan

If C, specify: _____ Year

NOTE IF A,B, OR C HAS BEEN ENTERED THE FOLLOWING SECTIONS ARE TO BE COMPLETED. HOWEVER, IF D OR E YOU MAY SKIP THE FOLLOWING SECTIONS.

2.2.3 SOURCE OF GIS TECHNICAL INFORMATION

- Enter all code(s) that apply: _____

- A. GIS journals
- B. Workshops
- C. Conferences
- D. Vendors
- E. Other (specify): _____

2.3.0 HARDWARE REQUIREMENTS (including all hardware equipment)

2.3.1 HOST COMPUTER(S) - Enter all code(s) that apply: _____

- A. Supercomputer
- B. Mainframe
- C. Minicomputer
- D. Microcomputer
- E. Workstation
- F. Other (specify): _____

2.3.2 HARDWARE SUPPORTED - Enter all code(s) that apply: _____

- A. Workstations (e.g. SUN, VAX, PC stations)
- B. Digitizing tables
- C. Scanners
- D. Video Cameras
- E. Printers and or Plotters
- F. Tape drives
- G. Other (specify): _____

2.3.3 NUMBER OF STATIONS - Enter all code(s) that apply: _____

- A. One
- B. Two
- C. Three
- D. Four
- E. Other (specify): _____

2.3.4 OPERATING SYSTEM(S) - Enter all code(s) that apply: _____

- A. VMS
- B. UNIX
- C. DOS
- D. OS/2
- E. Other (specify): _____

2.3.5 NETWORK CONFIGURATION

Is local area network in place?

- Enter corresponding code: _____

A. Yes

B. No

C. If A (Yes) (specify): _____

2.3.6 EXTERNAL COMMUNICATIONS (for external access to on-line data only)

Physical

- Enter all code(s) that apply: _____

A. Direct Connection (e.g. LAN, ETHERNET)

B. DataPac

C. Phone Link (Commercial carrier with modem)

D. Other (specify): _____

Network configuration Protocols:

- Enter all code(s) that apply: _____

A. DEC-DAN

B. DECNET

C. HDLC (IBM)

D. KERMIT

E. MAP (General Motors-Industry Standard)

F. SNA (IBM)

G. TOP (MacIntosh)

H. TCP/IP (Sun)

I. XMODEM

J. Other (specify): _____

2.4.0 SOFTWARE (developed, purchased or to be purchased)

2.4.1 SOFTWARE NAME

-Enter all code(s) apply: _____

- A1. AGIS
- A2. ARC/INFO
- A3. ARIES
- A4. ATLAS GRAPHICS
- A5. AXIS MAPPING INFO.
- C1. CARIS-GIS
- D1. DELTAMAP
- E1. EARTH ONE
- E2. EPPL7
- E3. ERDAS
- G1. GEOVISION "GeoPro"
- G2. GIMMS
- G3. GOS-GDS
- G4. GRASS
- I1. IDRISI
- I2. IGDS/DMRS
- M1. MacGIS (Oregon)
- M2. MAPII
- M3. MicorStation GIS
- M4. MIPS
- M5. MOSS
- N1. Nucor GIS
- P1. PAMAP GIS
- P2. PC ARC/INFO
- S1. SICAD
- S2. SPANS

Z. Other (specify): _____

2.4.2 SOFTWARE EVALUATION

Software Name: _____

Strengths

- Enter all code(s) that apply: _____

- A. Support various applications
- B. Full topology
- C. Spatial analytical capabilities
- D. User friendly
- E. Complete product
- F. Supports opens systems configuration
- G. Multi-relational DBMS
- H. Low cost
- I. Compatibility with other systems
- J. Other (specify): _____

Weaknesses

- Enter all code(s) that apply: _____

- A. Not user-friendly
- B. Lack of analytical capabilities
- C. Slow database access
- D. Single platform
- E. Expensive
- F. Not complete documentations
- G. Lacks customers supports and services
- H. Not available on PC
- I. Not a full GIS
- J. Limited display capability
- K. Needs two monitors
- L. Other (specify): _____

SECTION THREE: GEOREFERENCED DATA
IDENTIFICATION FOR GOVERNMENT DATA HOLDINGS FOR DATA
WHICH CONFORM TO ALL OF THE FOLLOWING CRITERIA:

- * **HELD BY THE GOVERNMENT OF SAUDI ARABIA**
- * **DESCRIPTIVE OF SOME PART OF SAUDI ARABIA**
- * **DIRECTLY GEOREFERENCED TO COORDINATES**
- * **MAP SCALES SMALLER THAN 1:500**
- * **PRESENTLY IN DIGITAL FORM OR WILL BE IN DIGITAL FORM WITH IN THIS DECADE**

This section **aims** to identify data sets that can be used in Geographic Information Systems. To limit the scope of the study, the data sets included must meet the following **criteria**:

The data set must be **held by** (in the possession of) a government department or agency in Saudi Arabia.

The data sets must be **descriptive of some part** of Saudi Arabia. For this survey, Saudi Arabia is defined as that area of space over which Saudi Arabia asserts its sovereign rights, including the 200 nautical-mile offshore economic zone. In vertical extent, this includes the area bounded by the top of the atmosphere to a distance 10 miles beneath the surface of the solid planet. Data sets of international scope are to be included in the survey if they include some part of Saudi Arabia as defined.

The data sets must be **directly georeferenced**. That is, they must be able to be related directly to a coordinate framework, references to which are part of the data set. Examples of such data sets may include: maps, charts, atlas sheets, remote-sensing imagery, statistical data related to coordinate points but not data related only to street addresses, postal codes, or other nominal codes.

Map data must be at a **scale smaller than 1:500**. Large-scale plans such as engineering drawings and other detailed maps which are at or larger than 1:500 are not to be included.

The data sets must be in **digital** form now **OR** the data sets must be those which the agency holds in **hardcopy** form now but plans to convert to **digital** form in the future.

Data sets that **do not meet the above criteria** of *being government holdings, descriptive of Saudi Arabia, georeferenced, smaller than 1:500 map scales and digital or planned digital data*, should be **excluded**.

3.1.0 IDENTIFICATION INFORMATION SECTION

3.1.1 DATA SET NAME (a unique name for the data set)

3.1.2 DATA SET ACRONYM (a unique acronym for the data set)

3.1.3 DEPARTMENT/AGENCY NAME (where the data currently resides)

3.1.4 DATA ACCESS CONTACT (for further information regarding access to the data set)

Name _____
Title _____
Department _____
Organization _____
Address _____

Phone #: _____
FAX #: _____
Other #: (TELEX, etc.): _____

3.1.5 DATA SET DETAILS CONTACT (If the person completing this form is other than the person identified in 3.1.4 above, please enter information in this section. Otherwise, skip to section 3.2.0)

Name _____
Title _____
Department _____
Organization _____
Address _____

3.2.0 DATA SET DESCRIPTION SECTION

3.2.1 DATA SET CATEGORY OR THEME (chose principal theme applicable)

* Enter the corresponding code: _____

A1- Agricultural	L1- Land Use
A2- Archaeology/Heritage	N1- Natural Resources
Boundaries:	Oceanography:
B1- Political	O1- Physical and Chemical
B2- Regulatory	O2- Biological
B3- Statistical	
B4- Cadastral	Planning:
	P1- Urban
C1- Climate/Meteorological	P2- Regional
C2- Costal Zone	
C3- Communications	R1- Recreation
E1- Engineering	Remote Sensing:
	R2- Spaceborne
Fisheries:	R3- Airborne
F1- Fish Management	R4- Ground Based
F2- Habitat	
	Socio-Economic:
Forestry:	S1- Census
F3- Inventory	S2- Demography
F4- Site Classification	
F5- Historical Activity	S3- Soils
F6- Infrastructure	
	Topography:
Geodesy:	T1- Planimetry
G1- Geodetic Survey	T2- Hypsography
G2- Nautical Geodesy	
G3- Geology	
G4- Geomorphology	Toponymy:
G5- Geophysics	T3- Surface
	T4- Undersea
Hydrography:	
H1- Bathymetry	Transportation:
H2- Tides and Currents	T5- Marine
H3- Nautical Charts	T6- Air
H4- Bathymetric Maps	T7- Land
Hydrology:	
H5- Surface Water	U1- Utilities
H6- Ground Water	
H7- Flood Hazard	W1- Wildlife/Wildfowl X1- Other (specify) _____

3.2.2 DATA CONTENTS (Variables contained in data set-key words to describe the principal elements of the thematic classification used within data set: 100 words maximum)

3.2.3 DATA TYPE

- Enter A, B, or C: _____

- A. 100% Digital
- B. 100% Conventional Hardcopy
- C. Partly Digital and Partly Hardcopy

Percent Digital in 1991: _____%

Percent Hardcopy in 1991: _____%

Estimate of year when data set will be 100% Digital (Year): _____

3.2.4 SOURCE OF BASE MAP DATA (Department or agency where planimetric/orthophoto base data originated, if applicable)

If Unknown, enter X _____

Scale of original base map or orthophoto if different from data set scale 1: _____

3.2.5 SOURCE OF VALUE ADDED THEMATIC DATA

-Enter all codes(s) that apply: _____

- A. Remote Sensing
- B. Conventional Air Photography
- C. Field Measurements
- D. Questionnaire
- E. Existing Statistical Compilations
- F. Other (specify below)

If "Other" Specify: _____

3.2.6 SOURCE OF DATA SET (Name of Department/Agency that generated/complied the data set if different from the Department or Agency where the data set currently resides.)

If Unknown, enter X _____

3.2.7 COVERAGE

Potential Coverage - Enter A, B, C, or D: _____

- A. International (must include some part of Saudi Arabia - specify part below)
- B. National (Saudi Arabia)
- C. Provincial or Local (specify below)
- D. Regional or Local (specify below)

If A or C, specify code(s) for Saudi Arabia Area Covered: _____
Select from:

E. Riyadh	N. Assir
F. Eastern Province	O. Jizan
G. Northern Territory	P. Najran
H. Hail	Q. Qurayyat
I. Qassim	R. Tabuk
J. Jouf	
K. Baha	
L. Makkah	
M. Medinah	

If D, specify: _____

Percent of potential coverage complete in 1991 _____ %

3.2.8 GEOGRAPHIC REFERENCING OF DATA CONTENTS

Map Projection(s) - Enter all code(s) that apply: _____

- A. Lambert Conformal
- B. Stereographic (including N.B. and P.E.I. double stereographic)
- C. Mercator
- D. Universal Transverse Mercator
- E. Other Mercator (including M.T.M.)
- F. Polyconic
- G. Other (specify below)

If G "Other", specify: _____

Coordinate System(s) - Enter all code(s) that apply: _____

- A. Latitude/Longitude
- B. Rectangular Grid (metres or feet)
- C. Azimuths of Bearings and Distances
- D. Other (specify below)

If D "Other", specify: _____

Graphical Attributes: Scale 1: _____

OR Range Scales 1: _____ To 1: _____

Date of Data Acquisition: Year: _____

OR Range of Dates of Data Acquisition:

From: _____(Year) To: _____(Year)

Absolute Positional Accuracy (range)

Horizontal _____metres to _____metres
Vertical _____metres to _____metres
Other (specify): _____

Resolution of Pixel/Grid Data: _____metres

OR Range of Resolution of Pixel/Grid Data:

from _____metres to _____metres

3.3.0 DATA AVAILABILITY

3.3.1 ACCESS POLICY

Access Conditions - Enter A, B, or C: _____

- A. Access on Request
- B. Limited Access (describe limits) _____
- C. No access

3.3.2 COST OF DATA OR ACCESS TO DATA

-Enter A, B, or C: _____

- A. Charge for Data
- B. Available at Cost of Reproduction
- C. No Charge

3.3.3 DATA PROCUREMENT SELECTION CRITERIA

Spatial Data - Enter A, B, C or D: _____

- A. Map sheet
- B. Lat/Long Coordinates
- C. Administrative Units
- D. Other (specify below)

If D "Other", specify: _____

Attribute Data (specify if different than spatial data)

3.3.4 DATA SUPPLY MEDIA - Enter all code(s) that apply: _____

Conventional: _____ Digital: _____

A. Paper	H. Magnetic Tape/Disk
B. Stable base material (e.g. Mylar)	I. Optical Tape/Disk
C. Photographs	J. Electronic Communication
D. Photo-Mosaic	K. Floppy diskette
E. Orthophotograph	L. Other digital (specify): _____
F. Microfiche	
G. Other conventional (specify) _____	

3.4.0 DATABASE STRUCTURE SECTION (For data that exist wholly or partly in digital form in 1991)

3.4.1 SPATIAL (Graphics) DATA FILE STRUCTURE(S)

- Enter all code(s) that apply: _____

A. Graphic (Vector)

B. Topological

C. Raster

D. Quadtree

E. Other (specify) _____

3.4.2 ATTRIBUTES DATA FILE STRUCTURE(S) (Logical Schema)

- Enter all code(s) that apply: _____

A. Lists (simple, multiple)

B. Array (tables)

C. Relational

D. Hierarchical

E. Other (specify): _____

3.4.3 FEATURE CODING STANDARD(S)

- Specify: _____

3.4.4 DIGITAL DATA INTERCHANGE FORMAT (supplier can make data available in the following format(s))

- Enter all code(s) that apply: _____

A. ARC/INFO

B. ATLAS GRAPHIC

C. DLG 2

D. DLG 3

E. DXF

F. FGEF

G. GDIL

H. GIMMS

I. GINA

G. ISIF

K. ISO-8211

L. LGSOWG (Standard)

M. MACDIF

N. MAPINFO

O. MDIF

P. NTX (CARIS)

Q. PCDATA

R. SASGRAF

S. SIF

T. STRINGS

W. TIFF

X. Other (specify): _____

3.5.0 DATA SET APPLICATION SECTION

3.5.1 EXISTING APPLICATIONS (Describe briefly-100 words max.)

3.5.2 POTENTIAL APPLICATIONS (Describe briefly-100 words max.)

3.6.0 FUTURE PLANS

3.6.1 NOTE ANY FURTHER PLANS FOR THE DATA (including: increasing accuracy, increasing precision, adding coverage, including additional thematic levels, test projects, etc.) (100 words max.)

3.6.2 NOTE ANY FURTHER UPDATES PLANS (or indicate the update cycle for the data set) (100 words max.)

3.7.0 THE FORMAT DESCRIPTION SECTION

3.7.1 REFERENCES (100 word max.)

- Published description of the data
- Memoranda describing the data structure
- Other applications references

PART TWO
EXPLANATION OF QUESTIONS AND TERMS

EXPLANATION OF QUESTIONS AND TERMS USED IN THE SURVEY

SECTION ONE: INSTITUTIONAL AND ORGANIZATIONAL ISSUES

The questions contained in SECTION 1.1.0 through SECTION 1.2.3 are self-explanatory.

1.2.3 FEASIBILITY STUDIES PRECEDED GIS IMPLEMENTATION

This question refers to preliminary planning or functional requirements. It is common, in this stage, that the users are identified, planning studies are designed, potential applications are visualized, responsibilities are assigned, and technical issues are assisted. In general, this refers the type of studies that usually preceded GIS procurement and implementation.

1.2.4 DECISION MAKING STYLE

This question refers to managerial practice at the organization or department. Note, all three options: delegation, consultative and centralized styles have advantages and disadvantages. If these styles are being used together, choose the most common one.

1.2.5 MAJOR PROBLEMS WITH GIS PROJECT

The purpose of this question is to identify the major problems with GIS project. These problems could either be faced before or after project implementation. One of the major problems with GIS technology in Third World countries is system maintenance and upgrading due to a fixed cost for GIS procurement and implementation.

1.2.6 MAJOR FUNCTIONS PERFORMED OR WILL BE BY GIS

What it meant by functions here is the tasks that automation will dramatize. Examples of these functions may include:

- replace manual cartographic methods (mapping systems not GIS).
- perform more sophisticated tasks i.e. overlays and other analytical functions.
- produce geographic information for other agencies.
- produce national or regional database i.e. master file.

1.2.7 AREAS WHERE AUTOMATION HAS OR WILL BE MOST BENEFICIAL

Use a key words to describe the type of applications where automation has proved or will be useful to your organization.

1.2.8 AREAS WHERE AUTOMATION HAS OR WILL BE LEAST BENEFICIAL

Use a key words to describe the type of applications where automation has proved or will be less beneficial to your organization. In other words, if your system is operational, indicate areas where technology did not meet your expectations. For example, if your organization is using manual digitizing technique and do not have access to scanners, digitizing could be a tedious and time consuming task. Another example is data conversion from one format to another i.e. Vector to Raster or v.s.

1.2.9 GIS RESEARCH AND DEVELOPMENT ACTIVITIES

Set a key words to describe research and development activities. Any type of activities related to GIS counts here. For instance, data structure and organization is a major area for research and development. User's needs is a leading concern to determine the type of activities that should take place.

1.2.10 COORDINATION AND COLLABORATION WITH OTHER AGENCIES

Use a key words to describe the degree of coordination with other domestic government, private or foreign agencies. Give details of the type of coordination. Data exchange, consultation, system design and development are few examples of joint venture with other agencies.

1.2.11 TECHNOLOGY TRANSFER

This question signifies the difficulties and advantages of technology transfer from The Developed World (US, UK Canada...etc.). Indicate briefly the type of restrictions i.e. political, administrative, financial, lack of communication, monopoly, and so forth that limit technology transfer from those countries. On the other hand, you may mention some of the advantages of importing this technology rather than developing it domestically. Importing experience rather than equipments could be one of the advantages.

1.3.0 TRAINING ISSUES

1.3.1 NUMBER OF STAFF INVOLVED WITH GIS

Indicate the number of people who are directly working with GIS at your organization or department. This may include managers, supervisors, DBA (Database Administrator), operators, engineers, technicians, researchers...etc.

1.3.2 TRAINING POLICY

Retraining existing staff, or hiring GIS specialists, should be included only if there is or will be a firm training program. Make this decision only if:

The responsible organization has a planned, approved budgeted program for training.

If there is no firm program or no clear intent to adopt training policy, this question may not be answered.

1.3.3 MAJOR AREAS OF TRAINING PROGRAMS

This question reflects the evident focus of the organization's training programs. To answer this question, there should be a determined training policy. Otherwise, you may skip this question.

1.3.4 TRAINING PROGRAM DURATION

Long or short term programs duration refers to the initial training policy. Long term training policy is a consecutive training policy for no less than 5 years. Short term training policy means adopting a training policy for a short period of time after system implementation. It may run for hours to months.

1.3.5 TRAINING PROGRAM TYPES

The type of training program refers to the derivation of training programs. It differs from question 1.3.3 which focuses on major areas of training programs. Whereas training program types focus on the source of these programs.

1.3.6 SKILLS, KNOWLEDGE, ABILITIES AND QUALIFICATIONS IN HIRING NEW STAFF

This question refers to the skills and knowledge your organization look for in hiring new staff. Examples of skills and qualifications may include database development, data modelling, data maintenance and management, and so forth.

1.3.7 AREAS WHERE STUDENTS MIGHT HELP

Areas where students might help through thesis studies, joint research projects...etc. refer to long term planning. Usually these types of studies take long time to be completed. The most likely areas in this regard may include methodologies of handling the data, system design and data management...etc.

SECTION TWO: TECHNICAL ISSUES

The questions contained in SECTION 2.1.0 through SECTION 2.2.1 are self-explanatory.

2.2.1 FAMILIARITY WITH GIS TECHNOLOGY

This question refers to GIS experience. Data entry, storage, manipulation, display and output in addition to system maintenance may be considered in evaluating staff experience with this technology.

2.2.2 GIS STATUS

This indicates the status of GIS. There are five items you may consider in deliberating the status of GIS. These are

- a) *In-house (operational)*: means products have been and will continue to be generated from the system.
- b) *Installed but not operational (testing stage)*: system(s) already installed, yet no products have been generated.
- c) *To be installed in the future*: feasibility study completed, implementation next stage.
- d) *To be determined (feasibility study)*: feasibility study in progress, yet system installation to be determined.
- e) *No plan*: no consideration of GIS implementation in the foreseeable future

NOTE: IF A,B, OR C HAS BEEN CHOSEN THE FOLLOWING SECTIONS ARE TO BE COMPLETED. HOWEVER, IF D OR E YOU MAY SKIP THE FOLLOWING QUESTIONS IN TECHNOLOGICAL ISSUES SECTION TWO AND CONTINUE WITH SECTION THREE GEOREFERENCED DATA.

2.2.3 SOURCE OF GIS TECHNICAL INFORMATION

This exposes the main sources of GIS information.

2.3.0 HARDWARE REQUIREMENTS

2.3.1 HOST COMPUTER(S)

This refers to the type(s) of primary computer used to process and store the data in the department or agency.

2.3.2 HARDWARE SUPPORTED

This refers to hardware equipments available to support GIS applications.

2.3.3 NUMBER OF STATIONS

This indicates the number of GIS workstations in the agency or department.

2.3.4 OPERATING SYSTEM(S)

The operating system(s) of the above-mentioned host computer (section 2.3.1)

2.3.5 NETWORK CONFIGURATION

This indicates internal linkage between systems in which the data is transferred to another system within the agency. LAN (Local Area Network) might be a good example of this type.

2.3.6 EXTERNAL COMMUNICATIONS

This question enquires about the ways in which the data is transferred to an outside agency and the physical communication links which the host organization can access. The convention or protocol used to establish the communication is also of concern here.

2.4.0 SOFTWARE

2.4.1 SOFTWARE NAME

Software refers to the type of GIS program that the operating system can execute. A list of software names is provided. If your software is not included, please indicate its name in the space marked Z (Other).

2.4.2 SOFTWARE EVALUATION

This question evaluates the software in terms of strength and weaknesses. Two lists are provided for evaluation purposes. You may enter all code(s) that apply or you may add in the space provided. However, do not forget to indicate software's name that will be evaluated.

SECTION THREE: GEOREFERENCED DATA

The questions contained in SECTION 3.1.0 through SECTION 3.2.2 are self-explanatory.

3.2.2 DATA CONTENTS

Use key words to describe the data elements contained in the data set or describe the principal groups of elements in a classification scheme. Data elements are the types of individual observations which the data set contains. A description of the various elements in the data set is required to assist potential users to determine whether the data set is appropriate for their needs. For example, a topographic map data set would contain roads, streams, contours of height, and so forth. A database of water quality statistics may contain chemical and biological analyses, observation dates, and the location of water samples. Nautical charts would show soundings, hazards to navigators, beacons, anchorages, wharves and so on.

3.2.3 TYPE OF DATA SET

Hardcopy data, or partly hardcopy data, should be included only if they will be in digital form before the year 2000. Make this decision only if:

- a) the responsible organization has a planned, approved budgeted program to convert the hardcopy data into digital form.
- b) the responsible organization wishes to state on this survey that certain data sets will be converted to digital form during the time period.

If there is no firm program or no clear intent to convert the data to digital form, the data set may be excluded from the survey.

3.2.4 SOURCE OF BASE MAP DATA

This is the name of the department or agency that produced the "base map" used in the data set.

The simplistic concept of a "base map" for the purposes of this questionnaire is that any map that is used as a base on which to plot other thematic data is regarded as a "base map", and that the agency that produced that base should be identified here.

NOTE, however:

"Base maps" may be any surface representation used as a foundation for thematic data. All types of "base map" count:

e.g. Topographic Maps
Planimetric Maps
Orthophoto Maps
Orthophotos
Rectified Photo-Mosaics

A "base map" may have been produced by any government agency, commercial or foreign agency. Give the appropriate name. Give the location (address) of agency if known.

Some data sets have no base maps,

e.g., Statistics related directly to coordinate points (such as a list of vegetation type locations) that are not plotted on a map - Not applicable

Some data sets are simply base maps, which carry no additional thematic data; hence they are not functioning as a "base map" for thematic data and their source does not need to be restated here - Not applicable

A "base map" may be used but its source may be unknown and can be so indicated.

If the original of the base map was at a different map scale than that utilized for the data set, particularly if the original has been enlarged and has thus been made potentially more unreliable, then give the scale of the original.

3.2.5 SOURCE OF VALUE ADDED DATA

Refers to the method of acquiring the data that comprise the principal theme of the data set. The six choices are remote sensing, conventional air photography, field measurement, questionnaires, existing statistical compilations and others. Check all that apply.

Remote Sensing data are typically obtained from satellite based observations. This source is identified if the data are:

- a) raw sensor data in digital form
- b) enhanced (e.g., geometrically rectified or false colour) sensor data in digital form
- c) enhanced sensor data in combination with map data in digital form
- d) interpretations of digital or hardcopy images by either image analysis or human inspection or both to yield thematic data. The thematic data from a new data set which is or will be in digital form.

Conventional Photography may be in black and white, colour, infrared (IR) or other categories. This source is identified if:

- a) the data are original air photographs scanned or planned to be scanned into digital form
- b) the data result from the human interpretation of conventional air photographs.

These data may have subsequently been transferred to base maps as an interim step to being digitized, but the air photograph is regarded as the source.

Field Measurements: This refers to data resulting from measurements of phenomena made by any various types of field survey, such as:

- survey measurements,
- gravity observations,
- weather station observations,
- topographic surveying,
- hydrographic measurements.

Questionnaire: Value-added thematic data derived from responses to door-to-door census, mailing questionnaires, telephone surveys, etc.

Existing Statistical Compilations applies to cases where the data set has been compiled from historical records of existing data. The records were not specifically gathered to create the data set as in the case of field measurement; the records already would have been gathered at some time in the past or by some other agency. Additional research and interpretation would have been performed to create the data set. An example of thematic data derived from statistical compilations is a map of demographic trends created by compiling historical and census data.

Other: Please specify any other sources of value added thematic data which do not fit the above categories.

3.2.6 SOURCE OF DATA SET

The name of the department or agency of any domestic or foreign provincial, territorial, or municipal government or any commercial agency that generate or compiled the final data set if different from the Saudi Department or Agency where the data set currently resides. Give the location (country, city) of source agency if known.

3.2.7 COVERAGE

Coverage is the horizontal area which the data for the set were gathered or are intended to be gathered.

The extent of the data contained in the data set does not have to be, and is frequently not, 100% of the potential coverage. For example, a road system data set for the Province of Riyadh has a potential extent of covering the entire province even though it might not contain data for abandon areas in some regions.

If the potential coverage is international, the data must include some portion of Saudi Arabia as defined in the introduction of this section.

If the data set is not yet complete, the respondent should specify the percent of the intended coverage which applies to the data set in 1991.

3.2.8 GEOGRAPHIC REFERENCING OF DATA

An important limitation on this survey is that it is only concerned with data sets that are related to some coordinate system that can by calculation (direct or complex) be related to the international geodetic reference system of latitudes and longitudes and, where appropriate, to mean sea level. In short, if the data set cannot be tied to a specific place in the world by information contained in the data set, it may be excluded from the survey.

There are several aspects of this ability to link data to world location and they are as follows:

Map Projection is the conversion used by cartographers to display the curved surface of the earth on a flat map. The name of the map projection used is usually given on a printed map sheet. In other circumstances an inquiry to the source of the base map may yield the name of the map projection used. List data (e.g., statistical data sets related to coordinate locations) have no map projection.

Coordinate System The data set must be able to be related to some coordinate system. To simplify description, these have been grouped into three types:

- 1) *Latitude and Longitude (with division given in degrees):* These are the common representations of parallel and meridian lines of latitude and longitude displayed in many map projections.

- 2) *Rectangular Grids (with division given in unit measure such as metres or feet):* These are the typical grid representations of given distance from some point of origin such as those found in Universal Transverse Mercator maps and other more local reference frames.

NOTE: If a rectangular grid is employed it must be able to be tied into a horizontal geodetic datum.

- 3) *Bearings (Azimuths) and distances:* These are the combination of angles and distances used in many descriptions of property boundaries.

NOTE: If bearing and distances are employed, they must be able to be tied into latitude and longitude or coordinate points which themselves are related to some horizontal geodetic datum. No map scales at or larger than 1:500 are to be included.

Graphical Attributes: This question relates to the composition and quality of the data set's graphic characteristics.

- 1) *Range of scales:* Give a single scale, e.g., 1:50,000 whenever the map scale is uniform for a data set. Where the maps have the same contents but vary in scale, give the range of scales, e.g., 1:12,500 to 1:15,000)

NOTE: that list data are scaleless (e.g., statistical data sets related to coordinate locations)

NOTE: that at maps scales at or larger than 1:500 are not to be included. This excludes most engineering drawings at that scale and other similarly detailed maps.

- 2) *Range of dates and data acquisition:* Provide a single date (nearest year) when the data set has been gathered at one time event. Examples of this type may include the results of a poll or a census as of a single date.

Give a single date (nearest year) if the most significant data (the principle theme) is dependent on observations taken within a year or are deemed to be representative of one year. An example might include an annual record of years but deemed to represent a specific year.

Provide a range of dates if the significant data represents observations from several years and if knowledge of this range is important to data set users.

- 3) *Absolute Positional Accuracy:* Specifying the absolute accuracy of cartographic products is often a complex and difficult task. Complete the two sections

below only if the accuracy and resolution are known and published or if you are able to make a reasonable estimate based on sound technical knowledge. If the accuracy is unknown or you cannot provide estimates, give the "unknown" response.

Absolute positional accuracy concern the possible amount of error (either horizontal or vertical) in the location of features in the data set with respect to known locations on the geodetic framework. This is expressed as the plus or minus error (standard deviation) of the feature locations.

The option "Other" is provided for cases where other accuracies are more relevant to user of the data, e.g., confidence limits on the accuracy of soil type identification, percentage limits on components of complex classification types, or percent potential error of areas of crops given on an agriculture map.

- 4) *Resolution of Raster or Grid data:* Give the length of the sides of smallest grid cell used, e.g., 10m x 10m. Resolution may be defined as the degree to which closely related entities can be discriminated and the actual separation between entities. Where raster or grid data apply, as in remote sensing imagery, give the resolution in metres for pixels. Where variations in resolution arise, give the range of resolution.

3.3.0 DATA AVAILABILITY

This section of the questionnaire evaluates the degree of access to the data.

3.3.1 ACCESS POLICY

Access policy refers to the conditions of access to the data, ie. whether external users may not gain access to the data. It also evaluates the degree of coordination between different agencies or department.

3.3.2 COST OF DATA OR ACCESS TO DATA

This question is designed to assess whether or not there are monetary costs associated with obtaining the data.

3.3.3 DATA PROCUREMENT SELECTION CRITERIA

Responses to this question should describe the basis on which a user would define and select part of or all of the data set. For example, the "Map Sheet" option for data sets would indicate data set which are based on individual sheets of the National Topographic Series maps. The "Lat/Long" option reveals if the user may describe the boundaries of the area of interest in terms of latitudes and townships, counties, management areas and, so forth.

If the basis for selecting attribute data is different than the basis for spatial data, specify the criteria for selecting the attribute data components, (e.g., name, range, date, volume, page, etc.).

3.3.4 DATA SUPPLY MEDIA:

Indicate the medium (media) on which the data can be disseminated for both conventional (hardcopy) and digital data.

3.4.0 DATA BASE STRUCTURE SECTION

This section is to be completed only for data set which are wholly or partly in digital form now.

3.4.1 SPATIAL (Graphics) DATA FILE STRUCTURE

Data structure concerns how the graphic data elements are arranged within the database. The basis for the file structure for graphics data only is required.

<i>Graphic (Vector):</i>	A representation based on vector coordinates of graphic features (X,Y).
<i>Topographical:</i>	A method of coding which enables the relationships among points, lines, and polygons to be explicitly described.
<i>Raster:</i>	A system of grid cells of uniform size within one data set.
<i>Quadtree:</i>	A system of stacked (recursively divided) grid cells of varying sizes within one data set.

3.4.2 ATTRIBUTES DATA FILE STRUCTURE

Refers to how attribute data, which describe graphic features, are structured in the database.

3.4.3 FEATURE CODING STANDARD

Where cartographic features have been coded according to a formal convention, the name of the standard is required. A specification of standard is required.

3.4.4 DATA INTERCHANGE FORMAT

A number of interchange formats in which the host organization can make the data available are listed as choices. If the option is "Other", please specify the data format at the host organization.

3.5.0 DATA SET APPLICATIONS SECTION

3.5.1 EXISTING APPLICATIONS

This question enquires about the ways in which the data set is used in the department or agency where the data set resides or elsewhere, if unknown. Responses should include the name of the user agency and how the data is utilized by the agency. If there are multiple users of the data, give examples of typical users to the extent known. Also, indicate if there are no users for the data. Any limitations on the use of the data imposed by their current content, format, resolution, accuracy, access or any other factor, should be mentioned here.

Examples of applications for data sets:

- underground water sample data used in locational studies.
- remote sensing imagery used to update crop conditions.

3.5.2 POTENTIAL APPLICATIONS

This question refers to plans for the use of the data in the foreseeable future.

Appendix B

The 1989 Software Survey

Table 1. General System Characteristics

System Name	Computing Environment	System Type	First Installed	Number of Users	Pricing	Source Code Avail.	Source Code Price	Support Available?	Fee
AGIS	PCs/DOS	GIS	1986	12	\$15,000 +	no	n	yes	\$2,000
ARC/INFO	DEC VAX/VMS, Prime/PRIMOS, Data General/AOS VS & UNIX, IBM/VM CMS, Sun/UNIX, Apollo/UNIX, IBM RT/UNIX, HP/UNIX, Olivetti	GIS	1981	nr	nr	no	na	yes	var
Aries	DEC VAX/VMS	IP	1978	2,004	\$65,000	yes	\$40,000	yes	var
ATLAS*Graphics	PCs/DOS	DM	1984	1000's	\$450-1,200	no	na	yes	free
Auto Mapping Info.	PCs/DOS, Sun, Apollo, VAX, IBM/UNIX	GIS	1978	25+	£7500-15000	no	na	yes	12.5%
CRIES-GIS	PCs/DOS	GIS	1978	60	\$1,500	yes	\$1,500	yes	\$200
Deltamap	HP9000, SUN, APOLLO, SGI/UNIX	GIS	1986	100+	\$8000-80,000	negot.	na	yes	\$2,200+
Earth One	PCs/DOS	GIS	1986	40	\$12-28,000	no	na	yes	\$2-5,000
EPPL7	PCs, PS-2/DOS	GIS	1987	335	\$500-1,000	no	na	yes	\$150
ERDAS	PCs/DOS, SUN/UNIX, VAX/VMS	GIS, IP	1979	900+	\$2,000	no	na	yes	\$250+
Filevision IV	Macintosh	FM, DM	1984	40,000	\$495	no	na	no	nr
FMS/AC	PCs/DOS, SUN/UNIX, Macintosh	GIS, FM	1987	500	\$2,500-7,500	yes	\$1,000	yes	\$300-1,000
Gas, Electric, Water, & Municipal FM	IBM 370/MVS, VM	GIS, AM, FM	1984-89	22	nr	yes	na	yes	nr
Geo Sight	PCs/DOS	GIS, AM	1987	65+	\$4,450	no	na	yes	\$500
Geo-Graphics	PCs/DOS	FM	1985	nr	\$2,400	yes	incl.	yes	10%
GeoSpreadSheet	PCs/DOS	GIS	1989	18	\$595-2,490	no	na	yes	\$250
GeoVision	VAX/VMS, ULTRIX, SUN, IBM-RT/AIX	GIS, FM	1976	47	nr	nr	na	yes	nr
Geovision "GeoPro"	PCs/DOS, Macintosh	AM	1988	2	\$1,995-4,995	yes	na	yes	var
Geovision WOW	PCs/DOS	GIS	1985	1,200+	\$595	yes	na	yes	var.
GFIS	IBM S/370 architecture systems	GIS	1977	180+	var	no	na	yes	nr
Glimms	Mainframes, Minis (incl. UNIX); PCs/DOS, Macintosh	DM, GIS	1970	300	\$1500-\$3000	yes	incl.	yes	incl.
GISIN	PCs, PS-2/DOS	FM	1986	5	nr	no	na	yes	nr
GDS	VAX/VMS, DEC station/Ultrex	GIS, AM	1980	800+	\$10,000+	no	na	yes	12%
GRASS	Sun, MASSCOMP, Silicon Graphic, HP9000, Tektronix, PC 386, Intergraph, Mac II/UNIX	GIS	1985	500-1000	\$1,000	yes	incl.	yes	var
IDRISI	PCs/DOS	GIS	1987	700	\$50-300	no	na	no	na
IGDS/DMRS	DEC VAX/VMS	CAD-CAE, FM-GIS	1973	1371	\$7,500-110,000	no	na	yes	12%
IMAGE	PCs/DOS	GIS, IP	1989	100+	\$395+	no	na	yes	\$195
Infocam	VAX/VMS	GIS	nr	23	\$40,000-65,000	yes	\$20,000	yes	12%
Informap	VAX/VMS	GIS	1975	nr	nr	no	na	yes	nr
Land Trak	PCs/DOS	GIS	1983	230	\$3,000-\$20,000	no	na	yes	\$2,500
Laser-Scan	DEC VAX/VMS	GIS	1985	150	£10,000-100,000	no	na	yes	12.5%
Mac GIS (Cornell U.)	Macintosh	GIS, AM, FM	1988	nr	150	no	na	yes	0
MacAtlas, PCAtlas	Macintosh, PCs/DOS	GIS	1985	5000+	\$79-199	no	na	nr	nr
MacGIS (U. Oregon)	Macintosh	GIS	1987	30	\$100-300	no	na	yes	nr
Manatron GIS	Unsys/DOS, UNIX	GIS	1983	60+	nr	yes	call	yes	nr
MapGrafix	Macintosh	GIS, AM	1987	nr	\$8,500	no	na	yes	\$500
Map II	Macintosh	GIS	1989	nr	<\$100	nr	nr	nr	na
MapInfo	PCs/DOS	GIS	1986	nr	\$750	no	nr	yes	\$195

GIS=Geographic Information System AM=Automated Mapping DM=Desktop Mapping FM=Facilities Management IP=Image Processing

Data Structure(s)	Topological Data Structure	Geographic Refer (Lat Long)	Convert Map Projections	Includes Map Digitizing Package	Data Input Formats	Database Management Software (on External File)	DBMS Interfaces
Vector, raster	no	yes	yes	yes	TIROS, TIPS, AVHRR, COLE III, DXF, ELAS, SPOT, CZCS	I	na
Vector	yes	yes	yes	yes	IGES, DLG, GBF/DIME, TIGER, SIF, ERDAS, ETAK, GIRAS, DXF, MOSS, MIADS, DTM/DEM	I, E	Info, Oracle, Ingres
Raster	na	yes	yes	yes	DLG3, ISIF	I	na
Vector	no	yes	yes	yes	DIF	I, E	DIF, Dbase, Lotus, etc
Vector, raster	nr	yes	yes	yes	LISP, DXF, MOSS	I	na
Raster	na	no	no	yes	DLG, ERDAS, SIF	I, E	Dbase III
Vector, raster, TIN	yes	yes	yes	yes	DLG, DXF, IGES, SIF, GPG, MOSS, Palette, DEM, Easydata, Calma	I, E	Oracle, Ingres, Informix
Vector & raster	yes	yes	yes	yes	DXF & DLG	I	na
Raster	na	yes	no	yes	ERDAS, ARC/INFO	I, E	Rbase, Dbase III
Raster	na	yes	yes	yes	DXF, ARC/INFO, DLG, etc.	E	Info
Raster	no	no	no	no	Pict 1, Pict 2, EPSF	I	na
Vector	yes	no	no	yes	DXF	E	Dbase, etc
Vector	no	yes	yes	yes	IBM	E	IMS, DB-2
Vector, quadtree	yes	yes	no	yes	DIME, TIGER, URBAN, ATLAS	I, E	Dbase
Vector	no	yes	yes	yes	nr	I	na
Vector	yes	yes	no	no	none	I	na
Raster, vector, quadtree	yes	yes	yes	yes	none	E	Oracle
Vector	no	yes	yes	yes	DLG, DEM, GIRAS, DIME, TIGER	I, E	SQL & DBF supported
Vector	yes	yes	yes	yes	DLG, DIME, DEM, GNIS, GIRAS	I, E	nr
Vector	no	yes	yes	yes	TIGER, GFIS, others from IBM	E	IMS/DLI, SQL/DB2
Vector, raster	yes	no	no	yes	OS DMC	I, E	Oracle, SAS, SPSS
Vector	yes	yes	no	yes	none	E	Condor
Object (vector)	yes	yes	yes	yes	IGES, ISIF, DXF, DLG3, DIME/TIGER	I, E	Oracle, etc
Vector, raster	yes	yes	yes	yes	Landsat, DLG 3, DEM, DTED, SPOT	I, E	nr
Raster	na	yes	no	yes	ARC/INFO, LANDSAT, DLG, CTG, Micropics, ODYSSEY, DXF, MAP	E	Lotus, Quattro, etc.
Vector, raster	yes	yes	yes	yes	DLG, DIME, TIGER, ISIF, IGES, DXF, DEM	I, E	Informix
Vector	yes	yes	yes	yes	TIGER, etc.	I, E	Lotus, Dbase, etc.
Raster, quadtree	na	no	no	yes	Gradis 2000/3000	I, E	Oracle
Vector	yes	yes	yes	yes	DLG, DIME, SLF, SIF	I, E	SQL-based
Vector	yes	yes	yes	yes	DLG, DXF, ASIF, DGN, DIME, TIGER, ETAK	I	na
Vector, raster	yes	yes	yes	yes	DXF, DLG, SIF, Informap, UK NTF, ARC	I, E	RDB
Vector, raster	na	no	no	yes	none	I	na
Vector, raster	no	no	no	no	na	na	na
Raster	na	yes	no	yes	none	I, E	Hypercard, etc
Vector, raster	yes	yes	yes	yes	DLG, DTM, GIRAS, SIF, DXF, DIME, TIGER	I, E	Oracle, Fastport, Adept, Paquest, etc.
Vector	no	yes	yes	yes	Own (CGDEF), DXF, DLG3, WDBII, ETAK, ATLAS Graphics, etc.	I, E	4th Dimension, Oracle, Double helix, Omnis, etc.
Raster	na	no	no	yes	TIFF, PICT, SYLK	nr	na
Vector	nr	yes	no	yes	DXF, MMI, MBI	I, E	Dbase

CAD=Computer Assisted Design CAE=Computer Assisted Engineering nr=not reported na=not applicable

Table 1. General System Characteristics (continued)

System Name	Computing Environment	System Type	Year Installed	Number of Users	Pricing	Source Code Avail.	Source Code Price	Support Available?	Fee
MatchMaker/GDT	PCs/DOS	DM	1987	10	\$5,995-9,995	no	na	yes	Var.
Micropics	PCs, PS-2/DOS	AM	1981	250	\$745-1,490	no	na	yes	nr
MicroStation GIS	Intergraph/UNIX	GIS	1989	11	\$8,300	no	na	yes	15%
MIPS	PCs/DOS	GIS	1987	nr	\$2-5,000	no	na	yes	\$800
MOSS	Data General/AOS-VS, Prime/Primos, Tektronix 4300 /UTEK	GIS, IP	1977	>100	(public)	yes	(public)	yes	\$5000
Nucor GIS	PCs/DOS	GIS	1988	15	\$500-4,500	no	na	yes	10%
Pamap GIS	Var./VMS, DOS, UNIX, ACS, CS/2	GIS	1983	200	\$7,500-\$80,000	no	na	yes	nr
Panacea	PCs/DOS	GIS	1986	500	\$500-2,000	no	na	yes	\$55 hr
PC ARC/INFO	PCs, PS-2/DOS	GIS	1987	nr	nr	no	na	yes	nr
PMAP	PCs/DOS	GIS	1987	180	\$895-1,600	no	na	yes	free
SICAD	Siemens/UNIX	GIS	1978	250	£20,000+	no	na	yes	var
SPANS	PCs/DOS OS2	GIS	1985	400	\$8000+	no	na	yes	*2%
StrataGIS	Tektronix/UNIX; IBM PCs/DOS	GIS	1988	20	\$7-25,000	no	na	yes	20%
STRINGS	PCs/DOS	GIS, FM	1979	150	\$3,500 - 5,000	no	na	yes	\$1,800
System 600	VAX/VMS, Sun/UNIX	GIS	1984	200	\$10,000-50,000	yes	Incl.	yes	18%
System 9	SUN/UNIX	GIS, IP	1987	25	\$40,000	no	na	yes	nr
Territory Mgt. Sys	PCs/DOS	GIS	1988	25	\$2,950-3,950	no	na	yes	\$500
Tigertools	PCs/DOS	GIS	1989	2	nr	yes	nr	yes	var
TIGRIS	Intergraph/UNIX workstations	GIS	1988	16	\$10,000	no	na	yes	*2%
UltiMap	Apollo AEGIS Operating System	GIS, AM	1974	40	\$19,000-50,000	no	na	yes	nr
USEMAP	PCs/DOS	GIS, AM, FM, CADD	1973	3	\$1,500-5,000	no	na	yes	\$150-500
VANGO	VAX/VMS	GIS	1981	96	\$12,000-17,000	no	na	yes	var
Zone Ranger/GDT	PCs/DOS	AM	1987	3	\$5,995-9,995	no	na	yes	var.
Systems Received too late to include in the table:									
Geo/SQL, MunMap	PCs/DOS, Sun/UNIX	GIS	1987	240	\$9,500+	no	na	yes	nr
Microimage Family	PCs/DOS, Sun/UNIX, Prime/Primos	GIS, IP	1984	nr	\$1995	no	na	yes	var
Topologic	PCs/DOS, OS-2, VAX/VMS	GIS	1987	18	\$2-7,000	no	na	yes	Free if...

GIS=Geographic Information System AM=Automated Mapping DM=Desktop Mapping FM=Facilities Management IP=Image Processing

GIS Systems & Sources

System: AGIS

Source: Delta Data Systems, Inc.

321 N. Curran Avenue

Picayune, MS 39466

Contact: Ren Clark

Phone: 601-799-1813

Other Services Offered:

Map scanning or digitization: y

System Integration: y

Other: Image proc., scan digitizing

Software Development in Progress:

Rev. 2, World Coordinate System, DBMS

System: ARC/INFO

Source: Environmental Systems Res. Inst.

380 New York Street

Redlands, CA 92373

Contact: Karen Hurlbut

Phone: 714-793-2853

Other Services Offered:

Map scanning or digitization: y

System Integration: y

Software Development in Progress:

Raster image integration

System: Arise

Source: Dipix Technologies Inc.

1050 Baxter Road

Ottawa, Ont. K2C 3P1

CANADA

Contact: R. G. Dixon

Phone: 613-596-4942

Other Services Offered:

Map scanning or digitization: y

System Integration: y

System: ATLAS*Graphics

Source: Strategic Locations Planning, Inc.

(Developer)

4030 Moorpark Avenue, Suite #250

San Jose, CA 95117

Contact: Stephen Poizner

Phone: 408-985-7400

Other Services Offered:

		yes	yes	no	yes	DIME	I	na
	Raster	na	no	no	no	Landsat	nr	
es	Vector, raster	yes	yes	yes	yes	DLG, DEM, DXF, DIME, TIGER, SIF, HPGL	E	Oracle, Ingres, Informix
ec	Vector, raster	nr	yes	yes	yes	TIFF, TARGA, ERDAS, TERRAMAR, IDIMS, ELAS, PCIPS, etc	I.E	Dbase
es	Vector, raster	no	yes	yes	yes	MOSS, DLG, DEM	I.E	DG/SQL, Oracle
s	Vector, raster	nr	yes	yes	yes	DXF, NUCOR	I.E	ZIM
es	Vector, raster	yes	yes	yes	yes	IGDS, ISIF, DLG, OSIF, DXF, etc.	I.E	RDB, Oracle, Dbase
s	Raster	na	no	no	yes	ERDAS, MAP	I	na
r	Vector	yes	yes	yes	yes	DIME, DLG, DXF, ETAK, TIGER, etc.	I.E	Info
	Raster	na	no	no	yes	GRD, DXF	I.E	Dbase
es	Raster, vector, quadtree	yes	yes	yes	yes	Ordnance survey, IGES, SISIF	I.E	DB2, Informix, etc.
	Raster, vector, quadtree	yes	yes	yes	yes	SIF, ARC/EXPORT, DLG 3, DIME, DXF, PCI, ERDAS, LMIC, etc	I.E	nr
s	Vector	nr	yes	nr	yes	SIF, DXF, IGES	I.E	Unity
	Vector	yes	yes	yes	yes	DLG, DXF, SIF, DIME, TIGER, DGN, ETAK	E	Ingres, Sybase, Britton Lee
s	Vector, raster	yes	yes	yes	no	Landsat, SPOT, DLG, DEM, DXF,	I.E	Ingres
	Vector	yes	yes	yes	yes	DXF, SIF, DLG, TIGER	I.E	Empress
s	Vector, quadtree	yes	yes	no	yes	DIME, TIGER	I.E	Dbase
	Vector	yes	yes	no	no	TIGER	I.E	nr
s	Vector, raster	yes	yes	yes	yes	DLG, DIME, TIGER, SIF, DXF, HPGL, DEM	I	na
	Vector, raster	yes	yes	yes	yes	DXF, ISIF, DIME, TIGER, USGS	I.E	Oracle, Informix, Ingress, IMS, etc.
	Vector, raster	no	yes	no	yes	none	I.E	Dbase III
	Vector	no	no	no	yes	DXF, DIME, DEM	E	UserBase
	Vector	yes	yes	no	yes	DIME	I	na
	Vector	yes	yes	yes	yes	TIGER, DLG, I graph, ARC/INFO, etc.	E	Rbase, Oracle, Ingres
	Vector, raster	nr	yes	yes	yes	DLG, DXF, ERDAS, A/I	nr	nr
	Raster, vector, quadtree	yes	yes	yes	yes	SIF, DEM, SPOT, LANDSAT, Atlas DLG, DIF, DXF	I.E	Dbase, RDB

CAD=Computer Assisted Design CAE=Computer Assisted Engineering nr=not reported na=not applicable

Map scanning or digitization: y
System Integration: y

-also-
STSC, Inc.
(Publisher)

2115 East Jefferson St.
Rockville, MD 20852
Contact: Rosemary Zimnoch
Phone: 301-984-5133

System: Axis Mapping Info. Sys.
Source: Axis Software Systems Ltd.
Park House, 88-102 Kingsley Park
Terrace, Northampton, Northants, NN2
7HJ
ENGLAND

Contact: Eric Malcomson
Phone: 0604 720477:

Other Services Offered:
Map scanning or digitization: y
System Integration: y
Other: consultancy

System: CRIS-GIS
Source: Michigan State University
302 Natural Resources
East Lansing, MI 48824
Contact: Gerhard Schmink, Proj. Director
Phone: 517-353-5363

System: Deltamap
Source: Deltasystems

2629 Redwing Rd., Suite 330
Ft. Collins, CO 80526

Contact: Carl Reed
Phone: 303-226-3283
Other Addresses: Genasys II Pty, Ltd.
Unit 19, 130 Pacific Hwy. Greenwich
NSW AUSTRALIA 2065

Other Services Offered:
Map scanning or digitization: prototypes
System Integration: y
Other: consulting, custom software

System: Earth One
Source: C.H. Gurnsey & Company
3555 NW 58th
Oklahoma City, OK 73112

ARC/INFO	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Aries	•	•		•						•	•	•	•	•	•	•	•	•
ATLAS*Graphics	•																•	•
Auto Mapping Info.	•	•	•	•	•	•	•	•	•							•	•	•
CRIS-GIS			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Edtmap	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Earth One	•	•	•	•	•	•	•	•	•							•	•	•
EPPL7	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ERDAS	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Flavision IV																		
FMS/AC	•	•		•	•	•	•	•	•	•	•	•				•	•	•
Gas, Electric, Water,	•	•	•	•	•	•	•	•									•	•
Municipal FM																		
Geo Sight	•		•							•							•	•
Geo-Graphics	•	•	•	•	•	•	•	•		•							•	•
GeoSpreadSheet	•	•			•						•						•	•
GeoV AMS/GIS	•	•	•	•	•	•	•	•										
Flavision "GeoPro"	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Flavision WOW	•	•	•	•														
GIS	•	•	•	•	•	•	•	•									•	•
Imms	•	•		•	•	•	•	•		•	•	•	•				•	•
SIN	•			•	•	•	•	•	•								•	•
S-GDS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ASS	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CRISI			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
DS/DMRS	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EDGE	•		•	•	•	•	•	•	•	•	•	•					•	•
Edtmap	•	•	•	•	•	•	•	•	•	•	•						•	•
Edtmap	•	•	•	•	•	•	•	•	•								•	•
Ed Trak	•	•		•	•												•	•

Contact: Jeff Provine
 Phone: 405-947-5515
 Other Services Offered:
 Map scanning or digitization: y
 System Integration: y
 Other: PSS/U Elect. Distribution Analysis
 Software
 Software Development in Progress:
 Conversions to Apollo & DG/UNIX

 System: EPPL7
 Source: MN Land Mgmt. Information Ctr.
 Centennial Bldg. 658 Cedar St.
 St. Paul, MN 55155
 Contact: Renee Johnson
 Phone: 612-297-2491
 Other Services Offered:
 Map scanning or digitization: y
 System Integration: y

System: ERDAS
 Source: ERDAS, Inc.
 2801 Buford Highway, Suite 300
 Atlanta, GA 30329
 Contact: Cathy Briggs
 Phone: 404-248-9000
 Other Addresses:
 ERDAS, Inc.
 4000 Blvd. Oaks Dr., # 2000
 Gilroy, CA 95020
 Other Services Offered:
 Map scanning or digitization: y
 System Integration: y
 Other: DMS, ERDAS-ARC/Info
 Live Link, Prod. Ser.

 System: Flavision IV
 Source: Marvelin Corporation
 3420 Ocean Park Blvd. Suite 3020
 Santa Monica, CA 90405

Contact: Craig Conger
 Phone: 213-450-6813

 System: FMS/AC
 Source: Facility Mapping Systems, Inc.
 38 Miller Avenue, Suite 11
 Mill Valley, CA 94941
 Contact: Kristen Routh
 Phone: 415-381-1750
 Other Services Offered:
 System Integration: y
 Other: customization

 System: Gas, electric, water, &
 municipal FM
 Source: WPS Development, Inc.
 504 North Adams Street
 Green Bay, WI 54301
 Phone: 414-433-1706
 Other Services Offered:

A grid of 10 columns and 20 rows of dots, resembling a dot grid paper. The dots are arranged in a regular pattern, with some columns having more dots than others. The grid is used for writing or drawing.

**1813-130th Ave., N.E., Suite 216
Bellevue, WA 98005
Contact: Richard Schweitzer
Phone: 206-867-1485
Other Services Offered:
System Integration: y**

System: GeoSpreadSheet
Source: Geographic Data Technology, Inc.
13 Dartmouth College Highway
Lyme, NH 03768-9713
Contact: Molly Hutchins
Phone: 603-795-2183
Other Services Offered:
Map scanning or digitization: y

ARC/INFO	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Aries	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ATLAS*Graphics	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Axis Mapping Info.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
CRIES-GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Deltamap	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Earth One	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EPPL7	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ERDAS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Filevision IV	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
FMS/AC	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Gas. Electric, Water, & Municipal FM	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Geo Sight	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Geo-Graphics	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GeoSpreadSheet	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GeoV AMS/GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Geovision "GeoPro"	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Geovision WOW	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GFIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Gimms	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GISIN	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GOS-GDS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
GRASS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
IDRISI	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
IGDS/DMRS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
IMAGE	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Infocam	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Informap	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Land Trak	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

GeoVision
165 N. Walker St. #403
Sydney, NSW
AUSTRALIA 2060
Other Services Offered:
Map scanning or digitization: y
Other: GIS Service Bureau, Data Conversion Consulting

System: Geovision "GeoPro"
Source: Geovision, Inc.
270 Scientific Dr.
Norcross, GA 30092
Contact: Kenneth S. Shain
Phone: 404-448-8224
Other Services Offered:
System Integration: y
Software Development in Progress:
UNIX/XENIX, OS-2,
PM and Mac Versions

System: Geovision WOW
Source: Geovision, Inc.
270 Scientific Dr. Suite One
Norcross, GA 30092
Contact: Kenneth S. Shain
Phone: 404-448-8224
Other Services Offered:
System Integration: y
Software Development in Progress:
Mac, PM versions

System: GFIS
Source: IBM Corporation
Old Orchard Road
Armonk, NY 10504
Contact: Alison B. Libshitz
Phone: 713-335-3217
Other Addresses:
IBM Corp.

GIS Solution Center
3700 Bay Area Blvd.
Houston, TX 77058
Other Services Offered:
System Integration: y
Other: Data processing solutions

System: Gimms
Source: Chefford Canada Ltd.
9 Antares Drive
Nepean, ONT K2E 7V5
CANADA
Contact: David Alford
Phone: 613-727-1738
Other Addresses:
Gimms Ltd.
30 Keir Street
Edinburgh
SCOTLAND EH3 9EU
Other Services Offered:

Table 2. System Functional Capabilities (continued)

System Name	Straight distance measurement	Curved distance measurement	Proximity distance	Area measurement	Buffer around points	Buffer around polygons	Buffer along straight lines	Buffer along curved lines	Weighted buffer	Add subtract maps	Multiply/divide maps	Exponentiate maps	Trigonometric functions	Differentiate map values	Nearest neighbor search	Analysis within corridor	Boolean ops
Laser-Scan	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MacGIS (Cornell)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MacGIS (Oregon)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Manatron GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MapGraftx	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MapII	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MapInfo	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MatchMaker/GDT	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Microtops	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MicroStation GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MIPS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
MOSS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nucor GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Pamap GIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Panacea	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
PC ARC/INFO	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
PMAP	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
SICAD	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
SPANS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
StrataGIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
STRINGS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
System 600	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
System 9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Territory Mgt Sys	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Tigertools	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
TIGRIS	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
UtiMap	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
USEMAP	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
VANGO	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Zone Ranger/GDT	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

System: IGDS/DMRS

Source: Intergraph Corporation

One Madison Industrial Park

Huntsville, AL 35807-4201

Contact: Tina T. Underwood

Phone: 205-722-1692

Other Services Offered:

System Integration: y

System: IMAGE

Source: U.S. Statistics, Inc.

1101 King St., Suite 601

Alexandria, VA 22314

Contact: Warren E. Glimpse

Phone: 703-979-9699

Other Addresses: 8777 E. Via De Ventura
Suite 1100

Scottsdale, AZ 85258

Other Services Offered:

Map scanning or digitization: y

System Integration: y

System: Infocam

Source: Kern Swiss

Schachenallee

Aarau, 5001

SWITZERLAND

Contact: Francois Garfroid

Phone: 064-264444

Other Addresses: Kern Instruments, Inc.

Geneva Road

Brewster, New York 10509

914-279-5095

Other Services Offered:

System Integration: y

System: Informap

Source: Synercom Technology, Inc.

2500 City West Blvd., Suite 1100

Houston, TX 77042

Contact: Mary Dawson

Phone: 713-954-7000

Other Addresses: Synercom Tech., Inc.

1595 Springhill Road

Vienna, Va 22182

Other Services Offered:

System Integration: y

Other: Education, consulting

System: Land Trak

Source: GeoBased Systems

4800 Six Forks Rd.

Raleigh, NC 27609

Contact: Nora Sherwood Bryan

Phone: 619-481-3119

Other Addresses:

12526 High Bluff Dr.,

Suite 160

San Diego, CA 92130-2041

Other Services Offered:

[illegible]

**464 Hollister Hall
Ithaca, NY 14853
Contact: Stephen D. Smith
Phone: 607-255-6520**

System: MacGIS
Source: University of Oregon
Department of Land Architecture
Eugene, OR 97403
Contact: David W. Hulse
Phone: 503-686-3634
Software Development in Progress:

Table 2. System Functional Capabilities (continued)

System Name	Polygon merge display	Delete spurious polygons after overlay	Generate Thiessen polygons	Command language user interface	Uses menu type user interface	Uses menu lists	Uses popup menus	Uses function keys	Uses icons in user interface	Multiple windows simultaneously	Color display	Three dimensional display	Single screen operation	Dual screen operation	X windows support	Page 4
Laser-Scan	•	•		•	•	•	•	•	•	•	•	•				
MacGIS (Cornell)				•	•	•	•	•	•							
MacGIS (Oregon)				•	•	•	•	•	•			•				
Manatron GIS				•	•	•	•	•	•	•	•		•	•		
MapGrafix	•			•	•	•	•	•	•	•	•		•	•		
MapII				•	•	•	•	•	•	•	•		•	•		
MapInfo	•			•	•	•	•	•	•	•	•		•	•		
MatchMaker/GDT				•	•	•	•	•	•	•	•			•		
Micropics				•	•	•	•	•	•	•	•		•	•		
MicroStation GIS	•	•		•	•	•	•	•	•	•	•	•	•	•	•	
MIPS	•	•		•	•	•	•	•	•			•	•	•		
MOSS	•	•		•	•	•	•	•	•	•		•	•	•		
Nucor GIS				•	•	•	•	•	•			•	•	•		
Pamap GIS	•	•	•	•	•	•	•	•	•			•	•	•		
Panacea				•	•	•	•	•	•			•	•	•		
PC ARC/INFO	•	•	•	•	•	•	•	•	•	•	•		•	•		
PMAP				•	•	•	•	•	•	•	•	•	•			
SICAD	•	•	•	•	•	•	•	•	•	•	•	•		•	•	
SPANS	•	•	•	•	•	•	•	•	•	•		•		•		
StrataGIS				•	•	•	•	•	•	•	•		•	•		
STRINGS	•	•		•	•	•	•	•	•	•	•	•	•	•		
System 600				•	•	•	•	•	•	•	•	•	•	•		
System 9	•	•		•	•	•	•	•	•	•	•	•	•	•		
Territory Mgt Svs				•	•	•	•	•	•	•	•	•	•	•		
Tigertools	•			•	•	•	•	•	•	•	•	•	•	•		
TIGRIS	•	•		•	•	•	•	•	•	•		•		•	•	
UnMap	•			•	•	•	•	•	•	•	•	•	•			
USEMAP			•	•	•	•	•	•	•	•	•	•	•			
VANGO	•			•	•	•	•	•		•	•	•	•			
Zone Ranger/GDT							•				•			•		

Source: ComGrafix, Inc.
620 E Street
Clearwater, FL 34616
Contact: Michael Lawrence
Phone: 813-443-6807
Other Services Offered:
Map scanning or digitization: y
System Integration: y
Other: Navplus, Mapstar
Software Development in Progress:
MapGrafix display - runtime version

System: MapII
Source: John Wiley & Sons
605 - 3rd Avenue
New York, NY 10158-0012
Phone: 212-850-6521
Other Addresses: University of Manitoba
Dept. of Geography
Winnipeg, Manitoba

CANADA R3T 2N2
Other Services Offered:
Other: Workbook in Progress

System: MapInfo
Source: MapInfo Corp.
200 Broadway
Troy, NY 12180
Contact: Renny Barton
Phone: 518-274-8673
Other Services Offered:
Map scanning or digitization: y

System: MatchMaker/GDT
Source: Geographic Data Technology, Inc.
13 Dartmouth College Highway
Lyme, NH 03768-9713
Contact: Molly Hutchins
Phone: 603-795-2183
Other Services Offered:

Map scanning or digitization: y

System: Microimage Family
Source: Terra-Mar, Inc.
1937 Landings Dr.
Mountain View, CA 94043
Contact: Donn C. Walklet
Phone: 415-964-6900
Other Addresses: 19 Briar Hollow Lane #
241, Houston, TX 77027
9175 Guilford Rd., #210, Columbia, MD
21046
Other Services Offered: System integration

System: Micropics
Source: The Telesys Group, Inc.
5455 Wingborne Ct.
Columbia, MD 21045
Contact: J. F. Rose
Phone: 301-997-7848

Appendix C

Example of Mandatory Database Requirements

Mandatory Database Requirements—Palo Alto, California

The following section is taken from the standard request for proposals used by Palo Alto, California, in its GIS procurement process.

As mentioned earlier, the system shall support the integrated management of both cartographic and attribute data. In particular, the system's data base characteristics must meet the following specifications:

- A. Support point, line, polygon (vector) features, grid cell-(raster), text graphics, and attributes.
- B. Define locations of cartographic features using an arc/node data structure which combines sequences of x,y coordinates or x,y,z coordinates with full topological encoding (as points, edges, nodes, and polygons).
- C. Represent polygon features as sets of arcs rather than closed loops of coordinates.
- D. Support up to 256,000 points per polygon, up to 512,000 map features per map, at least 512 attributes per map feature, files of virtually unlimited size and up to 2,048 files in a single data base. The software shall be capable of digitally representing large polygons in their entirety without artificially subdividing them into multiple smaller polygons.
- E. Provide for direct access to specific features.
- F. Provide a generalized mechanism for attaching graphic and non-graphic attributes to map features. The system must also provide for the capability to support direct linkages between graphic features and non-graphic attribute data in existing databases located on other machines.
- G. In the attribute database support a variety of data types such as binary integers, binary floating point numbers, integers, real numbers, and character strings.
- ~~H. Provide a minimum of 32,000 layers per map data file.~~
- ~~I. Require no more than one copy of any map partition except for edit/update.~~
- J. GIS must not require an external or other vendor Relational Database Management System to operate. GIS must have its own internal attributes management capability. GIS must also be able to support an SQL linkage to an RDBMS if this capability is required either initially or at some later date.

END

2|5| 0|5| 93|

FIN