

Geographic information systems

GIS



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GEOGRAPHIC INFORMATION SYSTEM

Chapter 1 : WHAT IS GIS?

1-1 Introduction and Brief History

The advent of cheap and powerful computers over the last few decades has allowed for the development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS).

The first computerized GIS began its life in 1964 as a project of the Rehabilitation and Development Agency Program within the government of Canada. The Canada Geographic Information System (CGIS) was designed to analyze Canada's national land inventory data to aid in the development of land for agriculture. The CGIS project was completed in 1971 and the software is still in use today. The CGIS project also involved a number of key innovations that have found their way into the feature set of many subsequent software developments.

From the mid-1960s to 1970s, developments in GIS were mainly occurring at government agencies and universities. In 1964, Howard Fisher established the Harvard Lab for Computer Graphics where many of the industries early leaders studied. The Harvard Lab produced a number of mainframe GIS applications including: SYMAP (Synagraphic Mapping System), CALFORM, SYMVU, GRID, POLYVRT, and ODYSSEY. ODYSSEY was the first modern vector GIS and many of its features would form the basis for future commercial applications. Automatic Mapping System was developed by the United States Central Intelligence Agency (CIA) in the late 1960s. This project then spawned the CIA's World Data

Bank, a collection of coastlines, rivers, and political boundaries, and the CAM software package that created maps at different scales from this data. This development was one of the first systematic map databases. In 1969, Jack Dangermond, who studied at the Harvard Lab for Computer Graphics, co-founded Environmental Systems Research Institute (ESRI) with his wife Laura. ESRI would become in a few years the dominate force in the GIS marketplace and create ArcInfo and ArcView software. The first conference dealing with GIS took place in 1970 and was organized by Roger Tomlinson (key individual in the development of CGIS) and Duane Marble (professor at Northwestern University and early GIS innovator). Today, numerous conferences dealing with GIS run every year attracting thousands of attendants.

In the 1980s and 1990s, many GIS applications underwent substantial evolution in terms of features and analysis power. Many of these packages were being refined by private companies who could see the future commercial potential of this software.

Some of the popular commercial applications launched during this period include: ArcInfo, ArcView, MapInfo, SPANS GIS, PAMAP GIS, INTERGRAPH, and SMALLWORLD. It was also during this period that many GIS applications moved from expensive minicomputer workstations to personal computer hardware.

1-2 Definition of GIS :

GIS is built upon knowledge from geography, cartography, computer science and mathematics.

A GIS is an integration of computer hardware and software which can create, manipulate, and analyze a geographically referenced data base to

produce new maps and tabular data.

In a GIS, a relationship between the graphic map data and the tabular database is maintained so that changes to the map are reflected in the data base.

Many definitions have been proposed for what constitutes a GIS. Each of these definitions conforms to the particular task that is being performed. Instead of repeating each of these definitions, I would like to broadly define GIS according to what it does. Thus, the activities normally carried out on a GIS include:

- The measurement of natural and human-made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: elements, attributes, and relationships.
 - The storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map. The features can be of three types: points, lines, or areas (polygons).
 - The analysis of collected measurements to produce more data and to discover new relationships by numerically manipulating and modeling different pieces of data.
 - The depiction of the measured or analyzed data in some type of display maps , graphs, lists, or summary statistics.
-
- GIS is a powerful set of tools for storing and retrieving as well, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986)
 - GIS is an automated system for capture, storage, retrieval, analysis and display of spatial data.(Clarke, 1995)

- A geographic information system is a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for queries and analyses (Duecker 1979)
- **Geographic Information System is :**
 - Container of data - Container of maps
 - Computerized tools for solving geographic problems
 - Spatial decision support system
 - Mechanized inventory of geographically distributed features and facilities method for revealing patterns and processes in geographic information
 - Tool to automate time-consuming tasks

1-3 Why Should I Care About Learning GIS?

- Making Maps: The connection between databases and maps is what gives GIS its power. Maps can be drawn from the database and data can be referenced from the maps, thereby linking spatial data and tabular data. When a database is updated, the associated map can be dynamically updated as well.
- GIS databases include a wide variety of information: Geographic, social, political, environmental, demographic , and many others.
- GIS provides a method to:
 - Analyze the spatial component,
 - Display the data spatially,

- Retrieve data spatially
- Increase Revenue
- Better Service
- Improve Organizational Integration and resource management. A GIS can link datasets together by common locational data that helps sharing data. By creating a shared database, one department can benefit from the work of another.
- Data can collected once and used many times. combing the data captured for only one system with different applications:
 - Reduce the initial effort for data capture
 - Reduce the effort of updating data
 - All users consult the same data avoiding interpretation differences and lower risks.
- Improved efficiency for better decisions. A GIS is not just an automated decision making system but a tool to query, analyze, and map data in support of the decision making process.

Disadvantages of GIS:

- The cost of GIS data can be relatively high to convert existing maps and attributes data into digital format suitable for GUS application.
- A relatively high level of technical expertise is required for successful GIS ventures.

1-4 GIS Applications:

Business

- Retail (locating new locations) - Financial Services

Communications

- Journalism - Media - Telecommunications

Defense

- Military operations on urbanized terrain (MOUT)
- Mission planning
- Targeting and battle damage assessment (BDA)
- Track management and remote sensor monitoring
- Intelligence, surveillance, and reconnaissance (ISR)
- Defense mapping
- Nuclear, biological, and chemical (NBC) incident planning and response
- Defense health systems management

Education

- Curriculum Development
- Enrollment Tracking
- Library Service Area Mapping

Engineering

- Architectural Design - Civil Engineering-
- Chemical Engineering - Environmental

Government

- Homeland Security
- Demographics and Population Trends

Health and Human Services

- Spread and Occurrences of Diseases
- Nurse Routing

Transportation

- Routing
- Public Transportation Efficiency Analysis

Utilities Management

- Electric, gas, and phone networks

Chapter 2 :

Components of a Geographic Information System

2-1 GIS Components:

GIS is an integration of five basic components :

Hardware - Software - Data - People - Procedures

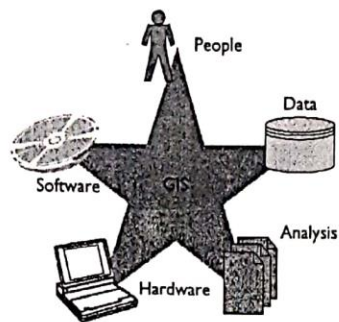


Fig (1) components of GIS

1- Hardware:

a- Input Devices

- 1- Digitizer



Fig (2) Digitizer

- 2- Scanner
- 3- Key board

4- Mouse

5- Disks & CDs

6- Global Position System (GPS)



Fig (3) Global Position System GPS

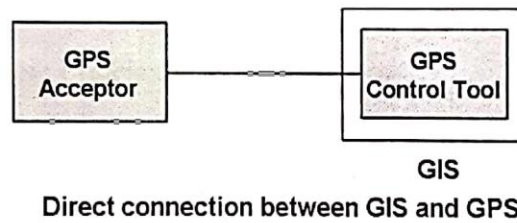


Fig (4) Direct connection between GIS and GPS

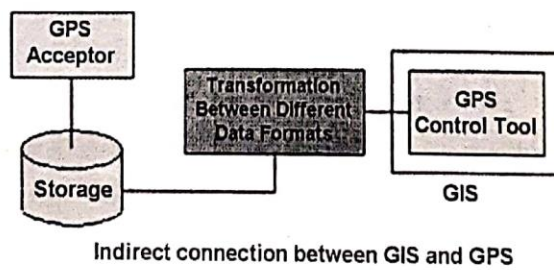


Fig (5) Direct connection between GIS and GPS

7- Digital Camera

8- Environmental Instrumentation

b- Process Devices

c- Output Devices

1- Monitor

2- Printer

3- plotter

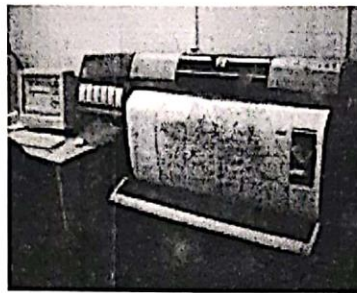


Fig () Plotter

2- Geographic Information Systems Data

▪ Data Comes From:

- Hard copy maps
- Aerial photographs
- Remotely sensed imagery (satellite)
- Point data samples from survey (GPS)
- Existing digital data file

▪ Types of data:

Two basic types of data are normally entered into a GIS.

- **Spatial Data:** It consists of real world phenomena and features that have some kind of spatial dimension. It describes the absolute and relative location of geographic features. (X/Y Coordinate – latitude/longitude). Usually, these data elements are depicted mathematically in the GIS as

either points, lines, or polygons that are referenced geographically (or geocoded) to some type of coordinate system. This type data is entered into the GIS by devices like scanners, digitizers, Global Positioning Systems (GPS), air photos, and satellite imagery

- **Attribute Data** describes the spatial features e.g., for a specific valve you might have the design pressure, manufacturer, model, etc. . Attributes are pieces of data that are connected or related to the points, lines, or polygons mapped in the GIS. This attribute data can be analyzed to determine patterns of importance. Attribute data is entered directly into a database where it is associated with element data.

Attributes and their Types:

- Nominal, e.g., land cover class
- Ordinal, e.g., a ranking
- Interval, e.g., Celsius temperature
- Ratio, e.g. map scale
- Cyclic, e.g., wind direction

Attribute data are stored logically in flat files.i.e., matrix of numbers and values stored in rows and columns, like a spreadsheet

▪ **Components of geographic data:**

Attributes , Geometry , Behavior rules

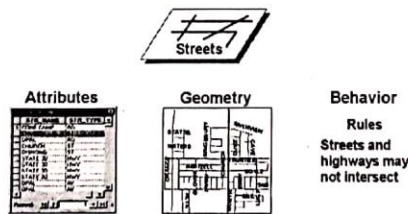


Fig. (6) Components of geographic data

▪ **Data requirement in an information system:**

- **Quality requirement:** there should be sufficient equivalence between the model together with the applied methods and reality
- **Uniformity requirement:** to avoid different interpretation
- **Integrity requirement:** relations and rules in the real world can be tested the integrity of the model
- **Consistency requirement:** updating or changing data should not cause inconsistency or contradiction between the data
- **Protection requirement:** unauthorized use should be prevented as well as the protection of data from outside calamities

▪ **Representing geographic features:**

Vector features : are stored as objects with lists of coordinates defining location and links to attributes.

- Points : a single coordinate
- Lines: a list of coordinates with a starting and an ending point
- Areas: a list of lines which indicate the boundary of the area and any holes or islands within the area.

Raster features : are stored in a matrix of rows and columns with cells defining location and attributes.

- Satellite imagery, scanned images, orthophotos
- No attribute data
- e.g. GIF, TIFF, JPEG, BMP-

▪ **Vector Data Structures/Models**

- **Advantages**
 - Good representation of entity data models

- Compact data structure
- Topology can be described explicitly , therefore good for network analysis
- Coordinate transformation & rubber sheeting is easy
- Accurate graphic representation at all scales
- Retrieval, updating and generalization of graphics & attributes are Possible
- **Disadvantages**
 - Complex data structures
 - Combining several polygon networks by intersection & overlay is difficult ; uses considerable computer power.
 - Display & plotting often time consuming and expensive; especially high quality drawings, coloring, and shading
 - Spatial analysis within basic units such as polygons is impossible without extra data because they are considered to be internally homogeneous
 - Simulation modeling of processes of spatial interaction over paths not defined by explicit topology is more difficult than with raster structures because each spatial entity has a different shape & form.

- **Raster Data Structures/Models**

- **Advantages**
 - Simple data structures
 - Location-specific manipulation of attribute data is easy
 - Many kinds of spatial analysis and filtering may be used
 - Mathematical modeling is easy because all spatial entities have a simple, regular shape
 - The technology is cheap

- Many forms of data are available
- **Disadvantages**
 - Large data volumes
 - Using large grid cells to reduce data volumes reduces spatial resolution; loss of information & inability to recognize phenomenologically defined structures
 - Crude raster maps are inelegant though graphic elegance is becoming less of a problem
 - Coordinate transformations are difficult & time consuming unless special algorithms & hardware are used and even then may result in loss of information or distortion of grid cell shape.

Rasters are faster...

- maps directly onto computer memory structure (array).
 - natural for scanned or remotely sensed data.
 - Continuous surfaces.
 - Spatial analytical operations are faster.
 - compression is easier
 - Rasters are easy to understand, easy to read and write, and easy to draw on the screen
- **Rasters are Faster, but Vectors are Corrector:**
 - Vectors can represent point, line, and area features very accurately.
 - Far more efficient than grids.
 - Work well with pen and light-plotting devices and tablet Digitizers.
 - Not as good with continuous phenomena

- **Vectors and Topology**

Vectors without topology are “spaghetti” structures.

- Points, lines, and areas stored in their own files, with links between them.
- stored w/ topology (i.e. the connecting arcs and left and right polygons).
- Relationships are computed and stored

- **Special Relationships: Topology and Network**

Topology is the mathematical representation of the relationships between spatial features. It is employed to manage common boundaries between features, define and enforce data integrity rules and support topological queries and navigation (e.g. to determine feature adjacency and connectivity, containment, Contiguity)

Networks : describes a connected graph of GIS objects that can be traversed . (pathways, pipelines, hydrology and many other network-based applications)

- **Layers (Themes):**

GIS uses layers called "themes" to overlay different types of information.

Layer: set of features with their attributes

Each theme represents a category of information, such as roads or forest cover.

As with the maps, the layers which are underneath remain visible while additional themes are placed above.

Map: set of layers

- **GIS Data is Complex**

- GIS data volumes are quite large in number and size of elements

- A map draw will require a data base query that returns hundred , even thousands of records
- Vectors or raster geometry be retrieved for display can be many megabytes and large size for each record
- GIS data also has complex relationships and structure, such as network, terrain and topologies

Metadata:

“data about data”

Describes content, quality, accuracy of data, origins, availability

Who created data set?

When was it created?

What format is it?

How accurate is it?

How do I get the data?

Surrogate for digital

3- Computer Software:

- ability to recognize and integrate locational information from a variety of sources
- ability to associate attribute information with geographic locations
- Ability to manipulate or analyze the data to meet the needs of users.
(Overlays – Buffers -Distance – adjacency...)

▪ **GIS functions :**

- 1-Capturing data: Paper maps, Digital data, Coordinates, GPS
- 2- Storing data: Vector formats .Raster formats
- 3- Query: Identifying specific features
Identifying features based on conditions
- 4- Analysis: Proximity - Overlay - Network
- 5- Display : Map – Graphs - Reports
- 6- Output : Paper map - Image - Internet – Document

▪ **What is Not GIS**

- It is not a program that can just display maps or a can just display data on maps, such as Excel can now do
- It is not just a program that allows the creation of maps, like CAD or cartography
- GIS can do all this, but it can also create new information through analysis
- GPS – Global Positioning System
- A static map – paper or digital

▪ **What Do We Know About Maps ?**

* Types of Maps (Familiar Examples)

- Street Maps Environmental Maps
- Census Maps Satellite Imagery

* Information on a Typical Map

- Location of an Object - Information About an Object-

* Problems Using Maps

- Objects can be off the Map
- Information can be missing or out of date

- What you see is what you get (Static)

- * Mapping Basics Projections

- Correct distance vs. correct area
- less important for small areas, but critical for GIS

- Map units (data)

- decimal degrees
- Meters, feet

- Scale or Distance Units (map)

- feet, miles, km

- * Mapping Precision

- Small scale maps generally lack precision to be useful for plotting PA data.
- More precise maps are made using surveying, aerial photos or Global Positioning Systems (GPS)
- Lack of precision can have substantial effects on spatial analysis (like area calculations)

- **Spatial Data Structures GIS and Database Concepts**

- The heart of a GIS is the database
- The heart of the database is the data model
- A geographic database is different than an image database
- The power of almost any information system lies in its ability to relate and combine information gathered from disparate sources

▪ **How does GIS work?**

Major Questions For a GIS

- what exists at a certain location?
- where are certain conditions satisfied?
- what has changed in a place over time?
- what spatial patterns exist?
- what if this condition occurred at this place?
(modeling, hypothesis testing)

The Process of GIS :

- Think about a place or a topic ...
- Ask a question about it ...
- Analyze data to make a map ...
- Explore the patterns that appear ...
- Enhance the data or modify the analysis ...
- Ask a new question ...
- Repeat ...

▪ **How Does GIS Work?**

A- The first step collecting of data: Most of data collection requires some type of data transformation

1. Entity to Object: real world entities to data
2. Symbolization Transformation
 - map to data - digitizing - data to map
 - mapping entities with locational information
3. Object to Object: changes in data structure or scale
4. Map Base Transformations:

- mapping units (e.g. degrees, meters, feet)
- Projection
- Coordinate system - datum

B-The next step is to store the data in a database:

- Database organization is the key to a successful project
- Once the database is complete, analysis can begin
- Analysis also involves the use of some algorithms
- Can be as simple as an overlay
- Can be as complex as a hydrological model

C- Using Information for Decision Making:

- After analysis, the information is communicated, most often through a map
- The information can then be used to make decisions

Chapter 3 : GIS analysis

What is GIS analysis?

The phrase "GIS analysis" encompasses a wide variety of operations that you can do with a geographic information system. This range varies from simple display of features to complex, multistep analytical models

Showing the geographic distribution of data

Perhaps the simplest form of GIS analysis is presenting the geographic distribution of data. This is conceptually the same as sticking pins in a wall map, a simple but powerful methods of detecting patterns.

Here, the map is the analysis. A police department might analyze burglary patterns by plotting the addresses of reported break-ins. The department could make the map more informative by displaying the incidents with different symbols to show the time of day, method of entry, or types of valuables reported stolen.

Querying GIS data:

Another type of GIS analysis is querying, or selecting from, the database. Queries let you identify and focus on a specific set of features. There are two types of GIS queries, *attribute and location queries*.

Attribute queries find features based on their attributes. The police department mentioned above could use an attribute query of its database to obtain a table of crimes that fall into a particular category.

Location queries, or spatial queries, find features based on where they are. The police department could use a location query of the database to find crimes that occurred within a given area.

One way to do a location query is by drawing a rectangle on the map. Here, the police department has selected only those crimes that occurred within the rectangle. These crimes could be studied together to determine if any of them are related.

The police department could also do more complex spatial queries using polygon features, such as census tracts, selected from another layer. One of the most useful features of a GIS is that you can see the results of both spatial and a spatial queries on the map.

Proximity Analysis: Identifying what's nearby:

A third type of GIS analysis is finding what is near a feature. One way to find what is near a feature is by creating a buffer around the feature.

A city planning commission could identify the area within 1.000 meters of a proposed airport by buffering the airport feature. The buffer could be used with other layers of data to show which schools or hospitals would be near the new airport.

Buffer and corridors:

It is a type of geographic analysis to identifying what's nearby from a feature by creating a buffer around the feature

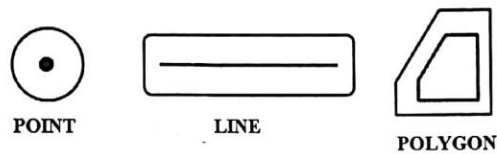


Fig. (7) Buffer and corridors

You can define the area around a hospital that serve an area by creating a buffer 1000 meters around the hospital.

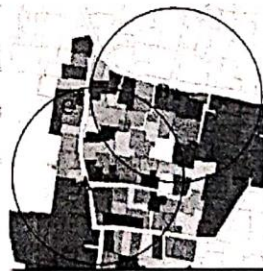


Fig. (8) rules not allow to have a pharmacy in site A because Pharmacy C not Far enough but site B is suitable. GIS can discover that through some steps without the user

Topological Relations

Topology is the mathematical representation of the relationships

between spatial features. It is employed to manage common boundaries between features, define and enforce data integrity rules and support topological queries and navigation (determine feature adjacency and connectivity, containment, Contiguity)

Overlay Analysis:

A fourth type of GIS analysis is overlaying different layers of features. You can create new information when you overlay on set of features with another. There are several types of overlay operations, but all involve joining two existing sets of features into a single new set of features.

GIS's origins lie in thematic cartography using the method of map overlay using manual techniques. The use of transparencies overlays is limited to 4-6 transparencies at maximum. More transparencies make interpretation impossible. Not so in digital situation, where the software can select, combine, integrate, and interpret the data independent of the data density or data type.

There are several different spatial overlay and spatial manipulation operations that you can use on layers including union, intersect, merge, dissolve, and clip.

For example, a farmer wants to find how much land can be planted with a new crop. The crop can't be planted on hillsides and needs soils that are highly permeable. The farmer combines, in a *union* overlay, two existing layers of data about the farm: polygons of the ground surface classified by slope and polygons of soil permeability. The farmer can now select the new polygons that have low slopes and high permeability



Fig. (9) Union overlay analysis

Case study:

what is the best land for planted with a new Species of Wheat crop?.

- The crop need dry condition , long growing season and alkaline soil

Solution:

combines, in a union overlay, several layers of data :

- polygons of soil water
- polygons of soil pH
- polygons of growing season
- select the new polygons that have low water content and high pH and long growing season

Network:

It describes a connected graph of GIS objects that can be traversed .
It describes the line features, how they connect and how that can be traversed

- pathways
- pipelines
- hydrology
- many other network-based applications

Digital Terrain Analysis:

Digital Terrain or Elevation Model (DEM و DTM)



Fig. (DEM)

Maps Production:

- Dynamic Map
- Thematic Mapping
- Free Scale

Doing a complex analysis:

You can combine all of these techniques and many others in a complex GIS analysis. With a GIS you can create detailed models of the world to solve complicated problems. Because a GIS can perform these operations rapidly, it is possible to repeat an analysis using slightly different parameters each time and compare the results. This can allow you to refine your analysis techniques.

Chapter 3: Modeling

Solving Problems with Spatial Modeling in GIS

- A model is an idealized and simplified representation of reality
Not always!
- A Globe is a model of the earth
- A Map is a graphical model of the earth surface

Models are of many different types:

A model could be :

- a theory ,
- a law ,
- a hypothesis ,
- an equation ,
- or even a structured idea

Ex : Vegetation Index Model

Normalized Difference Vegetation Index (NDVI) is used to model the abundance of living plant material from satellite data:

$$NDVI = \frac{IR-R}{IR+R}$$

Ex: A cooking recipe is a model

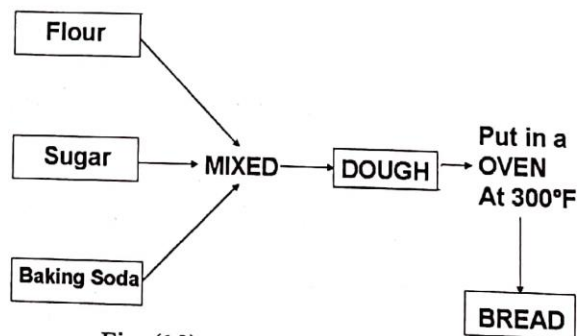


Fig. (10) model of cooking recipe

What is Modeling?

- Modeling is the process of making a model
- The process of making a map is known as Cartographic Modeling

What is Spatial Modeling ?

Is the process of manipulating and analyzing spatial/geographical data to generate useful information for solving complex problems

Why Spatial Modeling ?

- Defining the problem clearly and logically
- Providing a framework for understanding real world processes
- Simulation to extract information which is impossible or too expensive to measure

Modeling Process

- Identify the problem
- Breakdown (simplify) the problem
- Organize the data required to solve the problem
- Develop a clear & logical flowchart using well defined operations
- Run the model and modify it if necessary

Ex : Land Suitability Model

- Finding the suitable forest land for harvesting Criteria:
 - Can't harvest within 300 ft. of roads
 - Can't harvest within 500 ft. of streams

Required data sets:

- Roads
- Streams
- Forest

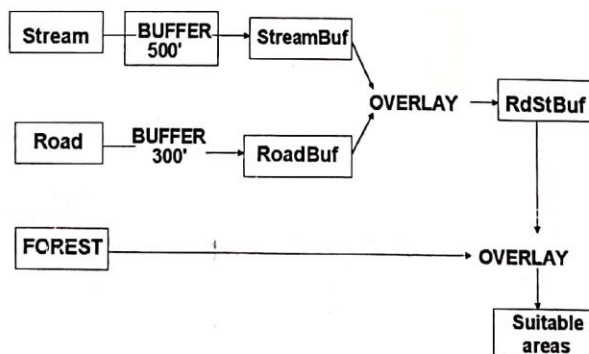
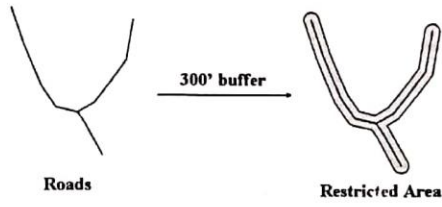
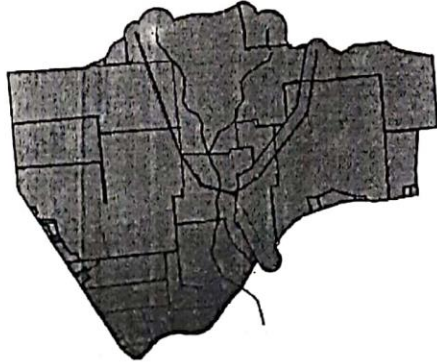
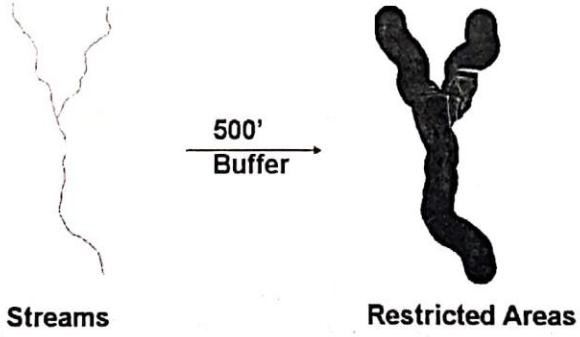


Fig. (10) Land Suitability Model



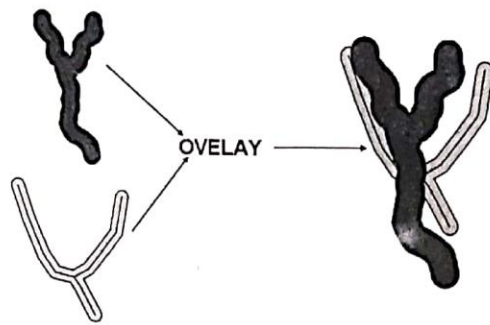
Roads

Restricted Area



Streams

Restricted Areas



Suitable areas for harvesting



Chapter 4: Planning a GIS project

The steps in GIS Project

Step 1: Identify your objectives:

The first step of process is to identify the objective of the analysis. You should consider the following questions when you are identifying your objectives:

- What is the problem to solve? How is it solved now? Are there alternate ways to solve it using a GIS?
- What are the final products of the projects- reports, working maps , Presentation , quality maps?
- Who is the intended audience of these products, the public, technicians, Planners , officials?
- Will the data be use for other purposes?
What are the requirements for these?

This step is important because the answers to these questions determine the scope of the project as well as how you implement the analysis.

Step 2: Create a project database

The second step is to create a project database. Creating the project database is a three-step process. The steps are designing the database, automating and gathering data for the database, and managing the database.

Designing the database includes identifying the spatial data you will need based on the requirements of the analysis, determining the required feature attributes, setting the study area boundary and choosing the coordinate system to use.

Automating the data involves digitizing or converting data from other systems and formats into usable format, as well as verifying the data and correcting errors.

Managing the database involves verifying coordinate systems and joining adjacent layers.

Creating the project database is critical and time consuming part of the project. The completeness and accuracy of the data you use in your analysis determines the accuracy of the results.

Step 3: Analyze the data

The third step is to analyze the data. As you've seen analyzing data in a GIS ranges from simple mapping to creating complex spatial models. A model is a representation of reality used to simulate a process, predict an outcome, or analyze problem.

A spatial model involves applying one to three categories of GIS functionality to some spatial data. These functions are:

- Geometric modeling function – calculating distance, generating buffers, and calculating areas and perimeter.
- Coincidence modeling functions – overlaying datasets to find places where values coincide.
- Adjacency modeling functions – allocating, path finding, and redistricting.

With a GIS you can quickly perform analyses that would be impossible or extremely time-consuming if don by hand.

Step 4: Present the results:

The fourth step is to present the results of your analysis. Your final product should effectively communicate your findings to your audience.

In most cases, the results of a GIS analysis can best be shown on a map.

Charts and reports of selected data are two other ways of presenting your results. You can print charts and reports separately, embed them in documents created by other applications, or place them on your map.

Case study:

Now that you have reviewed the steps in a GIS project, you are ready to begin planning your own project. The next section presents an overview of the steps for the Green valley wastewater treatment plant project.

Planning your project:

Planning is a critical step in any GIS project and can save you time and effort once you get to the database creation, analysis, and mapping steps. During the planning phase you identify the project objectives, define the criteria for the analysis, and identify the data required to support the analysis. You should also consider the approach you'll use for the analysis and what the final products of the project will be. Once you've done this, you can proceed to create the project database.

The city of Green valley is growing. To support this growth, the city is building a new wastewater treatment and recycling plant. The city plans to use conservation and wastewater recycling to help meet its expected water needs.

The diagram (Fig 11) outlines the steps in a GIS project

Step 1: Identify the project objectives:

The objective of this GIS analysis is to find a suitable site for the city's new wastewater treatment plant. The existing plant was sited many years ago using a quadrangle map, acetate overlays, and the city council's

knowledge of the area in consultation with the city engineer. This approach was adequate but time – consuming, and the public was not involved in the process.

The problem has become more difficult as the area has become more developed and environmental and public health regulations more stringent. The council has chosen to use a GIS model in order to speed the process and to ensure that the necessary regulations are complied with.

Because the council recognizes that siting such a plant can be controversial, it wants the analysis to identify all of the parcels that could be used for the plant site, then identify the highly suitable parcels, based on specific criteria. The possible sites will be discussed at a public meeting. The map you create for the meeting should make clear which parcels are highly suitable, which are less suitable, and which are unsuitable.

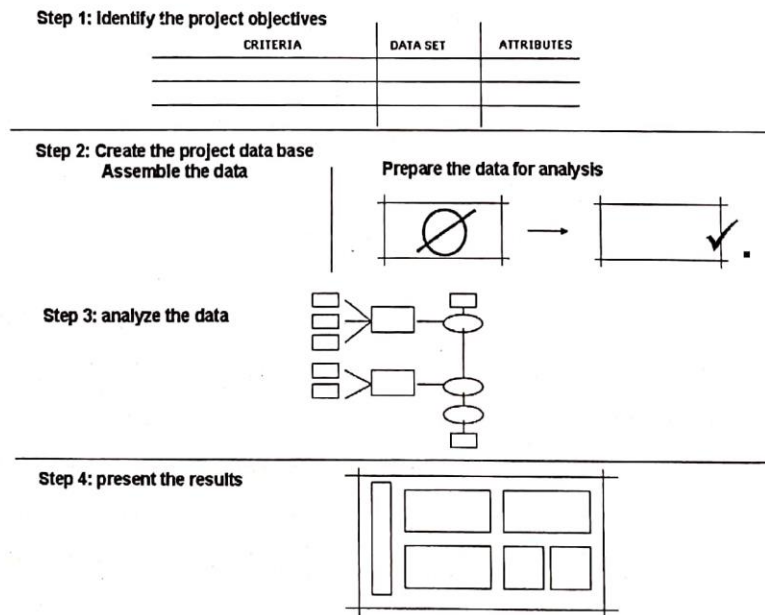


Fig . (11) The steps in GIS Project

The city has provided you with a list of the criteria for a suitable site. The parcels chosen for the site must be:

- Below 365 meters in elevation, to minimize pumping costs.
- Outside the floodplain, to avoid spillage during storms.
- Within 1.000 meters of the river, to minimize pipeline construction for treated water that is discharged.
- At least 150 meters from residential property and parks, to minimize the impact on the city's residents.
- On vacant land that can be developed, to minimize land acquisition and construction costs.

In addition, to further reduce construction costs, the city would prefer that the site be:

- Within 1.000 meters of the main wastewater junction (within 500 meters is considered even more suitable).
- Within 50 meters of an existing road.
- The plant will also require a total area of at least 150.000 m²

A preliminary review of existing paper maps has shown that the most likely location for the plant is in the northwest corner of the city, near the river, and in a low-lying area. This will be the study area for the project. The GIS analysis will allow you to combine the criteria to identify specific parcels that are suitable sites.

Step 2: Create the project database:

Creating the database for this project will be a two-step process. First you'll assemble the existing data and review it. Then you'll prepare the data for analysis. Some of the data will be usable as is; other layers will need additional processing. You may also need to automate some data. You can plan for those tasks by identifying the data layers you'll need and the sources of the data.

Assemble the project data:

Several city of Green valley departments maintain GIS data and have working arrangements to share data for city projects. The city also has data sharing agreements with several regional and state agencies.

Because a database containing much of the data you need already exists, you will not need to spend as much time on designing and automating your project database. However, you will still need to do some database design work for your project database. You'll need to identify the dataset and any attributes required for each criteria. You'll then research the available data to see which layers will meet your needs.

Each of the city's criteria will require a layer of data for the analysis.

Here is a list of the criteria and the corresponding datasets and attributes.

CRITERIA	DATASET	ATTRIBUTES
Less than 365 meters elevation	Elevation	Elevation in meters
Outside the flood plain	Flood plain	N/A
Within 1.000 meters of the river	River	N/A
At least 150 meters from residential property.	Parcels	Land use
At least 150 meters from parks	Parks	N/A
On vacant land	Parcels	Land use
Within 1.000 meters of the wastewater junction	Wastewater junction	N/A
Within 50 meters of a road	Roads	N/A
At least 150.000 sq meters	Parcels	Area in square meters

Note that the parcels dataset will be used for several criteria.

You can now take inventory of the data that you have and see which layers correspond to the required datasets. You can also identify other layers that you need to obtain or create.

- To find areas below 365 meters elevation, you need a source of elevation data. State Department of Transportation (DOT) has provided an elevation grid. You will use a polygon of areas below 365 meters, which has created from the grid. This data is in a shape file format.

- To find parcels outside of the floodplain, you will use the City Planning Department's digital flood zone layer, stored as a feature class in the city's GreenvalleyDB geodatabase.
 - To identify areas within 1.000 meters of the river, you will first need a Layer of the rivers. The County Water Resources Department has a shape file of the river.
 - You will need a dataset of the parcels in your study area. The city tax assessor has a tiled database of parcels stored as shapefiles. Two of these tiles cover your study area. The parcel database includes a land use attribute that you will use to identify residential parcels. So you can buffer them to 150 meters and vacant parcels. You will use the area attribute of the parcel shapefile to identify possible sites with an area of at least 150.000 square meters.
 - To find areas more than 150 meters from parks, you'll need a parks layer. The City Parks and Recreation Department has a feature class of existing parks, which is stored in the GreenvalleyDB geodatabase.
 - There is also a recently discovered historic site in the project study area. The city plans to develop a park around the site, but the proposed park boundary has not been placed into the park feature class yet. You will get this information into your project database by digitizing from a scanned image of the draft park boundary map.
 - To find parcels within 1.000 meters of the main wastewater junction, you will need a layer that includes the junction. The City Utility Department has coverage of the wastewater mains and the junction.
 - To identify parcels that are within 50 meters of a road, you will use the existing streets feature class from the Greenvalley DB geodatabase.
- The Table below lists the layers you'll assemble for the projects database, based on the available data. The source and the format of each layer are also listed.

Layer	Source	Format
Elevation	State Dept. of transportation	Grid
Elevation < 365 M	State Dept. of transportation	Shape file
Flood plain	City planning Dept.	Geodatabase
River	County water resources Dept.	Shape file
Parcels	City tax assessor	Shape files (Tiled)
Parks	City parks and recreation Dept.	Geodatabase
Historic park	City parks and recreation Dept.	Scanned Image
Wastewater junction	City utilities Dept.	Coverage
Streets	City streets Dept.	Geodatabase

- The database will also include the scanned image of the historic park, Which you'll use to digitize the new park. You'll also include the elevation grid, as you may want to display it on your final map.

Prepare the data for analysis:

Based on your review of the data, you'll determine which layers are currently usable and which require additional processing for use in the analysis. Some of the common tasks involved in preparing data for analysis include:

- Checking data quality-making sure the data is accurate and up-to-data.
- Converting data between formats.
- Automating data by digitizing, scanning, converting, or geolocating.
- Defining coordinate systems.
- Projecting layers to a new coordinate system.
- Merging adjacent layers.

You'll need to perform some of these tasks for your project database. You already know, for instance, that the boundary of the proposed park surrounding the historic site will need to be digitized. You have a scanned map of the proposed boundary that you will register to the city's geodatabase and digitize using the parcels layer as a backdrop. The

new park feature will be added to the existing park feature class in the Greenvally DB geodatabase.

You will also need to merge the two parcel tiles for your study area to make the analysis easier to perform.

Most of the data for the project is already in coverage, shapefile, geodatabase, or raster format, all of which ArcGIS can use, simultaneously. There may be cases, though, where you'll need to convert data to a different format—for example, if converting from vector to raster format or from shapefile to geodatabase feature class, for storage in an existing geodatabase.

ArcGIS can display and overlay layers in different coordinate systems as long as the coordinate system for each layer is defined. You'll need to check this, especially for data you've obtained from other sources.

Step 3: Analyze the data:

During the planning stage of the project, you'll want to consider the analysis methodology and list the major steps in the process. That way you can make sure you are aware of all the process. That way you can make sure you are aware of all the datasets you will need and can include them as you create the project database. You may want to create a schematic diagram of the process as a guide.

The diagram (Fig. 12) shows the process for the wastewater treatment plant siting analysis.

The analysis consists of three phases.

In the first phase, you'll create a layer of the areas the plant should be outside of and another layer of the areas the plant should be within.

In phase two, you'll use these layers to select a subset of parcels that are in a suitable location. You'll then select the subset of these that are vacant to create a layer of suitable parcels.

In the third phase, you'll consider the city's additional criteria that define the highly suitable parcels. You'll find the suitable parcels within 50 meters of a road and those within 500 and 1,000 meters of the wastewater junction, then tag them with the appropriate codes so they can be identified on the map. You'll also check to see which parcels are large enough for the construction of the plant.

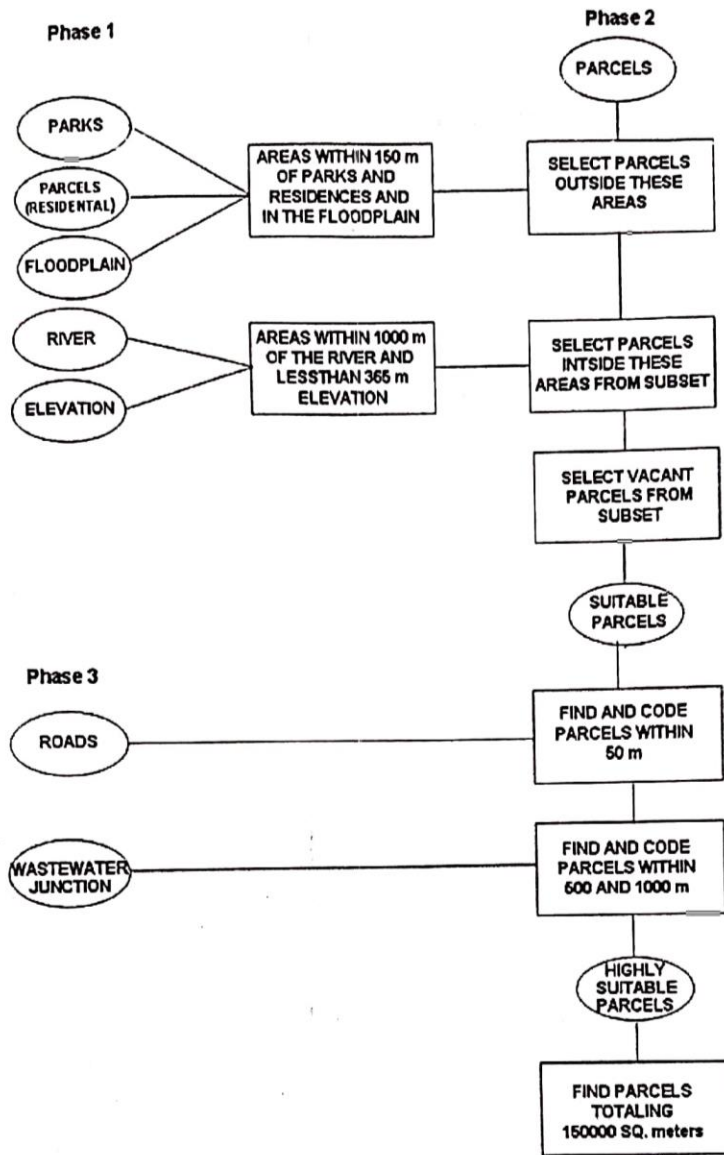
While the schematic shows the major steps in the process, there are a number of interim steps you'll complete in each phase.

Step 4: Present the results:

During project planning you should consider the purpose and audience for your final products. For this project, you'll present the results of the analysis on a presentation quality map that shows the parcels that are suitable and highly suitable sites. The map will be presented to a general audience at a public meeting.

While you don't need to design map layout at this point, you'll want to consider the layers that will be shown on the map. In addition to the analysis layers, you may want to include other layers that will provide context for the analysis results and make the map easier to read and understand.

For this project, in addition to the layers you'll use and create during the analysis, you'll want to show the elevation grid as a backdrop so map readers can see the areas of lower and higher elevation in the city, as elevation has a major impact on the location of the wastewater treatment plant.



(Fig. 12) The process for the wastewater treatment plant sitting analysis.