ISSUES IN THE DESIGN AND IMPLEMENTATION OF A
MULTIPURPOSE LAND INFORMATION SYSTEM (MPLIS)
WITH PARTICULAR FOCUS ON EGYPT

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LIST OF ACRONYMS AND ABBREVIATIONS

AM/FM    Automated Mapping/Facilities Management.
COGO     Coordinate Geometry.
CONSOIL  Conservation of Natural Resources through Sharing of Information Layers, Dane County, Wisconsin.
DCLRP    Dane County Land Records Project, Wisconsin.
DOT      Department Of Transportation, Wisconsin.
EGSA     Egyptian General Surveying Authority.
GPS      Global Positioning System.
GRF      Geodetic Reference Framework.
IMS      Irrigation Management System project, Egypt.
LIB      Land Information Board
LIC      Land Information Committee
LTP      Land Titling Project, Thailand
NRC      National Research Council, U.S.A.
PLSS     Public Land Survey System, U.S.A.
S&M      Surveying and Mapping component, IMS project, Egypt.
UNDP     United Nations Development Program
UNEP     United Nations Environmental Program.
USGS     United States Geological Survey.
WPG      Water Planning Group
CHAPTER I

INTRODUCTION

Land is the location of most human activity, and along with air and water is one of mankind's most important resources. Every activity of every society both impacts land and depends on it as its base. This makes it necessary to properly manage land resources. Although the management of land resources is not an easy task, it is critical to sustaining both future economic development and the natural heritage of any country.

In order to manage natural resources, it is first necessary to be able to acquire and manage information about these resources. Information must be recognized as a resource which requires explicit management strategies. Information management requires a Land Information System (LIS) capable of assembling an information base about land. Such an LIS, can be defined as "... a combination of human [individuals and institutions] and technical [e.g. GIS, Computerized Mapping Systems] resources together with procedures and standards for assembling an information base about the land" (McLaughlin
1983). Figure (1.1) illustrates the components of an LIS.

![Diagram of LIS components](image)

**FIGURE 1.1 - COMPONENTS OF AN LIS**
(Based on McLaughlin, 1983)

The operation of an LIS includes data acquisition, data processing, storage, maintenance, analysis and retrieval. In this context, a Geographic Information System (GIS) is regarded as the technical component of an LIS. A GIS can be defined as "... a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world, ..." (Burrough, 1986). The human resources component represents the available expertise as well as the existing institutional structure. The standards and procedures component represents the standards, policies and other arrangements to be followed to integrate different kinds of data, and to achieve an efficient institutional structure in order to assemble an information
base about land.

The variety of land information necessitates a system capable of integrating different information and improving the flow of information between different organizations. This different information can be classified into four major categories: (Palmer 1984)

(i) Environmental or natural information; focuses on soils, geology, wetlands, wildlife, and other natural phenomena that have unique physical, biological or chemical characteristics.

(ii) Infrastructure/Utility information; concentrates on engineering and utility structures such as transportation and pipelines (man-made improvements to land).

(iii) Legal/Fiscal, "cadastral" information; concerned with land tenure and land use.

(iv) Socio-Economic information; primarily focuses on population distribution, health, welfare and marketing (human and economic geography).

A Multipurpose Land Information System (MPLIS) is capable of integrating these different kinds of information and serves different purposes. This different information can be viewed as different layers within an MPLIS. Figure (1.2) illustrates the concept of an MPLIS.
Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:  
A. Parcels  
B. Zoning  
C. Floodplains  
D. Wetlands  
E. Land Cover  
F. Soils  
G. Reference Framework  
H. Composite Overlay

Responsible Agency:
Surveyor, Dane County Land Regulation and Records Department.
Zoning Administrator, Dane County Land Regulation and Records Department.
Zoning Administrator, Dane County Land Regulation and Records Department.
Wisconsin Department of Natural Resources.
Dane County Land Conservation Committee.
United States Department of Agriculture, Soil Conservation Service.
Public Land Survey System corners with geodetic coordinates.
Layers integrated as needed, example shows parcels, soils and reference framework.

FIGURE 1.2- CONCEPT FOR AN MPLIS
(Niemann et al, 1987, p. 63)
It should be noted that any action or decision applied to the land without incorporating all kinds of information could negatively affect some of the land resources. For example, suppose that a land-fill is to be constructed. If only the engineering criteria for construction such as slope and soil type are considered without studying the effect of the selected location on the surrounding area, the surrounding cultivated areas and natural habitat may be destroyed. The proper design of such a project should incorporate the available natural, environmental, social, and cultural information. The location can then be selected after taking into consideration all the necessary criteria. This cannot be achieved without a system that is capable of merging all of this information, i.e. an MPLIS.

This research provides an overview of technical, economic and institutional issues of the design and implementation of such an MPLIS. The second chapter deals with some of the technical issues related to the design and implementation of an MPLIS. Issues relevant to the establishment of a Geodetic Reference Framework (GRF), the creation of the cadastral overlay and the integration of different data sets are discussed.
Issues related to the GRF and cadastral layer are given special attention in this research due to their fundamental role in the system. The GRF establishes the spatial framework to which different data will be geographically referenced, and consequently different data layers registered to each other. The cadastral overlay represents the basic land tenure component; i.e. the human component. To demonstrate that an MPLIS extends beyond these two components, the technical and institutional issues of integrating different data sets within an MPLIS, as well as the overall economic analysis of the system, are discussed.

The third chapter deals with the institutional and economic issues related to the design and implementation of an MPLIS. The benefits and costs of an MPLIS are analyzed. The importance of efficient institutional cooperation for the development of an MPLIS is emphasized, as is how such cooperation can be achieved in both individual organizations and in joint efforts between organizations.

The fourth chapter establishes the need for an MPLIS in Egypt. These needs relate to better natural resource management (especially the irrigation water), as well as provision of up-to-date information needed for development, planning, management and decision making in order to satisfy
the growing population needs. Deficiencies in existing
surveying and mapping system are emphasized. Approaches to
improving such system and implementing a computerized MPLIS
are proposed. The last chapter presents a summary and
conclusions.

In this research, the terms "efficiency" and
"effectiveness" are frequently used. The term "efficiency"
refers to the ability of a system to provide required outputs
.maps, reports, analysis, etc.) in a short period of time.
The term "effectiveness" means that the system is able to
increase the quality of the output and/or produce new outputs.

Technical, economic, and institutional issues discussed
in this research are relevant to any country developing an
MPLIS. Since a great deal of the work and research in the
LIS/GIS field has been done in North America and Australia,
this work is used as a reference point. Many examples of
LIS/GIS implementation are mentioned and analyzed.
CHAPTER II

TECHNICAL ISSUES OF AN MPLIS

This Chapter discusses the technical issues related to two components of an MPLIS; the establishment of a geodetic reference framework and the creation of the cadastral layer. The issue of integrating different data layers within an MPLIS is also discussed.

2.1 THE GEODETIC REFERENCE FRAMEWORK (GRF)

2.1.1 DEFINITION AND FUNCTION OF A GRF

The GRF, as defined by the NRC (1983, P. 20):

"... consists of monumented points whose locations have been accurately determined with respect to a mathematical framework, this system permits the spatial referencing of all land data to identifiable positions on the Earth’s surface.....It also provides a uniform, effective language for interpreting and disseminating land information".

An MPLIS database will contain different layers of data about natural and physical phenomena such as wetlands, land cover, soils, cadastral parcels, highways, railways, etc. The integration of such data in order to assemble an information base about the land is the objective of an MPLIS. Such
integration requires universal compatibility between different data sets as well as spatial registration between the various data layers. The GRF is capable of performing this task.

One of the main functions of a GRF is to aid in the establishment of a spatially defined information system. If a query is done on an object or set of objects in the database, the system will identify the spatial position (x,y) of these objects, (the "where is what" question). If a query is done regarding a specific location, the system will specify what is situated in that location (the "what is where" question). The GRF should define the "where" in both questions (Dale and McLaughlin, 1988).

2.1.2 ISSUES IN THE DESIGN OF A GRF

The principle of control works from the whole to the part. Therefore, for any area (town, city or country) to be surveyed, a framework of points covering the whole area should first be established. These points should be well distributed throughout the area, marked and accurately measured. The absolute positions of these points with respect to the Earth's surface are then computed. These points now form what is called the primary (or first-order) network. A secondary (or second-order) network can be established by connecting its
points and adjusting them to the points of the primary network. The secondary network can also be broken down into smaller networks.

Generally, the primary network is the first to be observed and computed, followed by the secondary and tertiary networks and finally those of fourth order, if necessary. Higher levels require more time and effort for accurate observation than those below it.

There are many issues to be taken into consideration in the design and development of a geodetic reference framework: Type of map projection, consistency, accuracy and density.

2.1.2.1 TYPE OF MAP PROJECTION

Selecting the most appropriate type of map projection is crucial when designing a GRF. The selected projection should provide small distortions. The selected projection, and hence the amount of distortion, depends on the location, size, and shape of the area. For a GRF, a conformal projection is needed to preserve the measured angles. Using conformal projections, the measured values of angles can be used directly in computations. The linear scale changes from point to point and a scale factor is required to adjust the measured
distances.

There is a large number of conformal projections used all over the world. For example, the plane coordinate system in the U.S.A. uses different projections depending on the shape of each state. If the extent of a state in the east and west direction is wider than that in the north and south direction, the Lambert Conformal Conic projection with two standard parallels is used. This is because the scale is true along the standard parallels. On the other hand, if the extent of a state in the north and south direction is wider than that in the east and west direction, the Transverse Mercator projection related to a central meridian is used. This is because the scale is true along the central meridian or along two lines equidistant from and parallel to central meridian. So, such selections will minimize the scale distortion.

In Egypt, the coordinate system is based on the Transverse Mercator projection. This is because the extent of the country in the north and south direction is wider than that in the east and west direction. For a detailed discussion of different types of map projection and the characteristics and applications of each, see Richardus and Adler (1972) and the U.S. Geological Survey (1987).
2.1.2.2 CONSISTENCY AND ACCURACY

As mentioned earlier, there are different levels of geodetic networks, known as first-, second- and third-order or primary, secondary and tertiary networks. There must be consistency in the accuracy standards from one level to another. The positional accuracy of the different levels should be the same (the consistency concept).

Distances between points at the primary network level are greater than at subsequent levels. Therefore at this first level, any small error in the measured angles will result in a large error in distance. To fulfil the consistency requirements, the primary network should be established according to the highest possible standards followed by the secondary, tertiary and lower-order control. The most accurate instruments are used in the primary order and the observations are repeated more than in any other order.

There are no international accuracy standards for these different levels, but each country has its own specifications according to its needs. Table (2.1) illustrates the standards of geodetic control in Egypt and the U.S.A. Note that 1:10,000 indicates an expected error of ±1 meter for every 10 kilometers.
### TABLE 2.1— ACCURACY STANDARDS OF GEODETIC CONTROL IN EGYPT AND THE U.S.A.

(Ibrahim, 1984, P. 12 and Davis et al, 1981, P. 388)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>LEVEL</th>
<th>STANDARDS</th>
<th>POINTS SPACING</th>
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<tr>
<td>EGYPT</td>
<td>First-order</td>
<td>1:25,000</td>
<td>20-50 km</td>
</tr>
<tr>
<td></td>
<td>Second-order</td>
<td>1:10,000</td>
<td>10-20 km</td>
</tr>
<tr>
<td></td>
<td>Third-order</td>
<td>1:5,000</td>
<td>3-5 km</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>First-order</td>
<td>1:100,000</td>
<td>less than 15 km</td>
</tr>
<tr>
<td></td>
<td>Second-order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class I</td>
<td>1:50,000</td>
<td>less than 10 km</td>
</tr>
<tr>
<td></td>
<td>Class II</td>
<td>1:20,000</td>
<td>less than 5 km</td>
</tr>
<tr>
<td></td>
<td>Third-order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class I</td>
<td>1:10,000</td>
<td>as required</td>
</tr>
<tr>
<td></td>
<td>Class II</td>
<td>1:5,000</td>
<td>as required</td>
</tr>
</tbody>
</table>

Accuracy is a major factor in the design of a GRF. "The accuracy of the control needs to be greater than the positional accuracy with which final details is required" (Dale and McLaughlin, 1988, p. 101). The NRC (1983, p. 25) recommended that if the integration of collected data is to be achieved graphically (as in aerial photography and remote sensing), a relatively low order of accuracy is required; such as that of 1:5,000. On the other hand, if integration is to be achieved numerically (using ground survey techniques), and the control points are to serve multiple purposes, a higher
order of accuracy is required; such as that of 1:20,000 or 1:10,000.

These recommendations may not be valid to many countries. Accuracy requirements should be assigned in each country according to its needs and applications. In Egypt, the third-order (1:5,000) and lower-orders are used when photogrammetry is employed (when data is integrated graphically), and second- (1:10,000) and third-orders are used (when data is to be integrated numerically).

The introduction of new technologies such as the Doppler satellite and GPS, have created a consistency problem in geodetic networks. Inconsistencies occur when technologies such as the GPS obtain greater positional accuracy than that of the existing first-order networks themselves. As a result, either the high quality measurements must be distorted to fit within the existing control accuracy or existing control must be upgraded. The latter is the more desirable solution, but it is also more costly and time-consuming.

Upgrading the existing control using GPS does not necessarily require a resurvey of all higher-order control points; it is very expensive and time consuming. Upgrading existing networks can be done by introducing a number of new
measurements into the existing network and then recomputing
the original measurements (using the adjustment computations)
to compute new values for the coordinates. This approach was
taken in Egypt when the Doppler satellite technique was
introduced, and is currently being used by applying the GPS in
order to upgrade the existing control network.

2.1.2.3 DENSITY OF THE CONTROL POINTS

As stated by the NRC (1983, P. 24), the density of
control points required to fulfill the requirements of an
MPLIS generally depend on two factors:
(i) Whether the positional integration of the collected data
is to be accomplished solely in graphical form, or
(ii) The integration is to be achieved numerically.

When graphic integration is employed, the density of
control is dictated by mapping requirements. For example, if
aerial photography is being used, the number of control points
required to achieve the absolute orientation of a block of
photographs may be sufficient. If data is to be integrated
numerically, relatively high density standards are required in
order to overcome the intervisibility problem.
The recommended density of control points is as follows: Ranges from 0.2 to 0.5 mile (0.3 to 0.8 km) between monuments in urban areas to 1.0 to 2.0 miles (1.6 to 3.2 km) in rural areas (The NRC, 1983, p. 24).

These specifications may not be suitable for other countries as well as many areas inside the U.S. For small parcels (urban areas), it may make sense to put monuments every 0.3-0.8 km to provide the required reference framework (where a lot of features need to be mapped in urban areas which requires more control points). However, in the case of large parcels (rural areas), it is not practical to establish a lot of monuments where only a few of them will fulfill the mapping requirements (fewer features need to be mapped in rural areas). This will be a waste of time and money.

The NRC (1983, p. 24) also stated that: "Ideally the entire area concerned should be covered at a uniform density with a simultaneously adjusted network of control survey stations." Such an ideal situation is blocked by time and money constraints. The density of control points should be established according to the needs of the applications, the format in which the data will be collected (graphically or numerically), and other factors such as topography, land cover and land value. In many cases, responsibility for determining
the density of control points will fall mainly on the field surveyors, who should be familiar with all of the factors related to the area to be covered.

Photogrammetric triangulation is a very effective technique for control densification. It is generally used for large areas (in order to be cost-effective). The cost, in unit terms, can be greatly reduced by fixing more control points using aerial triangulation. The NRC (1983) noted that photogrammetric triangulation can provide as much as a 3-to-1 cost advantage over first-order ground traversing. Accuracies of 3 cm are being realized when the flying height is 1500 m or less (1:10,000 scale or greater).

2.1.3 POSITIONING WITH GPS

GPS provides new opportunities for the development of a GRF in terms of cost and time reduction and the achievement of higher positional accuracy. GPS is a revolution in land surveying because relative positioning accuracies ranging from about 5 mm to several centimeters can be achieved in a short period of observation time using the current available receivers. Cain (1991) stated that many states in the U.S.A., such as Tennessee, New Mexico, Florida, Wisconsin, Washington, Oregon and others have established statewide GPS networks to
accuracies better than one part per million (1ppm).

Intervisibility between the ground points to be fixed is no longer necessary. However, the proposed stations need to be checked for skyward obstructions; any existing obstructions should be carefully plotted so that observational planes can be developed around them. For a more detailed discussion of different GPS techniques and positioning with GPS, see Leick (1990) and Hurn (1989).

GPS capabilities facilitate the upgrading, densification, monitoring and maintenance of geodetic control networks. Moreover, GPS is faster and more accurate than most (if not all) of the other available positioning techniques. One of the most significant advantages of the GPS is that it is a three-dimensional system, i.e. can determine horizontal and vertical positions at the same time (unlike classical methods). Advances in design and manufacturer competition have accelerated the production of highly-sophisticated receivers. The development of GPS receivers was observed by Reilly (1992). This survey shows that the receivers' prices range from $62,500 for the GEOTRONICS receiver (Geotracer 100-2) that can track 12 satellites simultaneously, to $2,995 for the NAVSTAR receiver (XR4-G) that can track 8 satellites simultaneously. Another advantage of GPS is that it does not
require a high level of skill to operate the field equipment, which provides a further cost savings in terms of workload and staffing. All these advantages demonstrate that GPS can increase productivity, reduce costs, and provide accuracy higher than any other system. The following subsections discuss some applications that presenting the GPS capabilities.

(1) **Dane County, Wisconsin:**

The Dane County’s MPLIS provides a practical example of the opportunities that GPS can provide in terms of reducing the required number of control points, time and cost (Moyer and Niemann, 1990). In order to develop this MPLIS, it was necessary to develop a control network of sufficient density. Several techniques were used to establish the control points, such as conventional ground surveys, inertial surveys and GPS. A comparison of the costs of the various techniques was made. The comparison proved that conventional ground survey is the most expensive method, since it requires both more time and more monuments due to the line of sight restrictions. The Department Of Transportation (DOT) comparison between GPS and conventional methods showed that GPS provided the following:
- 82% reduction in the number of stations required,
- 60% reduction in the time required and
- 37% reduction in the total costs.
Table (2.2) gives the actual numbers from this study. By 1993, when the satellite constellation is completed, more reductions in time and cost will be available due to the fact that at least four satellites will be available for observation most of the time from any location on Earth.

**Table 2.2—GPS vs Conventional Techniques—Dane County, Wisconsin** (Moyer and Niemann, 1990, p. 226)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CONVENTIONAL TECHNIQUES</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>- NO. OF STATIONS</td>
<td>463</td>
<td>81</td>
</tr>
<tr>
<td>- TOTAL FIELD DAYS</td>
<td>673</td>
<td>264</td>
</tr>
<tr>
<td>- TOTAL COSTS</td>
<td>$152,410</td>
<td>$95,855</td>
</tr>
</tbody>
</table>

(2) **Phoenix, Arizona:**

Cain (1991) provides another example of the advantages of GPS compared with conventional techniques. A first-order geodetic network containing 85 stations was established using GPS by the Arizona State Department Of Transportation in 1986 in the Phoenix area (Arizona). It took only 10 days to complete the field observations, while it would have taken about 6 months using conventional surveying methods, i.e. 94% time reduction. The cost was about 50% of that of conventional methods. Moreover, the positional accuracy was much better than that of conventional methods.
(3) **Sinai, Egypt:**

In Egypt, the use of GPS to establish a geodetic network for Sinai demonstrated huge time and cost reductions. The time required to establish a control point was reduced to at least 40% of that required in case of using conventional methods. A 40-50% of cost reductions was also observed (Dawod 1992). In Egypt, at least 4 satellites are visible for about 14-18 hours per day as shown in Figure (2.1).

On the other hand, GPS does present some problems including the following:
- The receivers can not be used in cities with many high buildings or in densely-forested areas, unless the forest is cleared around the antenna.
- The cost of receivers may still be high for practicing surveyors with small businesses.
- Since the satellite constellation is not yet complete, observation time may be restricted in some locations (Thapa and Burtch, 1991).
FIGURE 2.1- NUMBER OF VISIBLE SATELLITES VS TIME, EGYPT
2.2 CREATION OF THE CADAstral LAYER (OVERLAY)

2.2.1 NEED FOR PARCEL AUTOMATION

One of the basic layers in the MPLIS environment is the cadastral overlay, which represents the current status of property ownership. The individual unit of the cadastral overlay is the cadastral parcel, which "is an unambiguously defined unit of land within which unique tenure interests are recognized" (McLaughlin and Clapp, 1978, p. 10). The cadastral overlay consists of a series of digital maps showing the size, shape and location of all cadastral parcels within a given jurisdiction. Each parcel is given a unique identifier.

The term "cadastral overlay" is used here to indicate the digital form of the cadastral map. There is currently an increasing trend towards the automation of the cadastral map due to the implementation of LIS/GIS in many counties and agencies. Compared with manual operations, GIS provides opportunities for the creation of cadastral overlay more efficiently and effectively. Cadastral transactions are increasing which requires more editing and continuous updating. Such tasks can be performed efficiently by using computers, thereby automating many of the necessary processes.
2.2.2 APPROACHES TO CREATING THE CADASTRAL OVERLAY

The cadastral overlay is created either by using the existing documents (eg. maps, survey records, deeds, subdivision plats, etc.) or by carrying out new surveys. The latter is very expensive and time-consuming, it should not be implemented unless the existing documents are out-of-date or do not cover the whole area or if no cadastral information exists. The following approaches can be implemented to create the cadastral overlay from existing documents:

(i) The manual digitizing approach:

Digitization is used to directly transform points and lines in existing maps to a digital format. Digitization has become the most common method of vector LIS/GIS data capture, especially in large-scale mapping which requires detailed data (Illert 1991); this is the case with cadastral mapping.

(ii) The automatic digitizing (scanning) approach:

Existing maps can be scanned to create the cadastral overlay, which will be in a raster format. This can be displayed on a graphic screen (of a mini-computer or workstation) and "heads-up digitizing" can be applied to transform the layer to a vector format. In heads-up digitizing, digitization will be done on the computer screen
using the mouse, while in manual digitizing it will be done on a map attached to the digitizer’s tablet. Heads-up digitizing enables the operator to correct any problems and remove any stains or spots that might be found on the original documents. Such stains would be scanned as any other features, since the scanner cannot differentiate between such spots and real features. Using heads-up digitizing, there will not be any need for a computer algorithm to perform the raster-to-vector transformation. The heads-up digitizing will perform both the transformation and editing at the same time.

In case of the cadastral map, manual digitizing is the common method used to convert existing maps to digital format. Dangermond (1989) stated many advantages for manual digitizing that make it preferable to scanning in creating the cadastral overlay: Low capital cost, can be taught to users easily, provides a quite high quality information, digitizing devices are very reliable, etc. Using scanning to create the cadastral overlay may not be practical due to the following: Existing records may not be in a form that can be scanned (maps are either of poor quality or condition), the features may be too few on a single map which make it not practical to be scanned, scanning may not provide the required precision for a cadastral overlay, etc.
However, scanning provides a very efficient tool for capturing large amounts of data, and in the case of maps that have only one feature type, such as soil and vegetation maps. The Dane County Land Records Project (DCLRIP) proved that scanning is very efficient in terms of time and cost when used for such type of maps (Moyer and Niemann, 1990). The DCLRIP used both scanning and manual digitizing to convert the 181 mylar soil sheets in the county into digital format (each map sheet covered an area of about 4300 acres). Manual digitizing was used to convert 62 sheets, while scanning was used to convert the remaining 119 sheets. Scanning increased the amount of data that can be converted into digital format in a certain time period by a factor of 13. Even though the editing time was the same for both scanning and digitizing, scanning reduced the time involved by 62%. The cost savings of scanning were dramatic. Including the costs of hardware, software and other miscellaneous items in the analysis, the average cost of scanning was only 18% of the cost of manual digitizing. Table (2.3) shows the time required to convert a soil map sheet into digital format using both manual and automatic digitizing.
TABLE 2.3- DIGITIZING VS SCANNING - DANE COUNTY, WISCONSIN
(Moyer and Niemann, 1990, P. 225)

<table>
<thead>
<tr>
<th>APPROACH</th>
<th>DIGIT. TIME (HOUR)</th>
<th>EDITING TIME (HOUR)</th>
<th>TOTAL TIME (HOUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Dig.</td>
<td>6.8</td>
<td>3.3</td>
<td>10.1</td>
</tr>
<tr>
<td>Scanning</td>
<td>0.5</td>
<td>3.3</td>
<td>3.8</td>
</tr>
</tbody>
</table>

(iii) The COGO approach:
COGO allows cadastral mappers, when using standard surveying principles, to convert field observations (tabular data) into coordinates. COGO requires entering the measurement of features (e.g. bearings and distances) from known control points. When provided by accurate measurements, COGO provides very high level of accuracy; this why surveyors and engineers like to use this technique.

The problem with COGO is its high cost compared with digitizing. A city with 100,000 parcels spends about $1.5 per parcel using digitizing (a total of $150,000), and spends from 5 to 10 times that amount using COGO (Dangermond, 1989). This creates a controversy between different GIS users. Planners and most of the digital files users are willing to accept the level of accuracy provided by manual digitizing. On the other hand, engineering professions often want highly accurate
coordinates for land boundaries even if it costs more.

The most popular scheme for creating the cadastral layer is the use of a combination of COGO and digitizing (Dangermond, 1989). This can be done by entering geodetic control information using COGO and manual entry of the actual subdivision lot boundaries. For example, Alberta (Canada) used COGO to enter the X,Y coordinates of block corners and block boundaries while the actual lots are manually entered by digitizing.

2.2.3 ATTRIBUTE ATTACHMENT

After the graphic component of the cadastral layer has been created, the attributes (non-graphical component) can be attached to the parcel through a unique parcel identifier (PID). Using this PID, the attributes can be searched and displayed directly onto the map without digitizing it or adding it manually. Many computer packages allow attributes to be associated with the graphic data for display and further manipulation, such as the Facility Mapping System FMS/AC and ARC/INFO. For a detailed discussion about linking non-graphic data to the graphic component, see Huxhold (1991).
There are many attributes which if available can be attached to a parcel, such as: city name; county name; subdivision name; a unique parcel I.D.; the owner's name and address; parcel address and area; the land use; the land value; public use properties and tax value.

2.3 ISSUES IN DATA INTEGRATION

Data collection and database building is by far the most expensive component in the establishment of any LIS/GIS (see Chapter III, subsection 3.1.1.2.2). The integration of different data sets within an MPLIS is not an easy task. The problem arises from the fact that data is collected using different techniques, in different formats, during different time periods, with different accuracies and scales and by different agencies.

Data integration within an MPLIS has two components. The first component deals with the institutional arrangements and cooperation. Chapter III discusses the institutional aspects of data integration and how an institutional cooperation can be achieved. The second component deals with the technical aspects of data integration. The following subsections briefly discuss the technical aspects of data integration and the available tools that help in overcoming technical
problems associated to such integration. Real applications of integrating different data layers using various approaches and techniques are presented.

2.3.1 THE INTEGRATION OF DATA LAYERS

Data integration is a central concept in the MPLIS environment in order to assemble an information base about land. This task requires the solution of many technical problems and the design of many computer programs and algorithms to help in solving such problems. It also requires the existence of different expertise.

The first step in data integration should be the removal of inconsistencies between data sets to ensure their compatibility. Different methods and techniques are applied to ensure consistent data. Shepherd (1992) states that these techniques may be classified on the basis of the information being handled. With spatial data, for example, the following techniques are applied to ensure data consistency: map projection standardization, coordinate registration, feature generalization, edge-matching, scale conversion, raster-vector transformation and others. With attribute data, the following techniques are used: aggregation of data classes, reclassification of raw data, reduction of levels of
measurement to a common level, and others. As a practical example, in the CO-ORDinated INformation on the European environment program (CORINE) which sought to demonstrate the viability and utility of integrated GIS for soil and land use planning in the European community, several techniques were adopted to reduce or remove incompatibility between data sources. These include: conversion of data to a single reference map projection, adoption of two standard scales (1:1 million and 1:3 million) at which to store data and generalization of larger scale data down to these standard scales.

By achieving consistent data sets, the integration of different data layers within an MPLIS database can take place. Different approaches and techniques can be used to integrate different data layers, examples of which are following.

(1) The City of Birmingham, Alabama:

Hanson (1988) explained the techniques applied in the creation of different data layers in the GIS project for the city of Birmingham, Alabama. The process required the conversion of map data from six separate maps in different scales (planimetric, ownership, water system, sewer system, zone districts and flood plain). About 484 planimetric maps were existing and required conversion plus over 152 new maps
for the area of annexation are produced and converted. Prior to conversion, all existing planimetric maps were updated using recent aerial photography. Conventional photogrammetric update using high precision equipment and the production of stable base plats of updated information keyed to each existing planimetric map was applied. Manual digitizing was applied for the conversion process to create 13 different layers.

The planimetric maps were converted first and served as the base map for fitting all layers to be created from the remaining source maps. All planimetric detail was digitized as a single coverage to be used later for the creation of seven layers. The planimetric map was used for the input of 4 tic (control) points of known state plane coordinate values, which are necessary for accurate map registration. The outside boundary of the planimetric map was digitized. This boundary and the tic points were copied to create blank/empty coverage used later to create seven separate layers (center lines, power poles, ownership, water system, sewer system, zone districts and flood zones). This process ensures absolute registration between topic coverages within the area of a single planimetric map.
After digitizing the planimetric map, the street center lines are digitized using streets and alleys depicted on the planimetric map. The ownership map was digitized using the same streets and alleys to position the ownership map to the blockfaces. Next, the zone district layer was digitized by extracting arcs from the centerline, ownership and planimetric coverages that shared boundaries between layers. Next, the water system and sewer system maps were converted. Data was digitized in such a way that maintain the proper relational position of different details to the right of way boundaries contained in the digitized ownership layer. The floodplain maps were converted independently of other source maps. Floodplain maps were digitized and matched with adjacent maps to create a single continuous coverage. The coverage was clipped to the planimetric map boundary to create the flood layer for each respective quarter section map. The creation of the different layers required the use of over 40 digitizing technicians on 3 daily shifts in two separate locations. For more details about this project, see Hanson (1988).

(2) **Prince William County, Virginia:**

McNoldy (1989) explained the techniques used for the implementation of a parcel-based GIS in Prince William County, Virginia. The first step in creating the database was the establishment of a geodetic monumentation network. Through
this network, parcels and other land records can be geographically referenced to the Virginia coordinate system. A network of 80 monuments were established at intervals of two mile spacing, a total of 134 monuments are in place for use by local surveyors. The second step was the obtaining of color aerial photography at 1:14,400 scale, and digitally compile all photo-interpretable detail in the ARC/INFO format. This step produces the coverages necessary to generate planimetric or topographic maps at the desired scale. Next, the parcel boundaries, soil classifications, floodplain boundaries, zoning and land use classifications, wetlands and other features were added. Parcels were identified through the establishment of a geographic parcel identifier number that is derived from the Virginia coordinate system. To keep a continuous updating, the county plans to conduct annual refilights of color aerial photography. To increase the efficiency of emergency services in the county through the E-911 system, a new county-wide addressing grid and street naming system that can be easily adapted to computer use was established. For detailed information about the related issues of creating the parcel-based GIS in the Prince William County, see McNoldy (1989).

AS a matter of fact, many technical issues related to data integration need to be addressed. These include data
editing, error detecting and corrections, the issue of relative positional and geometric accuracies, the integration of non-spatial data with spatial data, standards for data exchange, raster-vector transformation, generalization, edge-matching and many other issues. Each of these issues may require separate research. The literature of LIS/GIS field is full of research and articles related to these different issues such as Star and Estes (1990), Aronoff (1989), Burrough (1989) Ripple (1989), Piwowar et al (1990), Franklin (1979), Nichols (1981), Peuquet (1981 a and b), McMaster (1989) and Anderson and Mikhail (1985). The following subsection discusses available tools helping in addressing such issues.

2.3.2 AVAILABLE TOOLS

New developments in the computer technology and other factors such as human and information developments have provided the LIS/GIS community with new tools that could help in solving the problems of data integration. These tools are:

(i) **Hardware Development:**

New developments in hardware provide the opportunities for faster data processing (high CPU performance) and larger storage space at a reasonable cost. Hennessy (1991), stated that the microprocessor-based machines have been improving in
performance at a rate of between 1.5 and 2 times per year during the past 6 to 7 years. The improvement rates for the mainframes and minicomputers are about 25% per year. Also, the communication between different computer stations became more easily and effective than before. Figure (2.2) shows the CPU performance growth during the last 25 years. The performance is a measure for the computer power, i.e. the number of operations that can be performed per second. These developments in hardware will help in performing the operations required for data integration efficiently.

\[\text{FIGURE 2.2— CPU PERFORMANCE GROWTH (1965–1990)}\]
\[(\text{Hennessy, 1991, p. 19})\]
(ii) **Software Development:**

Data integration requires the design of many computer programs and algorithms to help in solving the technical problems associated with the integration process. As a matter of fact, there has been a huge development in the software field during the last few years, and without such developments it might be impossible to achieve efficient data integration. The new developments in software provide the following:

- New improved programming languages such as C++ and Modula-2 (object-oriented languages), Simscript and SES (simulation languages), etc.
- Software that transform data from one computer to another and integrating several computers in a uniform system (i.e. network communication) such as, NFS (Network File System), StarLan (Local Area Network), etc.
- Continuous developments in database management systems such as, ORACLE (relational database management) and Terra Data (for large volume databases).
- The availability of expert systems such as, NEXPERT-Object which used for planning, scheduling, diagnostics, etc.

(iii) **Human Factors and Information developments:**

There have been many advances in the human factors and information field which provide new capabilities for LIS/GIS. Regarding the man-machine interface, better understanding of
human factors related to the user-program interface has been reached, which lead to the development of user friendly programs. This can be seen through various features provided by different software such as, on-line help, pull down menus, branching menus, etc. There are also the Window systems such as, OpenWindows and XWindows software (on workstations) and Microsoft Windows (on PCs). Such software allows the user to control the size of window, open it at any place on the screen, provides different fonts and formats, etc.

In the information field, information has become more valuable and be considered as a resource that must be managed. This recognition of information value can be seen through the development of a large number of information systems such as, Geographic Information System, Land Information System, Management Information System, Computer Information System, Medical Information System, etc. It can also be seen through the large number of publications and journals such as GIS World, Geo Info Systems, Cartography and Geographic Information Systems, Surveying and land Information Systems, International Journal of Geographic Information System, etc. The fast growth of an association like URISA (Urban & Regional Information Systems Association) that was founded in 1966 reflects this recognition of the information value. "URISA has grown 25 percent annually since the latter part of the
1980s to reach 3,600 members in 1992", (Steger and Bannister, 1992, p. 16). The annual GIS/LIS conference also reflects the recognition of the information value.

These developments provide the tools that can be used to address the different problems of data integration. It is a challenge for the LIS users to learn how to use these tools in solving the problems related to data integration and other activities of an MPLIS.
CHAPTER III

ECONOMIC AND INSTITUTIONAL ISSUES OF AN MPLIS

Since the integration of different data sets is a central concept of an MPLIS in order to assemble an information base about land, it is important to address the institutional issue. This is because these data sets are collected by different organizations, which necessitates an institutional cooperation to integrate such data sets. Meanwhile, the implementation of an MPLIS requires substantial expenditures of time and money, and thus requires economic justification.

The economic and institutional issues relevant to the design and implementation of an MPLIS are the focus of this chapter. The value of an MPLIS and the extent to which the benefits and costs of the system can be quantified are discussed. The fundamental requirements for horizontal and vertical integration within individual organizations and between various organizations, and the impact of such integration on the efficiency and effectiveness of an MPLIS are also discussed.
3.1 THE ECONOMICS OF AN MPLIS

The following subsections discuss the value of an MPLIS, and how the benefits and costs of such system can be evaluated by using a benefit-cost analysis and an avoided cost approach.

3.1.1 THE VALUE OF AN MPLIS

An economic evaluation or justification of an LIS/GIS requires an assessment of its value. Since these systems are designed to serve multiple purposes, economic analysis becomes more complex and difficult. This is due to the fact that costs can be measured directly, while the benefits are not apparent until later.

It should first be noted that the economic value of any MPLIS is derived from the valuable resource provided by such systems, namely information. An MPLIS has tangible benefits in terms of cost and time savings that can be quantified, but many of the benefits are intangible and cannot be easily assigned a dollar value. These benefits include more effective decision-making, effective planning, etc. Intangible benefits should be taken into consideration and assigned a specific value in the assessment of the value of an
MPLIS; failure to do so will result in a significant underestimation of LIS/GIS benefits.

Different approaches can be taken to investigate the economics of an MPLIS and to evaluate the value of information produced by this system. The following subsections discuss two of these approaches: the avoided cost and benefit-cost analysis approaches.

3.1.1.1 AVOIDED COSTS

One of the invaluable benefits of an MPLIS is that the system can be used to serve many tasks in subsequent projects which were not foreseen at the time of design. This could be accomplished at little or no additional cost, thereby providing an avoided cost benefit. A practical example of such a situation, as illustrated by Moyer et al (1988), is the Dane County Land Records Project (DCLR), Wisconsin. This project was initiated in 1982 with the goal of establishing an MPLIS that integrates and uses local land records to meet the needs of a variety of users of such records. The project later demonstrated the capability of serving new or non-routine functions at little or no increased cost. For example, the DCLR was later able to perform an analysis of lands subject to the Food Security Act of 1985. The intent of
this act is to control the soil erosion on marginal farmlands. This involved the withholding of all farm subsidies of the affected land owners until a farm conservation plan is approved. To perform this task, it was necessary to integrate three layers of data: Land owners, soils and land use.

Prior to the DCLR, it took two to four hours to evaluate each of the 100 to 200 farms in each township. Using the database of several townships that was already available in the DCLR, it took only four hours to map an entire township. So, the project served a new function without additional costs plus performing the task more efficiently, i.e. additional cost savings in terms of time reductions.

In another example, a complex soil survey for Dane county was converted into a digital format as part of the Conservation Of Natural resources through Sharing of Information Layers (CONSOIL) Project. Later, the Department Of Transportation used the same digital data for carrying out the soil analysis required for the design of a new highway (Kishor et al, 1990). Such benefits, which are very difficult to assign a dollar value or even to predict at the inception of the program, should be considered and assigned a specific value in the assessment of the MPLIS value.
3.1.1.2 BENEFIT-COST ANALYSIS

Benefit-cost analysis is an economic tool used to organize and evaluate the information required in determining a project's worth. Epstein and Duchesneau (1984) stated that when used properly, benefit-cost analysis makes decision-making more difficult because it identifies a large number of relevant factors that must be considered. It forces the decision-makers to assign values to specific benefits and cost streams that are essentially non-quantifiable. The nature of benefit-cost analysis makes it highly useful in studying the economics of an MPLIS, since the majority of an MPLIS benefits cannot be easily quantified. In the next subsections, the basic benefits and costs of an MPLIS are discussed.

3.1.1.2.1 BENEFITS ASSESSMENT

As previously mentioned, it is not easy to evaluate all of the benefits of an MPLIS, since many are intangible. Drawing on the work of Kishor et al (1990), Wiley (1991) and Gillespie (1991), the following benefits can be identified:

(i) Efficiency Benefits: Efficiency is an overall measure of the performance of a task. Efficiency will result in higher staff productivity and shorter processing times. This results
in reduced time, reduced cost or both.

(ii) Effectiveness Benefits: Effectiveness is the capability of a system to perform tasks which were previously infeasible. This benefit arises when the system is able to increase the quality of the output or produce new outputs.

(iii) Equity Benefits: As cited by Kishor et al (1990), equity benefits occur when a system provides an overall fairness and impartiality through uniform treatment, as perceived by the institutions or clients using it. These benefits will lead to improved organizational or institutional arrangements. Equity is a long-term benefit.

(iv) Increased Revenues: The use of LIS/GIS capabilities in data processing, manipulation and analysis leads to new improvements and revenue potential.

An MPLIS provides many other benefits. The Wisconsin Land Records Committee (1986, p. 6) provides a Benefit-Cost checklist which includes the following benefits:
Enhanced efficiency, fiscal savings, improved service, more accurate and reliable information/records, more effective enforcement, more effective communication, increased opportunities, increased public confidence, technologically-
sound and improved staff morale. Different applications of LIS/GIS demonstrated that the system provides the above benefits. The following subsections discuss examples of such applications.

(1) **The CONSOIL Project**: Efficiency, effectiveness and equity benefits were tested against the different activities of the CONSOIL project and proved an overall success (Kishor et al, 1990). One of the CONSOIL activities was to identify highly erodible land in Dane county. The improved capability of spatial data manipulation and analysis (e.g. polygon overlay, buffering, etc) provided by the system resulted in a staff reduction time of at least 5:1 (efficiency benefit). The same steps were followed in this process for every client providing a perception of increased fairness and impartiality (equity benefit).

Another task of CONSOIL was the processing of soil data (e.g. integration of soil data with other data layers such as land use and land owners data) for the Dane County Soil Erosion Control Plan. This task provided efficiency benefits in processing time due to the flexible nature of the digital data. An effectiveness benefit was provided as a result of the powerful graphics display capabilities which improved the quality of the product. The improved spatial data
manipulation and analysis capabilities that treated the entire covered area in a uniform manner provided an equity benefit.

(2) Another example of increased staff productivity is the New York State Department of National Resources and the Carolina Power and Light which reported a 5 to 10% increase in staff productivity after developing a GIS (Wiley, 1991).

(3) The USGS Test: The USGS developed and tested a practical approach to measure efficiency and effectiveness benefits of GIS use (Gillespie, 1991). A digital benefits test was conducted during late 1990 and early 1991 consisting of over 40 case studies involving a variety of Federal GIS users. 63 successful GIS applications were studied, and the benefits were estimated for over 90% of them. Different techniques were used to measure both efficiency and effectiveness benefits. The efficiency benefits were measured by comparing the cost of producing the output both with and without a GIS. The effectiveness benefits were measured by determining the incremental value of the GIS products. The results of the test showed that 16 systems had only efficiency benefits, 32 system had only effectiveness benefits and 15 systems had both efficiency and effectiveness benefits.
(4) **Utah County:** Utah County (Utah) provides an example of increased revenue benefits. As discussed by Wiley (1991), the airlines in Utah pay taxes based on the number of miles they fly over each county. Prior to the implementation of the GIS system in Utah county (covers an area of 2,143 square miles), the airlines claimed that they flew over only a corner of the county, although the planes could be heard near the center of the county. According to the Federal Aviation Administration requirements, each plane was required to converge on a Very high frequency Omni-Range station (VOR) before turning into Salt Lake City. The county plotted the VOR on its digital map to show that the station is near the center of the county, not in the corner as the airlines had claimed. Using GIS capabilities, the county plotted each plane’s route, showing the convergence over the VOR and calculated the length of each flight over the county. As a result, the county increased its annual revenues by $180,000.

Utah County also used GIS to increase revenues from farm taxes. Many land parcels were identified by their owners as vacant. By overlaying the digital parcel boundaries and the infrared aerial photographs which identify land use, it was discovered that many of these parcels were actually irrigated and well-maintained orchards. These parcels were consequently assigned higher taxes.
3.1.1.2.2 COSTS ASSESSMENT

Theoretically, the cost of an MPLIS implementation can be measured directly. Practically, however, costs are not easily measured especially in the context of a comprehensive and complex MPLIS. The costs will depend on the size and function of the system and on the environment in which the system will be implemented (the institutional structure, the situation of basic infrastructure, the users, etc).

The most obvious costs involved in the implementation of any MPLIS are those invested in hardware, software and data acquisition. Data acquisition and database building account for the majority of the overall cost of the system. "It is a widely accepted fact that 70 to 90% of the cost of a GIS over its lifetime will be in the cost of building and maintaining the database" (Walklet 1991, p. 643). The following is a discussion of hardware, software and database costs required for establishing an MPLIS.

(i) Hardware Costs: Hardware costs include the money to be invested in the procurement of workstations, file servers, personal computers, input and output devices and network hardware. File servers are computers that hold the huge quantities of data contained in the system. The file server
could be a mainframe or minicomputer or workstation. File servers generally direct the data transfer within the network. The input and output devices include tape drives, printers, plotters, digitizers and scanners. Figure (3.1) illustrates a typical hardware configuration. The cost of hardware installation should also be taken into consideration.

FIGURE 3.1- TYPICAL HARDWARE CONFIGURATION ON A LOCAL AREA NETWORK (Sakashita and Tanaka, 1989, P. 584)

(ii) Software Costs: A variety of software provided by different vendors will be needed to run the system. The software selected should be able to provide the various capabilities required to integrate different data layers and performing the required data manipulation and analysis.
(iii) **Database Costs**: Database costs include those required for collecting data, creating the digital database and storing it in the computer. "The total data acquisition cost will be about two to three times that of hardware plus software" (Chock, 1990, p. 527). Following are some examples of real applications showing the costs of hardware, software and database.

(1) Figure (3.2) illustrates the money invested in software, hardware vendor services and consulting for the Department of Natural Resources' GIS, Washington State (Sugarbaker, 1991).
(2) Table (3.1) illustrates the typical cost range of hardware and software of a GIS for a medium-sized municipality covering about 10 square miles and having around 10,000 parcels (Korte 1991, p. 30). The cost of the "first seat" includes a software license, plotter and large disk drive. The cost of the "added seat" includes only a software license.

<table>
<thead>
<tr>
<th>UNIT</th>
<th>FIRST SEAT</th>
<th>ADDED SEATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERSONAL COMPUTER</td>
<td>$ 15 - 30,000</td>
<td>$ 5 - 20,000</td>
</tr>
<tr>
<td>WORKSTATION</td>
<td>$ 30 - 40,000</td>
<td>$ 20 - 30,000</td>
</tr>
<tr>
<td>MINI OR MAINFRAME</td>
<td>$ 50 - 100,000</td>
<td>$ 20 - 50,000</td>
</tr>
<tr>
<td>COMPUTER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3) Dane County, Wisconsin: Table (3.2) illustrates the cost of producing automated data layers for soil erosion control planning in Dane County, Wisconsin, using the database and system developed as part of the DCLRDP (see section 3.1.1.1). The costs are listed per square mile, per township (covering 36 square miles) and state-wide (the 55 counties which covering an area of 40,000 square miles for which an erosion control plan is required). The costs are based on personnel charges of $12.00 per hour, computing costs of $1.50 per CPU.
minute and $1.00 per connect hour on a VAX 8600 computer.

**TABLE 3.2 - COSTS OF PRODUCING AUTOMATED DATA LAYERS FOR SOIL EROSION CONTROL PLANNING IN DANE COUNTY, WISCONSIN.**
(Moyer et al, 1988, p. 204)

<table>
<thead>
<tr>
<th>LAYER</th>
<th>PER Sq. Mi.</th>
<th>PER TOWNSHIP (36 Sq. Mi.)</th>
<th>STATEWIDE (40000 Sq. Mi.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- SOILS</td>
<td>$12.00</td>
<td>$432.00</td>
<td>$480,000</td>
</tr>
<tr>
<td>- LAND COVER</td>
<td>$ 1.50</td>
<td>$ 54.00</td>
<td>$ 60,000</td>
</tr>
<tr>
<td>- WETLANDS</td>
<td>$ 0.05</td>
<td>$ 1.80</td>
<td>$ 2,000</td>
</tr>
<tr>
<td>- CADASTRAL DATA</td>
<td>$ 3.75</td>
<td>$135.00</td>
<td>$150,000</td>
</tr>
<tr>
<td>- PRODUCTION</td>
<td>$ 3.00</td>
<td>$108.00</td>
<td>$120,000</td>
</tr>
<tr>
<td>TOTAL COST</td>
<td>$20.30</td>
<td>$730.80</td>
<td>$812,000</td>
</tr>
</tbody>
</table>

The costs of the soils layer includes costs of scanning, polygon labelling, editing, check-plotting and edge matching of maps. Half of the costs associated with the land cover layer were derived from the acquisition of landsat thematic mapper imagery, and the other half from computer time and personnel. The costs of the wetland layer included only the computer costs needed to convert the format of data already automated by the Wisconsin Department of Natural Resources (this is why this layer's cost is minimal compared with other layers). The costs of the cadastral data represent only half of the cost paid by the county, (the USGS shared the cost of
producing this layer on a 50/50 basis). Production costs include the costs of producing maps and tables data for the erosion control plan. These costs include analysis, overlays and generating plots. For 1992, these layers would have cost more if we take into consideration the increasing personnel charges. The salaries represent a substantial amount of an MPLIS costs (see figure 3.2).

Chock (1990) lists other costs of LIS/GIS as follows:
(i) Preparing the location in which the hardware and software will be installed. This includes air-conditioning, upgrading electric systems, preparing extra walls or partitions to act as thermal insulation for air-conditioning and noise insulation, installing direct telephone lines in order to guarantee uninterrupted communication between the computer system and the outside world, purchasing well-designed and adjustable furniture (chairs), and other miscellaneous considerations.
(ii) The salaries, education and training of staff
(iii) Updating the database and maintaining the whole system.

An MPLIS savings obviously begin after the installation of the system. Savings will be minimal until the system is well-operated, and will increase steadily over time until they will finally exceed operation and maintenance costs. For
example, Korte (1991) demonstrated that the initial costs of the system are fully recovered (payback) by the 11th year of the project. Korte's cost/savings analysis was done for a medium-sized municipality that covers about 10 square miles, has around 10,000 parcels and a population of roughly 25,000. Figure (3.3) illustrates the cost/savings analysis for this GIS over a period of twelve years. The figure shows that a significant start-up expense is required. This initial cost is followed by ongoing system operation and maintenance costs. These annual operating costs are significantly lower than the initial start-up costs, yet they escalate over time due to increases in staff salaries and system management costs.

![Figure 3.3- Costs/Savings Analysis](image)

**Figure 3.3- Costs/Savings Analysis**
(Korte, G.B., 1991, p. 34)
It can be concluded that justifying LIS/GIS costs is not an easy task since the benefits and savings of the system are not immediately apparent. The system normally requires a significant start-up expense for the purchase of hardware, software and database building. Operation and maintenance costs follow, but these are generally lower than the initial start-up costs.

3.2 THE INSTITUTIONAL ISSUE

3.2.1 WHY INSTITUTIONAL COOPERATION

Since the objective of an MPLIS is to assemble an information base about land, it becomes necessary to integrate different kinds of data. As a matter of fact, this different data is generally collected and maintained by different organizations. As a result, the cooperation between these organizations becomes a necessary requirement in order to integrate such data. In the long-term, comprehensive information systems are always more cost-effective than independent systems. An effective organizational structure would reduce data duplication and redundancy, i.e. time and cost reductions.

Modern data processing and information technologies have facilitated the integration of data which is essential to an
MPLIS. This provides the opportunity for increased cooperation between various organizations. The following subsections discuss how effective institutional cooperation in both horizontal and vertical directions can be achieved within individual organizations as well as among various organizations.

3.2.2 COOPERATION WITHIN INDIVIDUAL ORGANIZATIONS

Three general levels of management decisions and control can be identified within any organization (IBM, 1986):

(i) **Top Management**: responsible for strategic planning and control and for deciding the long and short-term objectives of the organization;

(ii) **Middle Management**: responsible for management planning and control and for assuring that the required resources are obtained and used efficiently to accomplish the organization's objectives;

(iii) **Operational Management**: responsible for planning and controlling specific tasks and for assuring that these are carried out efficiently and effectively, figure (3.4).
In most public and private organizations, the implementation of GIS has been haphazard, and within a given organization any number of subgroups may be operating GIS in one form or another (Fisher and DeMers, 1989). These departmental (local) systems have evolved to support their own specific needs with little or no regard for the support they can provide or obtain from other departments. These sub-systems may use different software and hardware, even though they share the organization's database (or at least have data types in common).
This situation results in fractional and redundant data files, duplicated efforts in data collection, and consequently an overall higher cost. The most serious problem arising from these situations is that the organization's business is not handled efficiently or effectively despite the high level of investment in these systems. The main reason for such situations is the lack of horizontal and vertical cooperation within the organization.

The South Florida Water Management District presents a practical example for such a situation (Edmondson, 1989). The district is made up of 10 departments containing approximately 50 divisions. Over the years, there was a lack of interaction among different departments, which resulted in data collection activities and archival procedures without any district-wide standards. This lead to the development of databases in different formats and designs, to a lack of knowledge throughout the organization of existing databases and their accessibility, and to database redundancy.

To avoid these fractionalized systems, an organization-wide study should be conducted to indicate the short- and long-term needs of the organization. This study should indicate the form (centralized or decentralized) and size of the system that meets these needs. The success of this
endeavor depends initially on cooperation between management levels (vertical cooperation) and between different departments (horizontal cooperation) within the same organization.

3.2.2.1 COOPERATION IN THE HORIZONTAL DIRECTION

Cooperation at this level requires the standardization of database design and digital formats throughout the organization. A database committee including representatives of different departments can be established and assigned the responsibility of enforcing the database standardization procedures. This will help in reducing data redundancy and come up with one database representing the entire organization.

Such database can be stored in a central office (centralized system) with all departments having access to this database through a computer network. This is preferable if different departments are in one location or near one another. On the other hand, in an organization that has departments working in different places, a decentralized system is preferable where every department will be responsible for maintaining its own database. If the latter situation exists, a master copy of the organization's database
containing common data between different departments should be stored in a central office. Each department will be responsible for maintaining and updating its data and informing the central office of any changes. Through the central office, all departments can be informed of any changes affecting their database.

If such database is achieved, every user at the operational level knows where to locate the data that answers his questions and only one answer will be given. This helps to restore the lost trust between departments. The final result of that process will be that the organization's work will be done more efficiently and effectively.

The South Florida Water Management District presents an example for achieving horizontal cooperation between different departments (Edmondson, 1989). In 1987, the District adopted a relational database management system (ORACLE) as the organization's official database. This helped in the standardization of database design and digital formats. A year later, a database administrator was hired to develop and enforce new polices that addressed database standardization and design. A database committee including representatives of different departments was established, which promoted a cooperative effort in developing polices and fostered
confidence among various departments. Next, the District adopted a decentralized GIS distributed through three major departments.

3.2.2.2 COOPERATION IN THE VERTICAL DIRECTION

Managers at the three levels of management (top, middle and operational) require different kinds of information and different levels of detail in order to fulfill their tasks (Huxhold, 1991). Those at the operational level require detailed information. Middle managers require less detailed information, and the top-level managers require only summarized reports to make decisions.

Information collected at the operational level is used at the top management level to initiate policies, plans and programs. These plans are then sent to middle management to be formulated into the actions needed at the operational level. This requires efficient communication and an efficient flow of information in both "top-down" and "bottom-up" directions. In this type of communication all levels share in the decision-making process, which encourages cooperation between them.
In order to avoid failure in the system, several considerations should be made (IBM, 1986). The operators who will use the system, mainly those at the operational management level, must be involved in its planning and design. Information must be recognized and managed as a valuable resource throughout the organization. The system should be designed to survive long-term organizational and managerial changes. This can be accomplished by designing the system according to the basic business needs of the organization rather than on the needs of a specific department or section.

As a conclusion, integration in both the horizontal and vertical directions will provide a consistent database, which is one of the main requirements of any successful LIS/GIS (subsection 2.3.1). This integration will provide top-level management with the appropriate information necessary for making decisions that benefit the entire organization.

3.2.3 COOPERATION BETWEEN DIFFERENT ORGANIZATIONS

Cooperation between different levels in an individual organization is a relatively easy task. Cooperation and integration between various organizations having different structures and sizes and with different tasks and needs presents a more complex problem. This problem is considered
by the author to be the main obstacle blocking the development of an MPLIS.

Lack of cooperation between different organizations in collecting, using and storing similar information results in duplication in effort and hence a waste of more time and money which can be saved if such cooperation is achieved. Lack of confidence between different organizations and the difficulty in determining a unified policy are considered to be among the main obstacles in achieving organizational cooperation. The following subsections briefly discuss how the cooperation in both the horizontal and vertical directions can be achieved between different organizations.

3.2.3.1 COOPERATION IN THE HORIZONTAL DIRECTION

Once a consistent database is realized in each individual organization, the next step to be taken towards a county or state-wide MPLIS is the creation of a consistent database that integrates different kinds of data. First, all of the agencies using the same kind of data or sharing common or overlapping areas should correct any inaccurate data and remove any duplicated data (quality control procedures) in order to produce a database representing that kind of data, e.g. utility, geology, agriculture, etc. The next step
involves the integration of the various kinds of data to produce one database that represents the entire area.

The integration of databases will be achieved through two levels (Department of Lands, Thailand, 1985): the data level and the computer level. Integration at the data level includes map projection standardization, coordinate registration, standard codes for different data items, etc. Integration at the computer level includes the use of compatible hardware and software, standard data formats for data exchange, etc. This can be done through the establishment of a database committee including representatives of all sharing organizations. Such committee will be responsible for developing and enforcing new policies for data integration and exchange.

Theoretically, such steps are straightforward. Practically, this is a very difficult (though not impossible) task which requires extensive preparation. Two steps must precede this process. First, the organizations involved must be convinced that they will benefit by sharing their data with others. Second, confidence between the different organizations must be built. It will be difficult, if not impossible, to accomplish these two tasks if the staffs of each organization were not educated and trained in LIS/GIS and
aware that such cooperation is essential to the system.

3.2.3.2 COOPERATION IN THE VERTICAL DIRECTION

A multi-organizational MPLIS requires a new form of management that is responsive to all participants, such as a land information committee or top management control. The cooperation in the vertical direction requires a coordination mechanism among organizations at different levels and with different missions. This requires a cooperation between different levels of government as well as between the public and private sectors (similar to that required between the different management decisions and control in an individual organization).

IN THE U.S.A., the establishment of an MPLIS requires coordination between the federal, state and local governments with the participation of the largest users and contributors in the private sector. As cited by the U.S. Department of Interior (1989, p.3)

"without federal leadership, there will be little chance of compatibility among the land information systems of the individual states. Likewise, the individual county and municipal information will become compatible with each other only where standards and procedures are resolved by a higher level of government".
The U.S. Department of Interior (1989, p. 3) specified the different roles of federal, state, local and private sectors. Federal and state agencies have larger shares of responsibility. Federal agencies are assumed to provide leadership and support in research and technical standards, financial incentives to state and local governments and monitoring and program evaluation. State governments have the power to specify the collection and maintenance of data elements needed by state and local governments plus the use of standard terms and procedures. "The states create and define the legal and operating environment for local governments, where the primary responsibility for land record maintenance rests" (p. 3).

Local governments will be the operating agencies who provide most services to the public. Each local government is responsible for recognizing and maintaining the files for its own land area and uses them for the planning of local programs. Local governments should consider needs of other jurisdictions, including state and federal governments, and provide the means to transmit land information "to and from" the other levels of government". The NRC (1980) stated that the state in cooperation with local governments are responsible for the development of the system activities including organization of local programs, training,
administration of financial aid to localities and aggregation and forwarding of local data to federal programs.

"The private sector plays a dual role as builder and user of an LIS" (p. 3). Many components of the work can be contracted out to the private sector if the technical resources are available. The development of new hardware and software for LIS activities is a key role of the private sector. The private sector can also contribute to the development of the database as well as its maintenance. A strong LIS educational program should be supported by federal, state and local governments, by the private sector and professional associations. Such a program is required in order to provide an educated staff for the development of an MPLIS.

In Australia, the LIS concept has been embraced by the three levels of government (commonwealth, state and local) in addition to the utility authorities (Williamson, 1986). In general, the overall coordination of LIS activities in Australia falls upon the states. All states have developed an LIS strategy and introduced administrative arrangements to manage the statewide LIS. The commonwealth government has a coordinating role to some extent, but its main efforts are directed at commonwealth land data. A national coordination
committee on land information exchange was set up, comprising the chairmen of existing commonwealth, state and territory LIS steering committees to plan, develop and promote a national strategy. The local government and utility authorities take their directions from the respective state governments. Utility authorities have taken the lead in applying the latest technology in developing Facility Information Systems (FISs).

THE WISCONSIN LAND INFORMATION PROGRAM (WLIP) presents a relevant example for the horizontal and vertical cooperation between different agencies in order to create a state-wide MPLIS. The program evolved from 25 years of study, analysis and effort by the state, University of Wisconsin, local government and federal agencies. As defined by the Wisconsin Land Information Committee: Final Report (1987, p. 19):

"The Wisconsin Land Information Program is a long-range strategic mechanism by which Wisconsin can guide the development of modern, efficient Multipurpose Land Information Systems. The program also offers a flexible process through which to implement and maintain these systems".

In August 7, 1985, Governor Anthony Earl created the WLRC by executive order No. 79. The WLRC was comprised of 33 members plus more than 100 individuals affiliated with the WLRC and its subcommittees (12 subcommittee). Representatives to the committee come from the university community, counties,
towns, city government, public utilities, private planning and consulting firms and state and federal agencies. The WLRC's broad mandates were (Wisconsin Land Information committee: Final report 1987, p. 15):

1) To examine and address immediate needs of state and local agencies regarding land records collection and management.
2) To develop recommendation on how Wisconsin should approach the long-term issues of land record modernization.

Figure (3.5) illustrates the WLRC organization and activities.

**FIGURE 3.5 - THE WLRC ORGANIZATION AND ACTIVITIES**
(Wisconsin Land Records Committee: Final Report, 1987, p.16)
The committee's work included extensive reports from each of its 12 subcommittees that explored a wide range of issues related to the development of the program. The work of many dedicated individuals in the WLRC, Wisconsin Land Information association (WLIA), the University of Wisconsin System, state agencies and local governments resulted in the enhancement of the Wisconsin Land Information Program. The Wisconsin Act 31, 1989 created the program and the Wisconsin Land Information Board. The Board includes representatives of the different agencies and different levels of governments (see Wisconsin Land Information Board 1991, P.9) The board shall direct and supervise the land information program and serves as the state clearing house for access to land information. Figure (3.6) illustrates relationships among program components, and between program components and land information producers and users.

For detailed information about the Wisconsin Land Information Program, the duties of different committees and different levels of governments, applied standards, grants and existing situation, see Wisconsin Land Information Board (1991).
3.2.4 CENTRALIZATION VERSUS DECENTRALIZATION

One of the most relevant issues within the institutional context of integrating LISs is where the integrated database should be held: should it be a centralized or a decentralized system? As defined by Antenucci et al (1991), a fully centralized system is one in which a host processing unit stores all data and provides all the processing power to
support devices connected to it. The peripheral devices rely on the host for the execution of all tasks. A decentralized system is one in which the processing power is distributed to relieve one host unit of all the processing tasks, which makes the system more efficient.

The possible configuration of an MPLIS represents a continuous range of opportunities, from a fully centralized system to a fully decentralized one. Each of the two approaches has some merit. A decentralized approach is more popular for user groups who want more direct control of and access to their data. Distributing the processing power reduces response time problems (associated with a centralized system), which reduces time and cost. It provides the opportunity for user groups to develop their own applications rather than depending on a central data processing staff. In a centralized system, the whole job is done in one central office which provides more standardization of database and data exchange between different organizations. This also provides more economic benefits in terms of cost and staff time savings.

The decentralized system allots more control to each organization, and it is crucial that each organization feels such control to share and cooperate in the system. On the
other hand, it places a higher level of responsibility on each organization to maintain and update its data on a routine basis and inform the affected organizations with any changes. This requires additional staff time and effort, i.e. additional costs. A decentralized system is more complex and therefore requires more complex management and control as well as a mature environment of users and organizational structure. I believe that the system should be designed to provide a balance between centralization and decentralization. The next chapter presents an approach to be applied in Egypt that provides such a balance.

**In the U.S.A.,** decentralized systems are popular due to the nature of the society’s structure. In such a society, the centralization concept conflicts with the democratic principles in the decision making process. The Prince William County (PWC) presents an example of a comprehensive LIS that applies a decentralized approach (Barrino-Smith and Davidson, 1991). The system is needed to support the land-related business practices of at least 13 agencies. The county’s LIS is divided into two logical components: The Administrative Information System (AIS) operated by the Office of Management System (OMS) and the Geographic Information System (GIS) operated by the Office of Mapping. The AIS component was defined to be the tabular data and computer processing needed
to support the county's land-related functions. The GIS component was defined to be the geodetic data and spatial processing routines related to daily functions and special projects such as commission studies and census data analysis.

The county decided to adopt a decentralized approach rather than a centralized LIS on a greatly enhanced GIS computer system. The diversity of the required processing among different users in the county presented a strong case against a centralized approach. The county's information system architecture was decentralized without physical or logical interconnectivity among different systems. The GIS computer system (a Prime 2755) was not in any way networked to the AIS Computer system (Hewlett-Packard). GIS data was regularly transferred to the AIS database by magnetic tape. To meet its land information needs, the county progressed from a decentralized to a distributed data processing environment.

To transform the county's decentralized system to a distributed (integrated) one, the OMS sponsored two large procurements to address both the county's LIS and the office automation needs. A major features of these procurements were that any computer system can communicate with any other system in the county, and a single workstation at a user's desk could access any of the systems. The equipment and software
purchased in these two procurements played a vital role in an integrated LIS environment.

Many attempts have been made in the U.S.A. to establish a multi-participant LIS/GIS based on a decentralized or distributed environment. The systems may take different forms depending on the existing institutional structure. Examples of these attempts can be found in Clark County, Nevada (Foresman, 1991), Gwinnett County, Atlanta (Lee, 1991), the South Florida Water Management District (Edmondson, 1989 and 1991), Santa Clara County, California (Finkle and Lockfeld, 1990) and many others. These systems provide many lessons that would be very helpful in the development of an MPLIS.
CHAPTER IV

AN MPLIS IN THE CONTEXT OF EGYPT

4.1 BACKGROUND

Egypt is located at the crossroads of Asia, Africa and the Mediterranean basin. The official language of Egypt is Arabic. English and French are also spoken, especially in the capital city of Cairo. Egypt is the most populous country in the Arab world, and the second most populous country in Africa. The current population of Egypt is about 57 million, and it has an area of about 1,001,449 square kilometers (approximately 1/9 the size of the U.S.).

This chapter discusses the existing situation of the country in which surveying was born; it is a well known fact that ancient Egyptian history provides the earliest reference to land measurement and the registration of titles for land (Dowson and Sheppard, 1956). As early as 3,400 B.C. measures for length were in regular use; the Palermo Stone recorded the height reached each year by the Nile flood. This information
was recorded in Cubits and fractions of a Cubit (the Cubit is an ancient measure of length equalling approximately 18 to 22 inches). It has also been discovered that around 3,000 B.C. the property records of some high officials were recorded on the walls of their tombs (such as Methen on the walls of his tomb at Saqqara) and were recorded in the Royal Registry. These early registers were kept in duplicate, one copy in the treasury and one in the Royal Granary. These registered titles were used in the court in disputes over land ownership. There were no maps of the lands, but paintings on the walls of many kings’ tombs describe land measures. Properties were located and their areas determined after each Nile flood. Since that time, many attempts have been made to determine areas and ownership of lands, mainly for taxation purposes. For more details about the early surveying arrangements in Egypt, see Dowson and Sheppard (1956).

The following sections establish the need for an MPLIS in Egypt in order to meet the development needs. A model for an MPLIS is proposed as well as the approach to be followed for implementing such a model.
4.2 GROWING POPULATION AND THE NEED FOR AN MPLIS

The United Nations (1991) and the U.S. Department of Commerce (1991) reported that the population of Egypt increased from about 33 million in 1970 to about 55 million in 1990. This represents an increase of about 67%. The population is expected to reach more than 85 million by the year 2010 (Figure 4.1).

![Population Growth Chart](image)

**FIGURE 4.1 - POPULATION GROWTH IN EGYPT (1970-2010)**

These figures indicate that the population growth in Egypt is unlikely to diminish in the near future. Almost 98 %
of the population live either along the Nile River Valley and Delta or along the Suez canal. These areas make up only about 3.5% of the country's total area, making them some of the most densely populated areas in the world. Cairo, the capital of Egypt is one of the largest cities in the world, with a population approaching 15 million. This huge population frequently strains essential city services such as water, electricity, sewage and telephones because the original infrastructure was built to accommodate a city of two or three million people.

This situation requires an overall upgrading of various services and infrastructure throughout the country, but especially in Cairo. This is necessary to improve the people's welfare and the country's economy. Moreover, rainfall is minimal which makes the country dependent on irrigated agriculture. EL Kady (1991) assert that over 95% of the cultivated land depends on irrigation, and all of its irrigation water originates outside the country's borders. The increasing population is placing more pressure on the limited supply of agricultural land (7.4 million acres in 1990). Meanwhile, more than 50,000 acres are lost annually due to urbanization. This situation requires extensive agricultural development of formerly desert land to meet the nutritional demands of the population. It also requires
intensive development of all potential sources of water and proper management of the available water.

This situation also requires an efficient policy that controls land use and diverts urbanization into desert fringes of the Delta and Nile Valley. Such action would stop the loss of agricultural area and redistribute the population density. These tasks require the integration of up-to-date legal/fiscal, environmental, and socio-economic data in order to provide an efficient flow of up-to-date information needed for efficient management, better planning and more effective decision-making. This badly needed information can be provided through a well-designed and maintained MPLIS. The need for such system becomes more evident as a result of the shortcomings of the existing surveying and mapping system.

4.3 DEFICIENCY OF THE EXISTING SURVEYING AND MAPPING SYSTEM

The existing surveying and mapping system in Egypt is slow, and most of the data and maps require updating. Appendix A provides a detailed discussion of the existing surveying and mapping arrangements in Egypt as well as the organizational structure. The system cannot meet the needs of daily transactions as well as long- and short-term development needs. The value of an MPLIS must be realized by the Egyptian
government, especially after the failure of the existing system to meet the needs of development projects and keep pace with daily transactions.

The deficiency of the existing system has been evident on many occasions. For example, the system could not provide the data and maps required for the Irrigation Management System (IMS) project, which is financed by the USAID. This project is intended to strengthen the capabilities of the Ministry of Irrigation in the area of irrigation system planning, design, operation, management and maintenance. It was discovered that most of the available topographic and cadastral maps required for planning and designing irrigation improvements were prepared between 1900 and 1945. The majority of these maps are not adequate for the preparation of the feasibility studies and detailed project planning, because they are out-of-date and do not cover the whole area of the project.

The Egyptian Subway project which ran from 1982 to 1987 also proved the need for an efficient MPLIS. The objective of this project was to decrease traffic volume and capacity inside Cairo and to minimize air pollution, especially during rush hours. The subway is approximately 43 km long and contains 33 metro stations, five of which are underground. The construction of this underground section was an extremely
arduous task. Each time workers began to dig, they hit either the main water pipe or electricity and telephone lines, requiring work stoppages to repair the damage. This occurred simply because there were no accurate utility maps available. As a result, the work took longer than anticipated and cost almost twice the initial projected cost. The same situation is destined to be repeated in other projects due to lack of up-to-date land information.

4.4 IMPROVEMENT OF EXISTING INFORMATION SYSTEM

4.4.1 PROPOSED MODEL FOR AN MPLIS (MULTI-LAYER MODEL)

The conceptual model of an MPLIS introduced by Niemann et al at the University of Wisconsin is proposed to be implemented in Egypt, Figure (1.2). Within this model, each agency has a legal mandate to collect and store particular sets of spatial information and is responsible for maintaining its individual data layer in digital form. A mathematical framework provides the link between the individual layers (Niemann et al, 1987) (see the earlier discussion about the function of a GRF, chapter II). Within the organizational structure in Egypt, this model provides more flexibility in terms of organizational cooperation since each organization has a full control of its database.
This model is a decentralized one, it will be modified to be appropriate for Egypt and to create a balance between a centralized and decentralized system. The following subsection provides the proposed design of an MPLIS in Egypt.

4.4.2 PROPOSED DESIGN FOR AN MPLIS

This subsection provides a proposal for an MPLIS that integrates the different subsystems operated and maintained by different organizations, and provides a balance between a centralized and decentralized system. This approach is based on the Egyptian General Survey Authority' (EGSA) system being developed by the Surveying and Mapping (S&M) project (discussed in detail in Appendix B), and the existing organizational structure. Changes are recommended whenever it is necessary.

Since the EGSA is the agency responsible for surveying and mapping activities in Egypt, and to which all other agencies shall refer their surveying and mapping requirements, the EGSA system will represent the central part of the proposed design. The EGSA system is decided to be centralized in Cairo for the following reasons:
- The skilled personnel, expensive specialized equipment, maintenance and support infrastructure for stereo-
compilation/map production requirements are economically available only in Cairo.

- The government's decision-makers using the system are centrally located in Cairo.

- The growing population and migration to urban areas necessitate the existence of easily accessible registers and land use information (in the national level) required for quantitative monitoring of land carrying capacity, property assessment trends, tax rates assessment, planning and trend analysis.

- Allow for special quires and special purpose maps at various scales to demonstrate land ownership demographics and taxation attributes, to demonstrate all parcels within a specified search radius of particular area that might be overlapped between more than one governorate, etc.

The proposed system is as follows:

(1) The establishment of a "Land Information Center" in Cairo: This center will host the EGSA database. This database will contain the planimetric base upon which the national land inventory can be depicted. As planned in the S&M project, the EGSA LIS will consist of two components:

i) Text Land Information, containing information collected in different land registers (land records database)

ii) Spatial Land Information, containing the geographic
The connection between the two components will be the unique parcel identifiers (PID).

The geographic database contains the following layers:

* Cultural layer (buildings, houses, water tanks, etc)
* Transportation layer (roads, railroads, etc.)
* Vegetation layer (ground cover, trees, etc.)
* Hydrographic layer (canals, drains, rivers, etc)
* Political layer (governorate, village, district, hod, etc.)
  - Geodetic control layer (first-, second- and third-order)
  - Cartographic feature codes (for map symbolization)
  - Hypsographic layers (height contours)
  - Cadastral layer
  - Local survey control layer (local survey traverses)

The first five layers comprise the planimetric base. These layers will be created and maintained by the EGSA's Digital Cartographic Department. The information of the cadastral and local survey control layers will come from the EGSA's local survey offices located all over the country. These two layers will be maintained at the local level with regular updates to the Land Information Center (as planned by the EGSA). Since the cadastral layer will be created and maintained in the local level, I do not see that there is a
need for sending this data to the EGSA main office in Giza. Sending such a huge amount of data will reduce the efficiency of the EGSA system.

The land registers data will be acquired, processed and used locally (district or governorate level) and merged in the national land records database in the Land Information Center. Figure (4.2) illustrates the EGSA’s system, which will provide the geographic base for other organizations to create their own layers.

**FIGURE 4.2— THE LAND INFORMATION CENTER (EGSA SYSTEM)**
(2) Each organization will be responsible for creating and maintaining its own data layer (geology layer, utility layer, crime and accident data, etc.)

(3) All organizations will be responsible for informing the Land Information Center of any projects they perform which cause any topographic or property changes in order to update the central database. The Land Information Center will be responsible for informing the other organizations about any updates in the central database that might affect their database.

(4) Standard procedures must be established by the Database subcommittee (section 4.4.4) to facilitate the data exchange to and from the Land Information Center and between different organizations. This will insure that all organizations can send their map changes to the Land Information Center and obtain the most current updates.

(5) Data will be transferred between different agencies and the Land Information Center by using magnetic tapes. It is too costly and too early to develop a computer network that will allow data exchange throughout the whole country (such network is not existing almost in any other country). Meanwhile, within each individual organization, a local
computer network can be developed to facilitate data exchange between different departments and sections. Such networks should be developed under the directions of the System Design Subcommittee (section 4.4.4) to ensure they can be integrated later.

(6) The costs of establishing the Land Information Center as well as its operating costs should be divided among the different organizations depending on the size of their databases. The Land Information Committee (section 4.4.4) would estimate the share of each organization. Figure (4.3) illustrates the proposed design of an MPLIS in Egypt.
FIGURE 4.3 - AN MPLIS THAT PROVIDES A BALANCE BETWEEN CENTRALIZATION AND DECENTRALIZATION
Applying the proposed model requires an overall development of the existing system, including the acquisition of up-to-date data and the computerization of existing systems. The USAID surveying and mapping project in Egypt (Appendix B) is considered to be the logical start towards the establishment of an MPLIS in Egypt. The goal of this project is the production of badly needed topographical and cadastral maps and map-related products, as well as the upgrading of the technical and management abilities of the EGSA. This project will transform the manually operated system to a computerized one. This transformation need to be carefully planned to avoid any failure in the system.

Chrisman and Niemann (1985) mention two approaches to be applied for the computerization of existing systems. The first is the "incremental approach", in which new procedures and technology are brought in gradually without immediately throwing out the old system. The second is the "parachute approach," in which the modernization process is performed by an immediate and total replacement of the existing system.

4.4.3 THE INCREMENTAL APPROACH

The incremental approach has many advantages: The unmanaged rapid implementation of computer technology
(parachute approach) may result in each organization going its own way. In such case, the different organizations may use different hardware and software, which will be difficult and time and money consuming to be integrated later. Many of the systems that have applied a parachute approach have failed, such as several state natural resource inventory systems in the USA (Chrisman and Niemann, 1985). The incremental approach allows the development of LISs by individual departments and agencies that can be integrated later. These systems can be developed within a framework of policies and standards that can be determined and enforced by a central coordinating body. This produces the least number of disruptions among different organizations. As a result, organizational cooperation will be improved, which is essential for developing any MPLIS.

An incremental approach provides time for the preparation of experienced system analysts, programmers, computer and database specialists and data processing managers (training program). It also helps in investigating and evaluating user needs and in fixing problems before going to the next step. It allows the incremental replacement and improvement of technology.
THE LAND TITLING PROJECT (LTP) in Thailand presents a very relevant example of implementing an incremental approach (Department of Lands, Thailand 1983, 1985). It is a 20-year project which aims to issue title deeds for eligible landholders, to improve land administration, to establish a property valuation system and to map all urban areas. Three alternative strategies were evaluated for achieving the project's goals: The first alternative was the continuation of existing "manual" methods and manpower, which would take 85 years in order to issue full titles to all landholders. The second alternative was the introduction of advanced technology, or a "parachute approach". This approach would be blocked by major problems, such as the lack of sufficient, experienced and trained staff as well as the lack of system designers, analysts and software programmers. These problems made this approach inadvisable. The third alternative was a feasible 20 year program using a combination of manual and computerized techniques through different phases, "incremental approach", which was selected. The first (1985-1989) and second (1990-1994) phases proved a successful implementation.

AL-ANKARY (1991) presents another example for the implementation of an incremental approach to establish a GIS in Saudi Arabia. Two approaches were evaluated: The first was a comprehensive integrated information system. This was
difficult to implement due to the lack of technical experience in the field of LIS/GIS, the large requirements for hardware and software and the collection of vast amount of data. Both require substantial human and financial resources beyond the capability of any single municipality.

The second alternative was an incremental system with independently established information systems that could be integrated in a computerized system in a later stage. It was decided to establish the system through four main phases: establishing a central subsystem, regional branching, local branching and integrating the different subsystems. After the completion of the first and part of the second stage, such approach proved successful. The limitations that would block the first alternative were taken into consideration in each stage.

4.4.4 IMPLEMENTING AN INCREMENTAL APPROACH IN EGYPT

The establishment of an MPLIS in Egypt should be well designed to serve the different government's bodies as well as the public and private sectors. In Egypt, both governmental and public bodies are owned by the government with little differences. Mainly, the government's agencies are those responsible for services, such as utility agencies. The
public agencies are those responsible for production, such as industrial sector.

This subsection provides a discussion of the steps of an incremental approach to be implemented for the development of the proposed MPLIS (section 4.4.2).

(i) **Define User Requirements and Available Resources:**

The users of the system include the following: the EGSA, Ministry of Housing and Local Governments, Ministry of Education, The Authority of Roads and Bridges, Transportation Authorities, Police, Ministry of Irrigation, Ministry of Agriculture, Utilities Authorities, Railways Authority, Ministry of Defense, public sector companies, private sector, etc.

A wide study for the assessment and analysis of the needs of different users should be conducted. This study should identify potential LIS/GIS users, their requirements, their expectations from the system, goals and objective of the system, the potential for integration in and beyond each organization, etc. The results of this study should establish the basis for the system design. This should lead to the design of a system that will satisfy the needs of different users, define each organization's role, the implementation
procedures and other issues related to the establishment of such a system.

(ii) The Establishment of a "Land Information Board":

A Land Information Board (LIB) should be established. Such board should include representatives from different levels of government (federal, governorate, local), university community, private planning and consulting firms, and private and public sectors. The LIB will be the central coordinating body and responsible for the development of a national policies and strategies for an MPLIS within which the individual agencies will develop their subsystems. Such board will establish and direct programs and guidelines for design, implementation, planning, research and education, training, financing, etc. A Land Information Committee (LIC) should be established to administer and implement programs and guidelines developed by the LIB. The LIC should include representatives of the different users. It will be the responsibility of the LIC to minimize duplication and strive for linkages between individual subsystems.

The LIC should establish working parties in the form of various subcommittees and assign them the different aspects of the system. The size of each subcommittee will depend on the job assigned to it. These subcommittees would include the
System Design Subcommittee, Database Subcommittee, Training Subcommittee, etc. These subcommittees will prepare reports on land information issues describing the problems, opportunities and recommendations. The LIB will review these reports to develop a national policy and guidelines for an MPLIS. All subcommittees should work closely under the guidelines of the LIB to avoid any gaps or conflicts in their work. The LIC will be responsible for directing the different subcommittees, arranging the meetings between these subcommittees and between them and user groups, and receiving their reports and submit summarized reports to the LIB. The subcommittees' meetings should examine and address the immediate needs of different user groups and develop programs and recommendations to satisfy these immediate needs as well as long-term goals. Figure (4.4) illustrates the LIB and affiliated subcommittees.

(iii) Designing The System:

The System Design subcommittee should develop a system design that meets the requirements of different users. The system should be flexible enough to involve new users in the future. The System Design Subcommittee should develop a plan for hardware/software procurement, installation and provide time schedules for the different tasks.
FIGURE 4.4—LIB AND AFFILIATED SUBCOMMITTEES
(iv) **Training:**

LIS/GIS is still a new field to many users in Egypt (as well as in many other countries). Even if some users are familiar with LIS/GIS applications, they must be taught and trained on the specific GIS package selected for the system as well as the specific applications of the system. The replacement of manual operations requires training on the basic computer skills and computer-based operations. This requires a well designed training program which should account for the following:

- provide users with specific knowledge and computer skills to perform their tasks
- Teach users how to do the tasks they used to perform manually more efficiently and effectively using computer
- Plan for advanced training as well as basic training for new personnel
- Plan for updating training according to the different stages of the system implementation and operation

The training program needs to be designed early during the system design phase. Training schedule should be carefully developed to insure that skilled personnel are available at the time they will be needed during operational phases. The training program should develop a multi-media, multi-method approach to account for all learning styles.
Such approach should include classroom presentation, demonstrations, hands-on practice, operational simulations, etc. Such approach would keep trainee interest and provide the hands-on training that represent the operational environment. This reduces the trainees confusion that would occur if they were subjected to different training and operational environments. Feedback from and evaluation of trainees is very important for the improvement. This would help in adding new classes and/or eliminating ineffective classes and instructors in the future.

(v) Phases of System Implementation:

The following are the proposed phases of implementation:

1) The establishment of The EGSA Subsystem:
This system will be produced by the USAID S&M project. It will provide the EGSA with equipment, experienced staff and different facilities required for data acquisition and the establishment of database (see Appendix B).

Since the EGSA subsystem is already started, it is the responsibility of the Database and System Design Subcommittees to make sure that the rest of the subsystems to be developed by other bodies are compatible with this subsystem. This is necessary for integrating these subsystems in a later phase.
It is essential that this central subsystem be finished as soon as possible, because the EGSA is the only source of surveying and mapping data for the entire country. The EGSA subsystem will be stored in the "Land Information Center" to which the rest of the subsystems will be related, see subsection (4.4.2).

2) The Establishment of Other Individual Subsystems:
These subsystems will be developed and maintained by different agencies. Each subsystem will represent a specific kind of data such as: Utility data, traffic data and crime and accident data. The different agencies will build subsystems to meet their own legal, operational and strategic needs. There must be coordination between different agencies to ensure that these subsystems fit into the overall MPLIS strategy and avoid any duplication. It is the responsibility of the "System Design Subcommittee" and the "Database Subcommittee" to insure that hardware/software and database design of these subsystems are compatible with each other and with the EGSA subsystem so that they can be integrated later. It is the responsibility of the LIC to provide assistance and advice to help in the development of these subsystems and to make sure that they are being developed within the framework developed by the LIB.
3) Integrating Different Subsystems:

This phase will integrate the different subsystems together. This integration will be achieved through two levels: the data level and the computer level (see subsection 3.2.3.1). The integration in the data level has the first priority, because without such integration, combining or matching different data sets on a large scale would be impossible. Integrating different subsystems will be the responsibility of the System Design and Database subcommittees.

It is essential that pilot projects be planned for each subsystem. Pilot projects will help in testing and evaluating the hardware/software, database design, etc. and assure that the system is operational. It will also help in the replacement or the use of new hardware/software. Figure (4.5) illustrates the MPLIS concept in Egypt. The figure shows some of the data layers to be included in the system and the organization responsible for maintaining each layer.
FIGURE 4.5—AN MPLIS CONCEPT IN EGYPT
CHAPTER V

SUMMARY AND CONCLUSIONS

Land is the location of virtually all human activity, and every activity of society both impacts land and depends on it. This fact makes the management of land resources and information essential; such management cannot be achieved without an efficient MPLIS. The development of this system should be part of the basic infrastructure of any country.

Egypt, the country in which surveying was born 4,000 years B.C., badly needs MPLIS. The country has a huge population (57 million) which lives in approximately 3.5% of the country's area. This frequently strains essential services such as water, electricity, sewage and telephone. Moreover, there is a general lack of rainfall, which make the country dependent on irrigated agriculture. The irrigation water itself originates totally outside of the country's borders. Also, there is a continuous loss of agricultural land due to urbanization. The existing surveying and mapping system has failed to meet the needs of many development
projects.

New technologies and international aid provide opportunities for Egypt and other developing countries to improve their LISs and implement computerized systems. The implementation of a computerized MPLIS should follow an incremental approach. Such an approach will encourage organizational cooperation and provide the time required for user training and preparation.

It is recommended that the MPLIS approach developed by Niemann and others at the University of Wisconsin be applied in Egypt. This approach provides more flexibility in terms of organizational cooperation and requires a less sophisticated communication structure. The implementation of this approach requires the establishment of many components, such as the Geodetic Reference Framework (GRF), the cadastral layer, etc.

Concerning the GRF, there must be consistency in the accuracy standards between the different levels of the geodetic networks. The dilemma of establishing a GRF and tying the cadastral boundaries to control points does not
exist in Egypt. The country recognizes the importance and value of the GRF. The problem is that the existing GRF does not cover the entire country and needs to be upgraded and regularly maintained.

It is strongly recommended that GPS be used to upgrade existing control points and to extend new networks (first-order). GPS is both time- and cost-effective and provides the highest available positional accuracy. It provides new opportunities for an MPLIS economics in terms of cost and time reduction and reducing the number of control points. It is recommended that aerial photogrammetry be used for densification purposes (second- and third-order).

It is also recommended that the density of control points be driven by development needs, the format in which data will be collected (graphically or numerically), and other factors such as topography, land value and land cover. The points should not be uniformly distributed since this will increase the already substantial cost of developing an MPLIS.

The cadastral overlay is a basic layer within the MPLIS. The sophisticated mapping technologies that currently exist will significantly aid in the automation process. As cadastral mapping is a dynamic process that requires constant
updating, the system should be capable of performing this task. Manual digitizing, or a combination of digitizing and COGO, should be used to transform existing documents into digital format.

The integration of different kinds of data within an MPLIS is not easy. Accomplishing this integration involves two components. The first component involves the technical problems associated with the integration process. The second component refers to the achievement of institutional cooperation between the organizations using the data. The first step in data integration should be the removal of data inconsistency to ensure its compatibility. Next, the consistent data sets can be integrated using the available software/hardware. New developments in hardware and software provide efficient tools to help in addressing the integration problems.

The implementation of an MPLIS requires economic justification. Since such systems are designed to serve multiple purposes, economic justification becomes a more complex and difficult task. The use of cost-benefit analysis is recommended for analyzing the economics of an MPLIS.
An MPLIS has quantifiable benefits in terms of dollar and time savings, yet many of the benefits are intangible and cannot be easily assigned a dollar value. The tangible benefits include efficiency, effectiveness, equity and increased revenues. The intangible benefits include more efficient decision-making and planning, better information, etc. The use of the system at a later stage to serve new tasks at little or no additional cost represents another intangible benefit.

MPLIS costs depend on the size and function of the system and on the environment in which the system will be operated (the institutional structure, the basic infrastructure and the technical experience of the users). The system requires a significant start-up expense for the hardware and software purchase and for building the database. Operation and maintenance costs will follow, but these are generally lower than the start-up costs. The savings will not be evident immediately, they will be minimal until the system is well-operated, and will increase steadily over time until they will finally exceed operation and maintenance costs.

Institutional cooperation is one of the most powerful obstacles blocking the implementation and development of an MPLIS. The accomplishment of institutional cooperation should
be accomplished first at the level of the individual organizations and subsequently between different organizations. All involved organizations should share in the planning and design of the system. The system should be flexible enough to survive any organizational changes and to evolve with any future extensions. In order to meet these requirements, the system should be designed based on the basic business needs of the entire organization involved rather than on the needs of specific departments or sections. The people who will use the system, mainly at the operational level, should be involved in its planning and design.

A multi-organizational LIS/GIS requires a new form of management that is responsive to all participants. It is recommended that the federal government take the leadership in the development of an MPLIS. One of the most relevant issues in the institutional context is that of centralization versus decentralization. It is strongly recommended that an approach be taken which provides a balance between a centralized and decentralized system.

In Egypt, almost all surveying and mapping activities are assigned to one organization, the EGSA. This situation demands efficient cooperation between departments and sections of the EGSA throughout the country. If such cooperation is
not achieved, the system will be subject to failure.

The achievement of efficient institutional cooperation between the EGSA and other organizations will be the most difficult part of the MPLIS implementation, especially considering the poor telecommunications system in Egypt. Although the establishment of an MPLIS will require a substantial investment, it is critically needed to meet the needs of development projects and to help in managing the country’s natural resources. The establishment of such a system will put the country in which surveying was born on the right track again.
LIST OF REFERENCES


and Mapping (ACSM).


APPENDIX A

EXISTING SURVEYING AND MAPPING ACTIVITIES IN EGYPT

The information in the following subsections is based on
the Government of Egypt (1977 and 1980), Ibrahim (1984),
documents sent to me from Egypt and personal communication.

A.1 ORGANIZATIONAL STRUCTURE

This subsection provides an overview of the organizations
responsible for performing surveying and mapping in Egypt.

(i) The Egyptian General Survey Authority (EGSA)
EGSA is an agency of the Ministry of Irrigation, now the
Ministry of Public Works and Water Resources. It is
responsible for establishing geodetic control, producing
topographical and cadastral maps and establishing and
maintaining cadastral records. The EGSA was established in
1898 with the founding of the survey of Egypt and became the
Egyptian General Survey Authority in 1971. It is the sole
authority responsible for surveying and mapping in Egypt. All
other government bodies, local government units, general
authorities and public-sector companies are required to refer their mapping and survey requirements to the EGSA. These bodies have to present the maps and data resulting from the work carried out by other sources to the EGSA.

The EGSA is responsible for all mapping and surveying activities related to planning, management, development, and decision-making processes as well as presenting technical advice and experience to other countries. The following is a brief description of the EGSA structure in order to demonstrate how survey activities are carried out in Egypt.

EGSA ORGANIZATIONAL STRUCTURE

The EGSA is a large organization whose main office is in Giza with different offices and departments operating throughout the country. The main body of the EGSA consists of the following: (Figure A.1)
- The board of directors,
- The central department for financial and administrative affairs, who is responsible for accounting, routine purchasing and payroll activities.
- The central department for survey services, who is
responsible for individual property ownership information and estimating the value of land to be purchased from private owners for any public development projects.

- The central department for mapping affairs, who is responsible for all of the geodetic, topographical and cadastral surveys and mapping activities through five departments, see figure (A.1).

- The department of legal affairs, which is responsible for legal problems related to cadastral activities.

- The department of organization, planning and training, which is responsible for planning records, employee development and training and consultations.

**FIGURE A.1— THE EGSA ORGANIZATIONAL STRUCTURE**
(Adopted from Ibrahim, 1984)
Although the EGSA is responsible for the official production of surveys and maps in Egypt, other independent efforts also exist in order to meet the needs of projects and project studies initiated by the various government departments and private sector. These efforts must be done with prior arrangement with the EGSA, and the original maps and data of any work must be presented to the EGSA. The organizations other than the EGSA that perform surveying activities are described in the following subsections.

(ii) The Directorate of Military Survey

The Military Survey is the second largest agency responsible for surveying and mapping activities in Egypt. The military survey carries out surveying and mapping projects for military purposes. The main task of the military survey is to acquire and provide the aerial photography required by different organizations and agencies, either governmental or private (Egyptian National Report 1980).

(iii) The Surveying Research Institute (SRI)

The SRI is one of eleven research institutes that constitute the Water Research Center (WRC), the research body of the Ministry of Irrigation. The SRI conducts research related to different survey and mapping activities and carries out many application projects. Among these projects are the
establishment of a geodetic network for Sinai using GPS techniques, and the application of GIS for water resources management. The SRI is structured to cover four broad areas of surveying and mapping: geodesy, cartography (mapping), photogrammetry and LIS/GIS. The SRI obtains financial support from the USAID, UNDP and the International Development Research Center, Canada. The SRI is taking the lead in developing and applying new technologies in surveying and mapping in Egypt.

(iv) The Remote Sensing Center (RSC)

The RSC was established in 1971 as a research division of the Academy of Scientific Research and Technology. The RSC devotes the majority of its efforts to remote sensing imagery research but is also involved in some aerial photography activities. The RSC is involved in research work with government, national agencies and private firms on both local and international levels.

(v) Private sector

The private sector includes two private firms in Cairo which have active, experienced photogrammetric and mapping operations. These are Cairo Engineering and Aero-Precise.
A.2 CADASTRAL ARRANGEMENTS IN EGYPT

Since the MPLIS is the subject of this research, and since the cadastre is a basic component in this system, the cadastral arrangements in Egypt are discussed in details in the following subsections.

A.2.1 EGYPT'S ADMINISTRATIVE STRUCTURE

Egypt is divided into 26 Governorates (similar to states in the U.S.) which do not overlap. These governorates are:

- Four city governorates; Cairo, Alexandria, Port Said and Suez.
- Nine Upper Egypt governorates; Dumyat, El Daqahliya, El Sharqiya, El Qalubiya, Kafir El Sheikh, El Gharbiya, El Minufiya, El Beheira and El Ismailiya.
- Eight Lower Egypt governorates; El Giza, Bini Suef, El Faiyum, El Minya, Asyut, Sohag, Qena and Aswan.
- Five border governorates, Red Sea, El Wady El Gided, Matruh, North Sinai and South Sinai.

Figure (A.2) illustrates the administrative structure of Egypt.
FIGURE A.2—ADMINISTRATIVE STRUCTURE OF EGYPT
The governorates are structured as follows:

All governorates except the four city governorates are divided into towns (urban areas) and districts (agricultural areas). There are approximately 201 districts in Egypt, and none of the towns (or districts) overlap.

The districts are further divided into villages and, the towns are further divided into sectors. Neither villages nor sectors overlap. Each sector is contained in one and only one town, and each village is contained in one and only one district.

The village is further divided into hods. The hod consists of a number of land parcels that as nearly as possible have the same characteristics and the same tax class. The average area of a hod is approximately 80-100 feddan (feddan $= 4200 \text{ m}^2$, approximately one acre).

There is no maximum or minimum area of a parcel, hod, village or district. The sum of the areas of the parcels within a hod equal the total area of that hod, and the sum of the total areas of hods within a village equal the area of that village and so on.

Each governorate, district and village has a unique number and a unique Arabic (and English) name. Within a district, the hod has a unique name, but hods in different districts may have the same name. The hod contained in one village can be moved to another village within the same
district, but the hod cannot be transferred from one district to another.

A.2.2 CADASTRAL MAPPING AND LAND REGISTERS

(i) Cadastral Mapping

The first modern cadastral survey of Egypt was begun in 1898 and was completed in 1907. No triangulation points existed at that time, so the cadastre was done, village by village. The control was in the form of a rapid traverse (local control) around each village. This cadastral survey covered 7.3 million feddans. A series of large-scale map sheets was provided on a 1:4,000 scale and later on a 1:2,500 scale to show the extreme subdivision of land into small holdings.

In 1899, a systematic triangulation of the second-order was begun, and the Registration Of Title (ROT) has been in operation since 1917. This led to the second cadastral survey which was started in 1924. This survey was disrupted in the 1950's, but was later resumed and has been continued to this day. The second cadastral survey has not yet covered all the cultivated land. The developed and cultivated land in Egypt, to which most of the cadastral survey and mapping is directed, covers more than 8.5 million feddans. Approximately 4.5 million feddans of the agricultural lands have currently been
covered by the cadastral survey. Almost all of the planimetric base maps are out-of-date and should be replaced. The cadastral surveys, records and maps covering the other 4.0 million feddans date back to the first cadastre of 1907, and have not yet been updated.

The current rate of the cadastral surveying production is approximately 60 to 70,000 feddans per year. At this rate of production, it will take another 60-65 years to complete the second cadastral survey. A dramatic, sustainable increase in the rate of production is required; this is one of the main goals of the S&M Project that has been launched recently in Egypt, see Appendix B.

To summarize, lands were surveyed and mapped at scale of 1:4,000 and 1:2,500 during the first cadastral survey (1897-1907). By introducing the ROT and triangulation control, the second cadastral survey (begun in 1924) provided more accurate maps and the scale changed to 1:2,500 (compiled from 1:1,000 manuscripts) in rural areas and 1:500 in urban areas. For more details about the procedures of the cadastral survey (field work) and mapping in Egypt, refer to Ibrahim (1984).

(ii) Land Registers

By law, the EGSA regional cadastral survey offices keep
land registers for all parcels. Many registers are produced through the cadastral process. This section briefly discusses these registers and the data they contain. The name of the register is written as it is pronounced in Arabic, and the corresponding English name is written next to it.

- "Daftar EL-Masaha", The Survey Register:

This register provides abundant information on each parcel of land. The register and the map supplement each other, and both are needed for ROT. The current form of the register is the same since 1897, and contains about 14 columns from right to left (as Arabic is written). Each column specifies one attribute related to the land parcel. These columns represent the following: "Name and Number of Hod", "Number of Each Plot", "Area of Each Plot", "Areas of Classes in each Hod", "Category of Lands", "Old Name of Hod", "Final" (permanent) and "Temporary" rates of land tax, "Names of Registered Owners and Names of Occupiers", "Names of Present Occupiers", "Kind of Occupation" and "Distribution of Shared Plots".

- "Daftar EL-Mizanya", The Owner's Register:

This register contains almost the same information as Dafter El-Masaha, but it is arranged by land owners. This register shows the land belonging to each owner, the different tax rates due from each portion, and the total tax due from
that owner to the state. The current registration system is undergoing revision, consolidating the two registers described above. The new register is called "Sigil El-Ainne".

- "Sigil EL-Atyan", The Land Register:

Each village has a land register in which each plot is given a separate page and assigned a reference number. This register provides a comprehensive record of all rights over real estate, their nature and duration, as well as the names of the persons enjoying these rights. As long as the plot remains undivided, the register keeps a continuous record of its life history. If the boundaries of the parcel changed or the parcel is subdivided, the original page and reference number representing the parcel change and new page(s) and name(s) are used to represent the new situation. The old page(s) is carefully preserved in the central archives in Giza as a historical record of the land.

- "Sigil EL-Mullak", The Proprietors Register:

This register contains the names of each proprietor and his plot(s) of land in different hod(s) in one village (note that the owner's register includes the land belonging to each owner in a hod, not a village). Any changes due to sale or transaction of a parcel or a part of parcel is recorded. In this case, the old number(s) of the parcel(s) are canceled and
assigned new number(s).

- "Mukallaфа", The Land Tax Register:

  As determined by law, the cadastral survey department is charged with the transfer of all deeds registered after 1923 to any provincial governorate in order that the land tax register of each governorate is up-to-date. These documents are sent twice a week.

A.2.3 PROBLEMS IN THE CADASTRAL SYSTEM:

There is a considerable amount of data redundancy in the present system. While some records are updated, others are not, which creates an inconsistency in the system. There is a substantial amount of work to be done and many documents are required to update these different records, i.e. time, effort and money consuming. The most serious problem with the system is the slow rate of the cadastral survey, which leaves many cities, towns and agricultural areas without any cadastral maps or records or with out-of-date maps and records.

A.3 GEODE蒂C ACTIVITIES

A.3.1 Horizontal control

The coordinate system in Egypt is based on the Transverse Mercator Projection, and the Helmert 1906 Spheroid with a Semi
major axis = 6,378,200 m and Flattening = 1 / 2983. The Nile Valley and the Eastern Desert area are covered with a complete network of first-, second- and third-order triangulations. The Western desert is less fortunate, containing a very sparse network, with the exception of the New Valley. The EGSA uses precise theodolites, EDM’s, aerial triangulation (for densification purposes) and the Doppler Satellite technique (since 1979) for carrying out geodetic control. The EGSA has recently begun to apply the GPS technique which was applied first by the Survey Research Institute for the establishment of geodetic control in Sinai.

A.3.2 vertical control

The datum adopted for precise levelling in Egypt is the mean sea level at Alexandria Harbor. The first-order level lines in the Nile Valley and Delta are descended from a network begun in 1906. The initial network formed 32 lines in the Delta and was completed in 1936. This network was later extended south along the Nile to Wadi Halfa, near the Southern border of Egypt with the Sudan. Additional lines were run to the Gulf of Suez, to the Red Sea and along the Mediterranean Sea. Another line was extended into the Western Desert.
A.4 AERIAL PHOTOGRAPHY ACTIVITIES

The EGSA has no aircraft; aerial photography is obtained by the Egyptian Air Force or by private or international bodies through special arrangements with the EGSA and the Air Force. The EGSA owns aerial photographic equipment for production and processing, and maintains a staff of photogrammetrists trained and experienced in the field of aerial photography.

The entire country is almost covered by aerial photography at scales ranging from 1:10,000 to 1:60,000. A considerable part of the Western desert is covered by aerial photography at a scale of 1:50,000. Since 1954, photogrammetry has been used exclusively for the production of small- and medium-scale mapping. Systematic coverage of the entire cultivated area at 1:10,000 scale was undertaken three times a year in 1966-1967, in order to survey the main summer, winter and flood crops (cotton, wheat and rice). The horizontal and vertical ground control are based on third-order triangulation chains and levelling bench marks. Aerial triangulation techniques are used to extend the control points. Aerial photography of various areas in Egypt has been taken through cooperation between the Egyptian government and other governments, such as those of France and Canada, and
private and governmental surveying and mapping bodies.

A.5 TOPOGRAPHIC MAPPING ACTIVITIES

Topographical and cadastral maps have been produced in Egypt since 1920. Mapping activities between 1920 and 1980 have included the following:

- A series of 1:500,000 scale maps was completed for the entire country by 1945.
- The Nile basin and Sinai have been mapped at 1:100,000 scale (before 1950 and up to 1960).
- The Nile Valley and Delta plus the Suez Canal have been covered at 1:25,000 scale (most of this series was completed before 1956).
- The most recent series of topographic mapping was done from 1978-1979 by Kenting Earth Science, Ltd., Canada under contract with the Ministry of Irrigation. 400 map sheets at 1:10,000 scale with 0.5 meter contours covering a 4.0 km wide band were made of the area from the Aswan High Dam to the Mediterranean Sea. The 4.0 km wide band was centered on the Nile in the Valley and on both the Rosetta and Damietta branches in the Delta.
- An urban map series of Cairo was completed in 1980 by IGN of France at a scale of 1:5,000 with one meter contours.
Two other large projects have recently been undertaken. The first will map the Eastern Desert and the Sinai at a 1:50,000 scale by a Finnish-funded project in cooperation with the EGSA and the Finnish company Finnmap. The second project will map 400,000 sq. km of the Western Desert from the border of the Sudan to the latitude of Asyut at 1:100,000 scale; this will be a joint project of the Egyptian Military Survey and the U.S. Defense Mapping Agency. In addition to these projects, there is a large-scale project that has been launched by the USAID, see Appendix B.

A.6 REMOTE SENSING ACTIVITIES

The Egyptian Remote Sensing Center (RSC) offers a full range of earth resources data acquisition and processing services. It also conducts many national projects in Egypt such as, the interpretation of geological, geophysical, soil characteristics and ground-water potential in many areas of the country and regional prospecting for iron ores in the Bahariya Oasis in El Fayom area. The RSC conducts many regional and international projects such as, the feasibility study of a proposed transnational project for the major regional aquifer in north-eastern Africa and the Arabian peninsula aquifers, under contract with the United Nations Environmental Program (UNEP).
APPENDIX B

THE USAID SURVEYING AND MAPPING PROJECT IN EGYPT

This project is a component of the IMS project, and is known as the Surveying and Mapping (S&M) component. As described by the GIS World magazine (1989), the S&M project is believed to be the largest mapping project in the world. This project will handle about 10 million parcels, and is under a contract valued at $34 million awarded to the Geonex Company of St. Petersburg, Florida on December 17, 1989. The EGSA is the Egyptian representative responsible for the mapping.

The primary goal of the project is the production of the badly needed, accurate topographic and cadastral maps and map related products, as well as the upgrading of the technical and management abilities of the EGSA. The central management component for all the collected data will be one of the largest LISs ever developed (GIS World, 1989).

B.1 PARTICIPATING ORGANIZATIONS

Almost all of the agencies of the Egyptian government
will use the outputs of this project, as well as the private sector. As the surveying and mapping activities were assigned to the EGSA, the number of participating organizations in this project is limited. Following the successful implementation of the pilot LIS, different organizations can take part. The participating agencies in this project are listed below.

(i) Geonex

The Geonex company is responsible for providing the project team leader and a team of technical experts for the supervision of all technical activities. It is also responsible for planning the project, serving as the EGSA’s agent for the procurement of project-related commodities and training EGSA and Water Planning Group (WPG) personnel on the efficient use of the new equipment and technical procedures.

(ii) The EGSA

The EGSA is responsible for providing counterparts of each surveying and mapping activity. It will also provide production managers, surveying and mapping technicians, programmer/analysts, and other technical and non-technical staff and facilities. The EGSA will neither purchase new equipment nor hire new personnel for this project. The purchase of equipment will be the responsibility of Geonix, as will the training of the existing staff. The EGSA will
organize, schedule and manage the following activities:

- Acquisition of aerial photography
- Photo laboratory processing and print reproduction
- Geodetic and photo control surveys
- Aerial triangulation
- Analog and digital photogrammetric compilation
- Manual and digital cartography
- Printing
- Cadastral surveying
- Land records and cadastral map conversion (input in the LIS/GIS)
- Systems development and programming
- Production scheduling and management
- Training and subcontracting

(iii) The Water Planning Group (WPG)

As the EGSA was assigned the surveying and mapping activities by law, the WPG was included under the same contract. The WPG has responsibilities similar to those of the EGSA with regard to Geonex's technical expertise necessary for the accomplishment of the crop and soil inventories. The WPG will be responsible for the analysis of cropping patterns and soil salinity, and water logging studies. This requires organizing, scheduling and managing the following activities:
- Acquisition of aerial photography
- Photo laboratory processing and print reproduction
- Photographic interpretation
- Data transfer to uniform scale base maps
- Data analysis
- Report preparation
- Production scheduling and management
- Training and subcontracting

(iv) The Egyptian Air Force (EAF)

The Egyptian Air Force works as a subcontractor to Geonex, and is responsible for providing aircraft, crews, mapping cameras and access to its photo lab.

The USAID is responsible for the majority of the funding during the early years of the project, and for the monitoring of the EGSA's and Geonex's progress. Almost $30 million will be paid by the USAID and an Egyptian contribution of 6.5 million Egyptian Pounds (about $2.0 million) will be made in the three-year period of the project.

B.2 PRODUCTION GOALS

The project's three year work plan anticipates the following productions:
(i) **Aerial Photography**

Over 100,000 air photos will be flown in order to cover all of the Nile River from the High Aswan Dam through and including the Nile Delta and the Fayoum Depression. The aerial photography will be acquired by the Egyptian Air Force (EAF), with technical assistance from contractors as needed. All of the production services will be accomplished using the EAF equipment and personnel, according to Egyptian regulations, for security considerations. Table (B.1) illustrates the production goals of aerial photography.

**TABLE B.1- PRODUCTION GOALS OF AERIAL PHOTOGRAPHY, SURVEYING AND MAPPING PROJECT, EGYPT**

<table>
<thead>
<tr>
<th>SCALE</th>
<th>AREA, SQ.KM</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:40,000</td>
<td>50,000</td>
<td>In Delta, Nile Valley, Fayoum and desert fringe.</td>
</tr>
<tr>
<td>1:20,000</td>
<td>35,000</td>
<td>Color Infrared phot., in Delta, Nile Valley and Fayoum during the three growing seasons (winter, summer and flood)</td>
</tr>
<tr>
<td>1:10,000</td>
<td>11,805</td>
<td>In Baheira, Sharqiayah, Assut and Sohag governorates</td>
</tr>
<tr>
<td>1:3,000</td>
<td>200</td>
<td>Covers 40 to 50 villages and towns</td>
</tr>
</tbody>
</table>
(ii) **Mapping**

The mapping production includes cadastral and topographical mapping, cartography operations and field contour surveys. Up-to-date surveying and mapping equipment such as GPS receivers, analytical plotters, digital cartographic input and output devices and map printing equipment will be used.

The following map products will be produced:

- Scale 1:50,000 and 1:100,000 planimetric maps newly constructed from the 1:40,000 photography for the Delta, Nile Valley and Fayoum, (35,000 SQ.KM), as well as topographic contour maps with 5 meter contours for 15,000 SQ.KM of the desert fringes of these areas. 1:100,000 maps will be produced by photographically reducing the 1:50,000 maps.

- Scale 1:10,000 orthophoto maps from the 1:40,000 aerial photography for a 35,000 SQ.KM area will be produced. Overlays with 1 meter contours will be produced from the 1:10,000 aerial photography covering the four governorates previously mentioned, covering an area of 11,805 SQ. KM.

- Scale 1:2,500 digital maps with both planimetry and photography will be constructed from the 1:10,000 aerial photography of the four governorates covering an area of 8,019 SQ. KM. Additional digital maps of scale 1:2,500 covering an area of 1,000 SQ. KM in the Sharqia governorate will be produced.
- Scale 1:500 digital town maps (covering about 40 to 50 towns and villages) will be produced from 1:3,000 aerial photography; this covers a total area of about 200 SQ. KM. The digital maps will show both planimetry and spot heights in the built-up areas and in the surrounding rural areas, and show 0.5 meter contours.
- Cadastral maps of different areas (with a total area of about 6,452 SQ. KM.), in the four governorates.

(iii) Photo Interpretation Products

This portion of the project includes the purchase of commodities to establish a photo interpretation capability within the WPG. The WPG currently does not have any photo interpretation capabilities. The products will include the following:

- Crop identification using 1:20,000 color infrared photography, which covers 35,000 SQ. KM of agricultural area; this will be conducted during each of the three consecutive growing seasons. The resulting information will be transferred to overlays of 1:50,000 scale.
- Overlays of 1:50,000 scale maps will be constructed showing soil salinity changes and areas of water logging, as they are interpreted from the color infrared aerial photography.
- Reports containing several statistical and technical
information such as:
* The total cultivated area in each agricultural district;
* The total area of each of ten major crops during each of the three consecutive growing seasons in each agricultural district;
* The total area served by each main canal and drainage system as identified on topographic maps;
* Any other features of irrigation and/or agricultural interest that can be interpreted from the 1:20,000 color infrared photography.

(iv) Land Information System (LIS)

The central management component for all of these mapped data will be one of the largest LISs ever developed. The data to be entered into this system includes digitized topographic line sheets, crop polygons and the existing cadastral records. The system will handle over 10 million parcels of land-related data, and incorporate the latest GIS, CAD/CAM and AM/FM developments.

At the outset, a pilot LIS is to be established in the Beheira governorate for an area of 666 SQ. KM, with a second pilot covering an additional 1,000 SQ. KM established in the Sharqiya governorate. The pilot project will determine the data input and data usage requirements, hardware and software
needed and other issues related to LIS/GIS. Following successful implementation, the EGSA will extend the system to the rest of governorates.