Implementing A GIS: A Framework of Alternative Technology Options[1]

Working Draft # 2

[1] Prepared by Ramesh S Arunachalam through compilation and analysis from several resources. This paper was drafted at the request of **Shri Karna Ji, Director, Administration and Finance, NCRPB, New Delhi** *and his ideas and comments for drafting of this paper are gratefully acknowledged*. **2nd Draft, dated, D**ecember 13th 2008. References are to be added and will be done in 3rd draft. **This can become a GIS orientation manual subsequently.** *Please do not circulate or quote or cite without permission. This is not to be used for commercial purposes. This note has been prepared, on pro bono basis, primarily for knowledge sharing, capacity building and strategic choice of alternative GIS technology options.*

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Implementing A GIS: A Framework of Alternative Technology Options[2]

A The Need for Geographical Information Systems (GIS)

1. Ninety percent of all information has a geographic context. Simply put, most of the information that exists can be placed on a map. Because this information is context or location specific, it can be stored in a GIS. A GIS[3] is a computer system designed for capturing, storing, integrating, analyzing and displaying data from a geographic perspective. It is essentially a tool for decision making. Its powerful analytical and visualization capabilities provide answers to important questions that must be answered in order to make sound and informed decisions. A GIS allows us to develop models, create scenarios and ultimately provide solutions for various environmental and socio-economic problems that exist. Undoubtedly, Geographical Information Systems are helping to create revolutionary new applications and possibilities. Google Earth, online vehicle tracking and internet mapping applications are types of technologies that have significantly altered the way we exist and perceive reality. The future of GIS looks brighter now than ever before and with the continuous improvements in technology, it is evident that GIS is here to stay.

B What is Geographic Information Systems (GIS)

2. A GIS is much more than simply a program that draws elegant maps. A GIS not only shows a map of a geographic region, it also associates some database with that map. The map can then be used for more than presentation purposes: it can also be used as a "handle" to grab the data that is associated with the map. For example, a simple map-drawing package might enable you to display a map of NCR showing various cities in different colours. A GIS could add more capability by associating a database of demographic variables such as population or average income with each city. You could then draw a map of NCR that showed each city coloured by a demographic variable, with more populous city's coloured blue and less populated city's coloured green and cities in between coloured some intermediate shade from blue to green. Even a very simple GIS should be able to draw the map based on information from the database associated with the map.

3. A GIS comprises the following basic elements:
   - Technology that is used to analyze features that make up the earth's surface
   - System that includes software, hardware, data, and personnel
   - Use of the relative location of features in x, y, and z space to establish relationships between features

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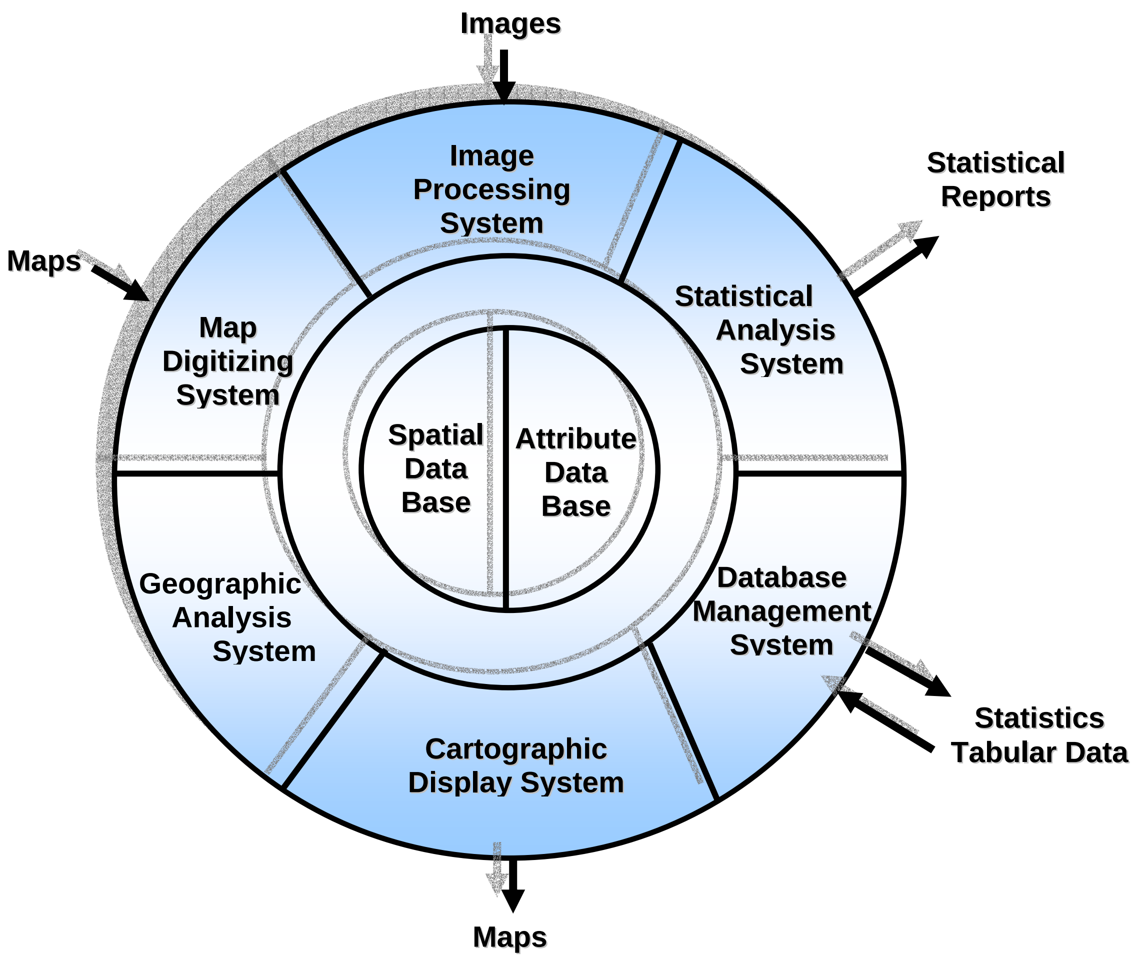
[3] Globally GIS is being utilized in almost all industries. For instance, emergency planners utilize it to determine flood prone areas, first responders utilize it to find the best route to an emergency, businesses utilize it to find suitable locations for their stores, insurance companies utilize it for risk management and reinsurance purposes, banks utilize GIS to find suitable locations for ATM machines and the police use it to analyze and determine crime hotspots. Globally, there are more than 2 million users of GIS. However most people are still unaware of how the technologies impact upon their daily lives.

4. GIS software provides the functions and tools needed to store, analyze, and display information about places. The key components of GIS software are:

- Tools for entering and manipulating geographic information such as addresses or administrative boundaries
- A database management system (DBMS)
- Tools that create intelligent digital maps that you can analyze, query for more information, or print for presentation
- An easy-to-use graphical user interface (GUI)

5. A GIS system typically includes the following (functional) sub-systems, each with different functions and objectives

Figure 1: GIS and its Various Sub-Systems



6. Further, GIS stores information in themes or layers that hold data about a particular kind of feature. Each layer is linked to a specific position on the globe.

7. A GIS usually has the following objectives:
   - Maximize the efficiency of planning and decision making
   - Provide efficient means for data distribution and handling
   - Elimination of redundant data base - minimize duplication
   - Capacity to integrate information from many sources
   - Complex analysis/query involving geographical referenced data to generate new information.

8. Typically, for any application there are five generic questions a GIS can answer:
   - *Location* - What exists at a particular location?
   - *Condition* - Identify locations where certain conditions exist.
   - *Trends* - What has changed since?
   - *Patterns* - What spatial pattern exists?
   - *Modeling* - What if ……….?

9. Benefits from implementing a GIS generally are the following:
   - better maintenance of geospatial data in a standard format and geospatial data and information are easier to search, analyze and represent
   - easier revision and updating
   - more value added products
   - easy sharing and exchange of (geospatial) data
   - improvement in productivity of staff and enhanced efficiency
   - time and money savings
   - better and timely decisions

C Elements of a GIS

10. The GIS has four basic elements. They are hardware, software, data, and liveware and table 1 gives details of the different elements below.

Figure 2: Elements of a GIS

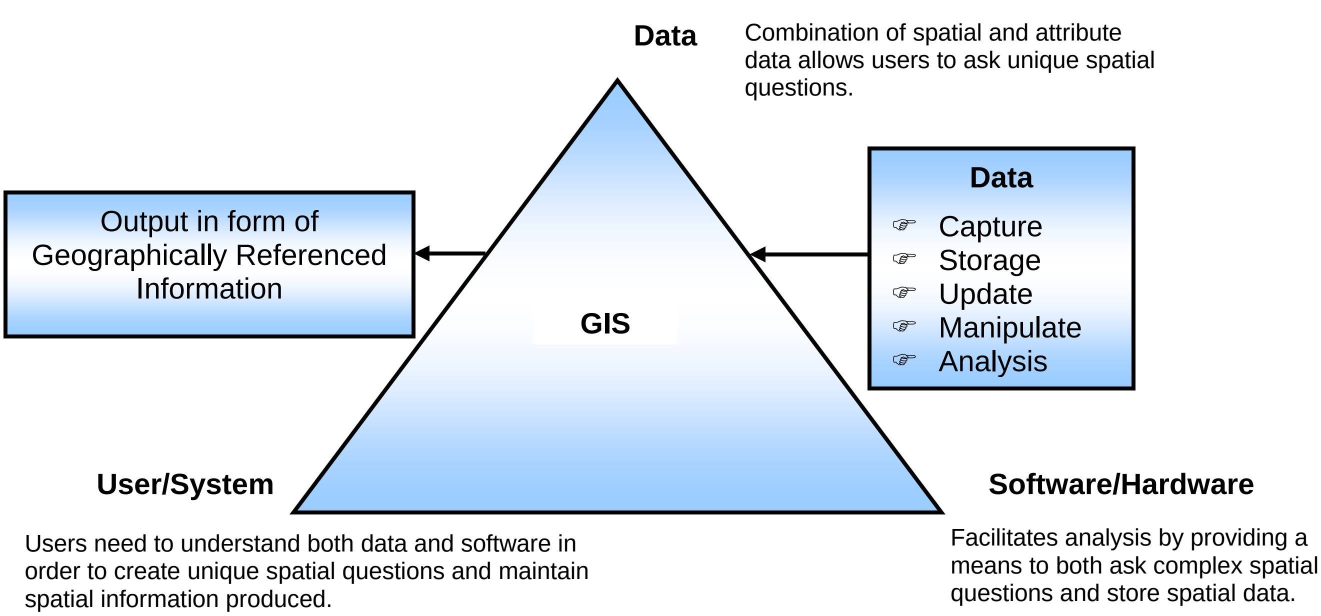


Table 1: GIS Elements			
S. No.	**Elements of GIS**	**Description**	**Details**
1.	Hardware	☞ The computer, peripherals, and sometimes servers on which the GIS operates	☞ Type of Computer Platforms ☞ Personnel Computers ☞ High Performance Workstations ☞ Minicomputers ☞ Mainframe Computers ☞ Input Devices ☞ Scanners ☞ Digitizers ☞ Tape Drivers ☞ CD Keyboard ☞ Graphic Monitor ☞ Output Devices ☞ Plotters ☞ Printers
2.	Software	☞ Provides the functions and tools required to store, analyze, and display data	☞ Input Modules ☞ Editing ☞ MRP Manipulation/ Analysis Modules ☞ Modeling Capability
3.	Data	☞ Data is stored as vector, raster, or attribute data	☞ Attribute Data ☞ Spatial Data ☞ Remote Sensing Data ☞ Global Database
4.	Liveware	☞ The guidelines, specifications, standards, and procedures for collecting and analyzing data and applying GIS ☞ GIS needs people to ask the questions; choose, collect, and analyze the data; and interpret the results	☞ Procedures and Guidelines ☞ People responsible for digitizing, ☞ Implementing using GIS Trained personnel

D Data for GIS

11. There are four basic aspects with regard to data in a GIS
   - ☞ **Spatial Data:** Features that have a known location on earth.
   - ☞ **Attribute Data:** The information linked to the geographic features (spatial data) describing them
   - ☞ **Data Layers:** Are the result of combining spatial and attribute data. Essentially adding the attribute database to the spatial location.
   - ☞ **Layer Types:** A layer type refers to the way spatial and attribute information are connected. There are two major layer types, vector and raster. How geographic features are related to one another, and where they are in relation to one another.

12. **GIS Thematic Layers and Data Sets:** GIS organizes geographic data into a series of thematic layers and tables. Because data in a GIS are referenced to geographic context, they have real-world locations and could overlay one another. GIS links the location to each layer (such as people to addresses, buildings to parcels, or streets within a network) to give a better understanding of how the features interrelate.

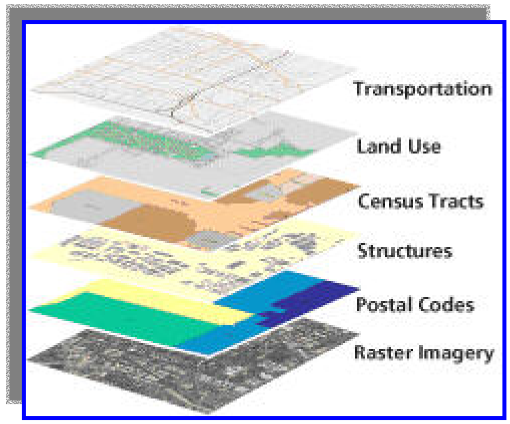


Figure - Types of Spatial Data

13. In a GIS, collections of geographic features are organized into data sets, such as land parcels, fire locations, buildings, orthophoto imagery, and raster-based digital elevation models (DEMs). Precisely defined geographic data sets are critical for useful geographic information systems, and the layer-based concept of thematic collection of information is critical for GIS data sets.

E Type of GIS Data Formats

14. As noted above, there are two formats used by GIS systems to store and retrieve geographic data:

- Raster
- Vector

15. Raster Formats are:

- Data are divided into cells, pixels, or elements
- Cells are organized in arrays
- Each cell has a single value
- Row and Column Numbers are used to identify the location of the cell within the array.
- Perhaps the most common example of raster data is a digital image.

16. **Raster Data Types:** Raster data represent features as a matrix of cells within rows and columns in continuous space. These cells are formed by pixels of a specific dimension size, and can be described as either "cell-based" or "image-based" data.

17. **Cell-based Data:** Each raster data layer represents one attribute. Most analyses combine these layers to create new layers with new cell values, as either continuous or discrete data. Continuous data types have gradations, such as temperature or elevation. Discrete data types have clearly delineated boundaries, such as a city boundary or specific vegetation type.

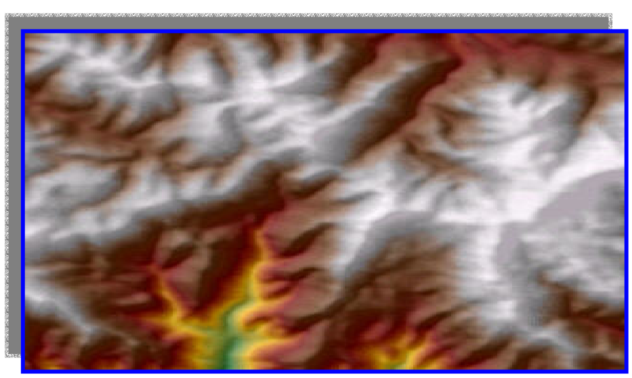


Figure - Cell-based Raster Data

18. The cell size used for a raster layer affects the results of the analysis and how the map looks. Using too large a cell size will cause some information to be lost. Using too small a cell size will significantly increase the storage space and processing time required, without adding precision to the map. To create an effective cell size, base the cells on map scale and on the minimum mapping unit of the other GIS data.

19. **Image-based Data:** Image data ranges from satellite images and aerial photographs, to scanned maps that have been converted from printed to digital format.


Figure - Image-based Raster Data

20. Vector Formats are:

- Data are associated with points, lines, or boundaries enclosing areas
- Points are located by coordinates
- Lines are described by a series of connecting vectors (line segments described by the coordinates of the start of the vector, its direction, and magnitude or length).
- Areas or polygons are described by a series of vectors enclosing the area.
- Any number of factors or attributes can be associated with a point line or polygon.
- Data are stored in two files:
  - a file containing location information
  - a file containing information on the attributes
- A third file contains information needed to link positional data with their attributes.

21. **Vector Data Types:** Vector data is composed of discrete coordinates that can be used as points or connected to create lines and polygons. Coordinates for fire data are typically provided in geographic format (latitude/longitude) or projected (typically UTM for the lower 48 states; Alaska uses the Albers projection):

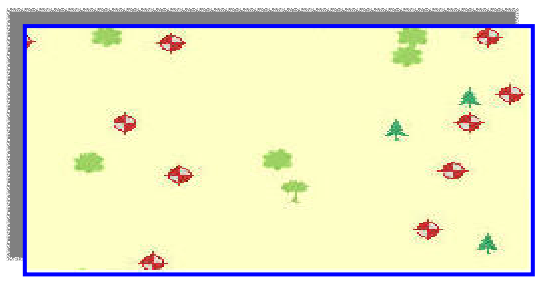


Figure - GIS Points

22. **Points:** Discrete location on the surface of the planet, represented by an x-y coordinate pair. Each point on the map is created by latitude and longitude coordinates, and is stored as an individual record in the shape file.

23. **Lines:** Formed by connecting two data points. The computer reads this line as straight, and renders the line as a vector connecting two x-y coordinates (X = longitude, Y = latitude). The more points used to create the line, the greater the detail. FPA requires that the line and polygon features include topology. For lines, this means that the system stores one end of the line as the starting point and the other as the end point, giving the line "direction".

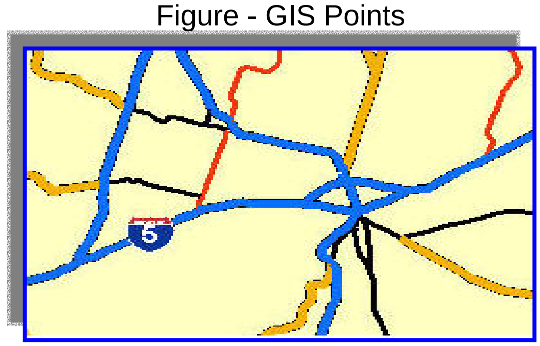


Figure - GIS Lines

24. **Polygons:** An area fully encompassed by a series of connected lines. Because lines have direction, the system can determine the area that falls within the lines comprising the polygon. Polygons are often an irregular shape. Each polygon contains one type of data (e.g., vegetation, streets, and dispatch locations would be different polygons). All of the data points that form the perimeter of the polygon must connect to form an unbroken line. When preparing files for FPA, verify that the polygons are closed.

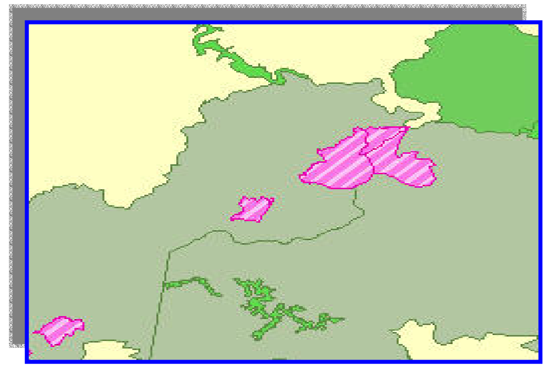


Figure - GIS Polygons

25. Other Data Aspects are:

26. **Grid Data:** The grid provides the simplest way of dealing with the data. Grids speed the calculation time required for the computer to determine the location of the data points within the polygon. For example, elevation data are stored in this layer.

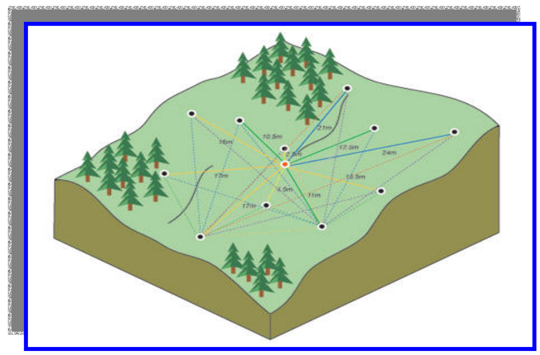


Figure - Grid Cell Data

27. **Attributes:** Attribute (tabular data) is descriptive data that GIS links to map features. For example, attributes of a dispatch location, which is represented by a spatial point, might include an engine bay that accommodates a certain number of engines, crews, dozer pads, and so on. These attributes are stored in a database and relate to the feature using a primary key (unique identifier).

28. **Database:** The database forms the foundation of the GIS system. All the information about the GIS system is stored in the database. The first 5 fields of every GIS database for FPA always contain the same type of information, and provide a way to link each record with a unique identifier.

29. **Topology:** Topology describes the spatial relationships between adjacent features, and uses x, y coordinates to identify the location of a particular point, line, or polygon. Using such data structures enforces planar relationships, and allows GIS specialists to discover relationships between data layers, to reduce artifacts from digitization, and to reduce the file size required for storing the topological data.

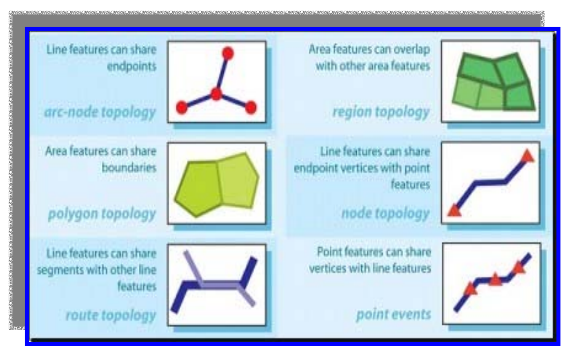


Figure - Types of GIS Topology

30. **GIS Shapefiles:** A shapefile is a type of GIS data layer that is used to transfer vector data. Each shapefile can contain only one feature class. While less robust than coverages, shapefiles tend to be significantly smaller, which reduces processing time. For FPA-PM, shapefiles are stored as a set of related files, which must be moved and stored as a group in order for the data to be interpreted correctly. For FPA, use the *.zip file format to transfer information about the FMUs.

31. **Geodatabases:** Geodatabases are object-oriented data models that are stored in a relational database management system. They enable you to store multiple feature classes and the topological relationship among them. All feature classes in a feature data set must share the same spatial reference. Geodatabases have the ability to implement sophisticated business logic that can build relationships between data types, validates data, and controls access (import, editing, & export).

32. Vector and Raster Format are:
- Most GIS software can display both vector and raster data.
- Raster formats are efficient when comparing information among arrays with the same cell size.
- Raster files are generally very large because each cell occupies a separate line of data.
- Vector formats are efficient when comparing information whose geographical dimensions are different.

Table 2: Comparison of Raster and Vector Data Models	
Raster Model	**Vector Model**
Advantage	**Advantage**
☞ It is a simple data structure. ☞ Overlay operations are easily and efficiently implemented. ☞ High spatial variability is efficiently represented in raster format. ☞ The raster format is more or less required for efficient manipulation and enhancement of digital images. ☞ Raster representations are relatively coarse and imprecise ☞ Raster files are generally very large because each cell occupies a separate line of data, only one attribute can be assigned to each cell, and cell sizes are relatively small.	☞ It provides a more compact data structure than the raster model. ☞ It provides efficient encoding of topology and as result more efficient implementation of operations that require topological information, such as network analysis. ☞ The vector model is better suited to supporting graphics that closely approximate hand-drawn maps. ☞ Vector representations of shapes can be very precise
Disadvantage	**Disadvantage**
☞ It is less compact - therefore data compression techniques are required to overcome this problem. ☞ Topological relationships are more difficult to represent. ☞ The output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps.	☞ It is a more complex data structure. ☞ Overlay operations are more difficult to implement. ☞ The representation of high spatial variability is inefficient. ☞ Manipulation and enhancement of digital images cannot be effectively done in vector domain.

33. Most GIS software can display both raster and vector data. *Only a limited number of programs can analyze both types of data or make raster type analyses in vector formats.*

F Spatial Analysis and GIS Applications

34. GIS is used to perform a variety of Spatial analysis, including overlaying combinations of features and recording resultant conditions, analyzing flows or other characteristics of networks; proximity analysis (i.e. buffet zoning) and defining districts in terms of spatial criteria. GIS can interrogate geographic features and retrieve associated attribute information, called identification. It can generate a new set of maps by query and analysis. It also evolves new information by spatial operations. Following are the analytical procedures applied with a GIS. GIS operational procedure and analytical tasks that are particularly useful for spatial analysis include:

- Single layer operations
- Multi layer operations/ Topological overlay
- Geometric modeling
- Calculating the distance between geographic features
- Calculating area, length and perimeter
- Geometric buffers.
- Network analysis
- Surface analysis
- Raster/Grid analysis

35. There are many applications of Geoinformatics, viz. facility management, planning, environmental monitoring, population census analysis, insurance assessment, and health service provision, hazard mapping and many other applications.

Table 3: Major Areas of GIS Application

Area	GIS Application
Facility Management	☞ Locating underground pipes and cables ☞ Planning facility maintenance ☞ Telecommunication network services ☞ Energy use tracking and planning
Environment and Natural Resources Management	☞ Suitable study for agricultural cropping management of forests, agricultural lands, water resources, wetlands etc. ☞ Environmental impact analysis ☞ Disaster management and mitigation ☞ Waste facility site location
Street Network	☞ Car navigation (routing and scheduling) ☞ Locating houses and streets ☞ Site location ☞ Ambulance services ☞ Transportation planning
Planning and Engineering	☞ Urban planning ☞ Regional planning ☞ Route location of highways ☞ Development of public facilities
Land Information System	☞ Cadastre administration ☞ Taxation ☞ Zoning of land use ☞ Land acquisition

G Errors in GIS

36. Uncertainties and errors are intrinsic to spatial data and need to be addressed properly, not sweeping away the users by high quality colour outputs. Data accuracy is often grouped according to thematic accuracy, positional accuracy and temporal accuracy occurring at various stages in spatial data handling. Given below are some of them while creating the spatial database and analysis.

37. Errors in GIS environment can be classified into the following major groups:
- ☞ Age of data - Reliability decreases with age
- ☞ Map scale - Non-availability of data on a proper scale or Use of data at different scales
- ☞ Density of observation - Sparsely distributed data set is less reliable
- ☞ Relevance of data - Use of surrogate data leads to errors
- ☞ Data inaccuracy - Positional, elevation, minimum mappable unit etc.
- ☞ Inaccuracy of contents - Attributes are erroneously attached

38. Errors associated with processing:
- ☞ Map digitization errors - due to boundary location problems on maps and errors associated with digital representation of features
- ☞ Rasteurization errors - due to topological mismatch arising during approximation by grid
- ☞ Spatial integration errors - due to map integration resulting in spurious polygons
- ☞ Generalization errors - due to aggregation process when features are abstracted to lower scale

39. Attribute mismatch errors.

H Generic GIS Architecture

40. Basically, GIS architecture includes the following:

41. **Traditional GIS:** The development of GIS technology has evolved from traditional GISystems to client/server GISystems to distributed GIServices. The mainframe GIS and desktop GIS are traditionally called GISystems. Traditional GISystems are closed, centralized systems that incorporate interfaces, programs, and data. Each system is platform dependent and application dependent. Every element is embedded inside traditional GISystems and cannot be separated from the rest of the architecture. Traditional GISystems works on stand alone system.

42. **Client Server GIS:** Client/server GISystems are based on generic client/server architecture in a wired network design. The client-side components are separated from server-side components and usually platform dependent. Client/server architecture allows distributed clients to access a server remotely by using distributed computing techniques such as Remote Procedure Calls (RPC) or database connectivity techniques such as Open Database Connectivity (ODBC). Each client component can access only one specified server at one time. Different geographic information servers come with different client/server connection frameworks which cannot be shared.

43. **Distributed GIS:** Distributed GIServices enable users to manipulate GIS data and maps interactively over the wired Internet or wireless telecommunication networks. It is not necessarily required for the user to install GIS programs on the user's desktop. Distributed GIServices can interact with heterogeneous systems and platforms without the constraints of traditional

client/server relationships. There is no difference between a client and a server. Every GIS node embeds GIS programs and geodata. Each GIS node can become a client or a server based on the task at hand. A client is defined as the requester of a service in a network while a server provides a service. There are two categories of distributed GIS: Internet GIS and mobile GIS. The major difference between them is that Internet GIS works on the wired Internet networks and the client is usually a desktop computer, while mobile GIS works through the wireless telecommunication networks and the client may be a laptop computer, a Personal Digital Assistant (PDA), or a mobile phone.

44. **Evolutions of Distributed GIS:** The evolution of distributed GIS is following the development of computer technologies and telecommunication networks. It started with static map publishing and evolved to static Web mapping, to interactive Web mapping and to the distributed GIServices. Static Map Publishing distributes maps on the Web page as static map images in graphic formats like Portable Document Format (PDF), Graphic Interchange Format (GIF), or Joint Photographic Experts Group (JPEG). The ready-made maps on the Web are usually part of HyperText Mark up Language (HTML) document. Users cannot interact with the maps or change their display format in any way.

45. Static Web mapping involves the use of HTML forms and the Common Gateway Interface (CGI) to link the user input on the Web browser with GIS or mapping programs on the servers. Users make requests from the Web browser using customized HTML forms. Then the request is sent to the CGI through a HyperText Transfer Protocol (HTTP) server to invoke GIS or mapping engines. The GIS or mapping engines create the map based on the user's request and generate an image map. The image is sent via HTTP back to the user on the Web browser. Users cannot define or draw anything on the image maps because the HTTP form is text based and allows limited user input.

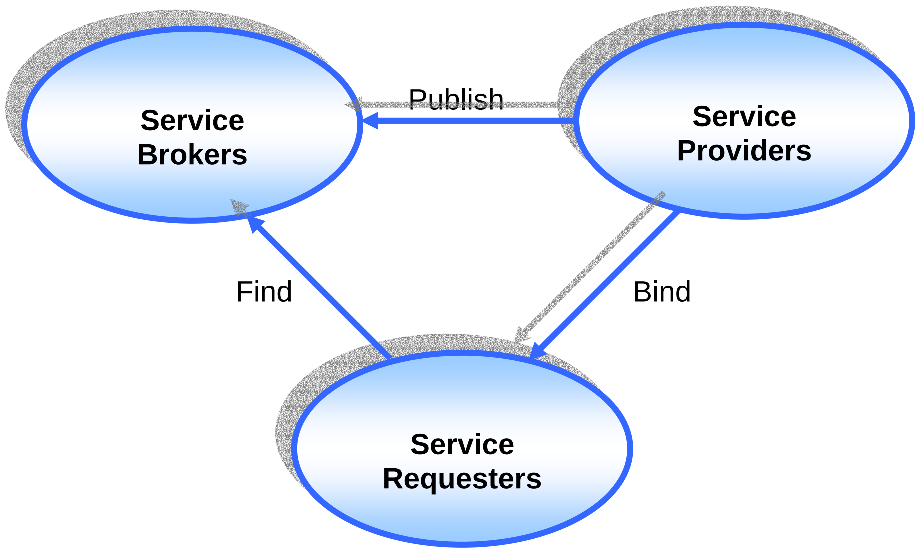
46. Interactive Web mapping adds scripts like Dynamic HTML (DHTML) and/or client-side applications like plug-ins, ActiveX control, and Java applets to the Web client side. Some user queries can be processed on the client side without sending requests to the servers. This approach requires HTTP connections and the Web servers to mediate between software objects running on the client and the servers which store these objects. Interactive Web mapping does not meet the requirement of distributed GIServices completely. Client-side application as mentioned above are designed essentially for graphic display of maps rather than truly providing GIS operations and analysis. Interactive Web mapping gives very limited functionality that does not offer much interactivity and flexibility for complicated GIS modeling and processing.

47. Distributed GIServices refers to a specific software framework. GIS components on the client side can directly communicate with other GIS components on the server without going through the CGI middleware and an HTTP server. Distributed GIServices rely on the communication between Common Object Request Broker Architecture (CORBA)/ Java ORB or Microsoft Simple Object Access Protocol (SOAP) on the client side.

48. According to ISO 191191, the term of "services" means a collection of operations, accessible through an interface that allows a user to invoke a behavior of value to the user. Web services are interoperable, self-contained, self-describing, module components that can communicate with each other over the Web services platform.

49. Web services architecture performs three roles – as a service provider, service requestor, and services broker (Figure below). It performs three essential kinds of operations - publish, find and bind. The service providers publish machine-readable information (metadata), receiving requests and binding a service to a service requestor. In the client/server model, the service requestor is a client, the service provider is a server, and the service broker is a middleware.

Figure 3: Generic Components of Web Services



I Enterprise GIS: The In-Thing!

50. **Enterprise GIS:** Is a set of applications and tools which provides complete solutions, from data capturing till presenting the data over Map overlays. A new strategy for implementation is the Enterprise GIS concept which refers to a geographical information system that integrates geographic data across multiple departments and serves the whole organisation. The basic idea of an enterprise GIS is to deal with departmental needs collectively instead of individually. When organisations started using GIS in the 1960s and 1970s, the focus was on individual projects where individual users created and maintained data sets on their own desktop computers. Due to extensive interaction and work-flow between departments, many organisations have in recent years switched from independent, stand-alone GIS systems to more integrated approaches that share resources and applications.

51. Some of the potential benefits that an enterprise GIS can provide include significantly reduced redundancy of data across the system, improved accuracy and integrity of geographic information, and more efficient use and sharing of data. Since data is one of the most significant investments in any GIS program, any approach that reduces acquisition costs while maintaining data quality is important. The implementation of an enterprise GIS may also reduce the overall GIS maintenance and support costs providing a more effective use of departmental GIS resources. Data can be integrated and used in decision making processes across the whole organisation.

52. **Enterprise GIS Benefits:** An enterprise GIS, by definition, is a centrally managed integrated, multi-departmental system of components used to collect, organize, analyze, visualize, and disseminate geographic information using a distributed network architecture. The

basic idea of an enterprise GIS is to address the needs of departments collectively instead of individually through common standards, procedures, and methodologies.

53. How is an enterprise GIS beneficial? Basically it includes the above mentioned benefits, but extends these capabilities to the entire organization. In an enterprise GIS, geographic information is acknowledged as an organization (enterprise) wide asset that needs to be closely managed to ensure maximum efficiencies. For organizations, the benefits of an enterprise GIS translate into:

- Improved operational efficiencies;
- Economies of scale;
- The ability to integrate geographic data seamlessly with other business systems;
- The ability to streamline workflow;
- Better accuracy, security, and integrity of geographic data;
- Improved coordination amongst departments;
- Improved distribution of geographic data;
- Improved management of the system at a programmatic level.

54. In order to accomplish an enterprise GIS and create a more efficient model for geographic information, the following strategic initiatives are recommended:

Table 4: Recommended GIS Strategic Initiatives (SI)	
Steps	**Description**
SI # 1: Develop and Implement an Enterprise GIS Strategic Plan	☞ A strategic plan is the guiding framework document for establishing the initial vision, goals, objectives, requirements, and other parameters associated with implementing an enterprise GIS.
SI # 2: Conduct a Pilot Project	☞ Given the magnitude of the investment for an enterprise GIS and the timeline associated with deployment of the technology, a pilot project is an excellent opportunity to merge early on the planning stages with the implementation stages of project development and provide a tangible product that will serve as a way to educate stakeholders and build support for the project.
SI # 3: Establish System Architecture Hardware/Software Environment	☞ The foundation of an enterprise GIS is its architecture design, hardware environment and suite of software. ☞ The system architecture should reflect the needs and requirements defined in the strategic plan
SI # 4: Develop Map Base	☞ The foundation of the enterprise database is a map base and associated data models. ☞ Databases can be the most time-consuming and expensive part of an enterprise project. Development of a map base will require careful evaluation, needs assessment, and prioritization.
SI # 5: Develop Standards and Procedures	☞ A GIS is more than hardware, software, and data. ☞ It must also include standards and procedures that enable the data and technology components of the system to work consistently and efficiently.
SI # 6: Web-based Mapping	☞ In order to ensure an efficient integration with other business systems, use a standards based open architecture development environment, and improve mapping services to the community, **a web-based mapping application is needed.**
SI # 7: Priority Application	☞ The enterprise GIS will need to have the appropriate environment to allow the system to be enhanced over time as systems are replaced

Table 4: Recommended GIS Strategic Initiatives (SI)	
Steps	**Description**
Development/Integration	or upgraded. ☞ This environment should be flexible and low-cost to allow ease of integration. Application development and integration capability need to be designed into the system early on during the design phase. ☞ Initial application development and integration efforts should focus on priority applications.
SI # 8: Develop Training Plan	☞ The implementer will also need to develop a training plan so that the knowledge base within the organization is at established levels and users receive the appropriate amount of training relative to the level of interaction they have with the system.
SI # 9: Transition to Program	☞ In an enterprise environment, a GIS cannot be implemented and left without leadership, coordination, support, and the ability to develop the system. Some level of program management will need to be established in order to ensure continuing success, value, and operational efficiencies.

55. **Deliverables:** The enterprise GIS implementation will result in distinct deliverables. The following lists the expected end products:

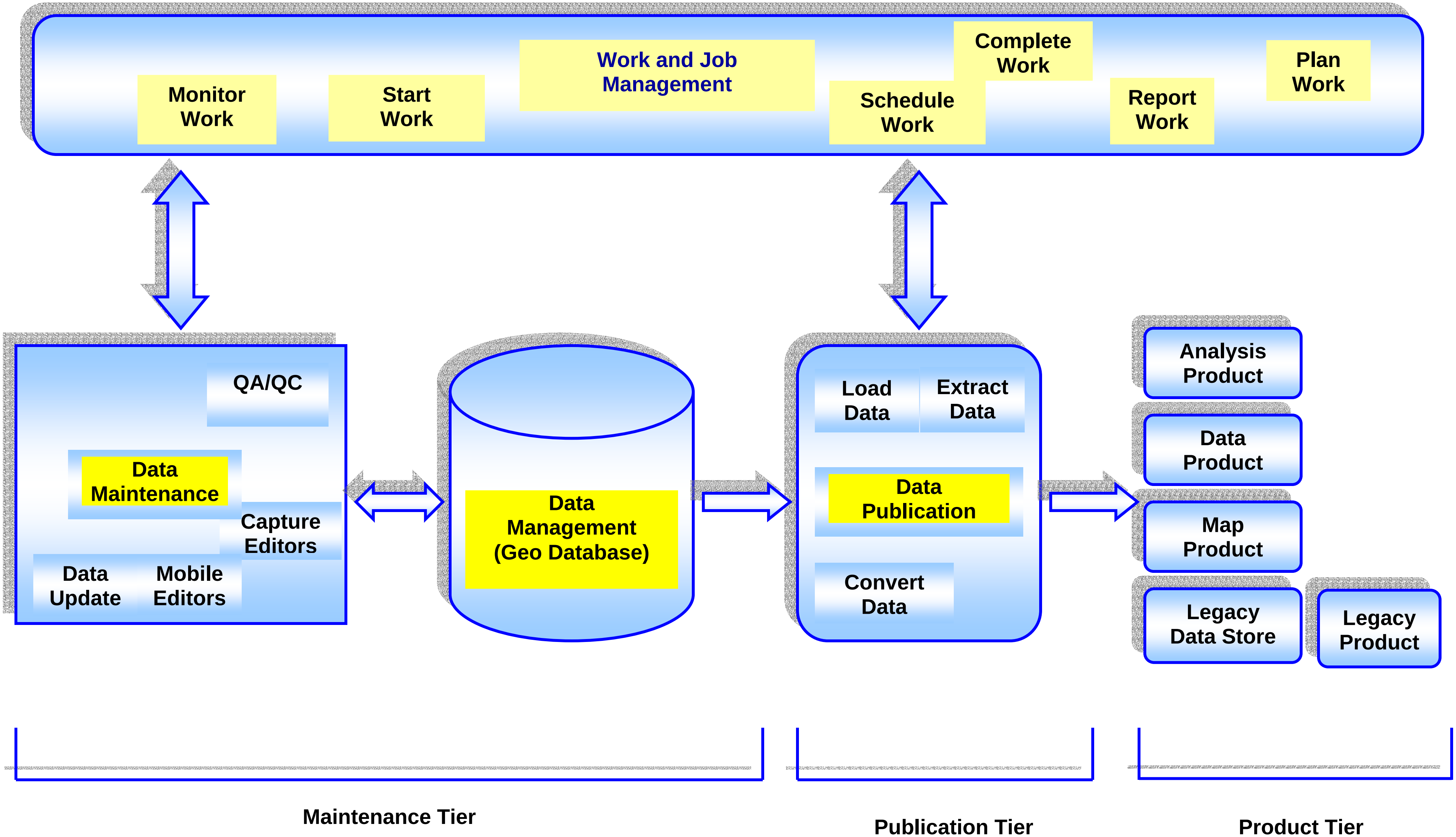
Table 5: Enterprise GIS Implementation and Deliverable	
Deliverables	**Description**
Base Map/Corporate Data Model	☞ The base map generally consists of streets, parcels and other fundamental layers. ☞ Because the base map will serve as the point of reference when creating other spatial databases, it will have the highest level of accuracy requirements. ☞ The overall model will provide the overall spatial framework for how geospatial data is organized, managed, maintained and collected within the organization.
Software/Hardware	☞ It is anticipated a suite of software and hardware will be necessary to successfully deploy the enterprise GIS. ☞ While users may already have some desktop application of GIS, the existing inventory would need to be evaluated in terms of its ability to meet the business requirements found during the needs assessment phase. ☞ Where there are gaps, new software will be required. In addition, it is anticipated that hardware purchases in the form of servers will be necessary to adequately store the centralized database.
Web-based Mapping	☞ One of the anticipated major components of the enterprise GIS will be a web-based application, or series of applications that will deliver GIS functionality via the web.
Standards/Procedures	☞ Promoting organization wide standards will ensure consistency, reliability, and quality in the GIS. Promoting procedures will ensure a consistent approach towards GIS data maintenance and application development and, in the long run, reduce overall costs. ☞ Types of standards and procedures generally consist of metadata standards, data development/maintenance standards, software standards and application development environment standards.
Application Development Capability	☞ It will not be possible to have all GIS requirements satisfied through “commercial-off-the-shelf” (COTS) applications; therefore, it will be necessary to establish an application development environment to address additional requirements as new systems are developed and requirements are updated. ☞ This application development environment is anticipated to be one that is scalable

Table 5: Enterprise GIS Implementation and Deliverable	
Deliverables	**Description**
	and easily customizable.
Training	☞ A training program will have to be established in order to ensure that an adequate GIS knowledge base is established and continues as necessary for the organization. ☞ The training program will need to be consistent with the proposed user groups (Administrator, Analyst, and Viewer) as defined later
GIS Program	☞ After the initial enterprise deployment, GIS will transition into a program. ☞ The program will help promote and coordinate the use of GIS technology, especially those projects which are critical to improving overall efficiency and effectiveness of business processes and organisation's services. ☞ In addition, the program will help departments with GIS development, standards, training, and guide overall system performance.

56. **Risks:** As with any major technology deployment, there are risks associated with the implementation of an enterprise GIS. Some of the risks that users could face while buying commercial off the shelf (COTS) applications will be mainly its own during development and management of the system. These include:

Table 6: Risks in Development, Deployment and Management of the System	
Risks	**Description**
Data Conversion Costs	☞ Data collection/conversion is usually the most expensive component of a GIS implementation. Estimates need to be correctly and accurately made. A needs assessment can provide a more accurate picture of the magnitude of the conversion effort. If it is found that the data collection/conversion efforts will be more considerable, then the cost-estimates may have to be refined.
Department Conflicts/Scope Creep	☞ In the enterprise GIS model, one comprehensive system will be designed to serve all departments. In such a model, there will inevitably be varying opinions and conflicts in how the system is designed. ☞ While this is typical in any multi department endeavor, during the enterprise GIS implementations it will be particularly important to manage the scope of work closely and develop/change management procedures to ensure there aren't any excessive delays, excessive costs, or incidences of scope keeping on broadening the project beyond its original intent.
On-going Support/Coordination Requirement	☞ An enterprise GIS will not persist, and subsequently not provide the intended return on investment, if it does not receive on-going management, coordination, and staffing as required ☞ The technology is expensive and can provide significant cost-savings; however, it takes special and devoted personnel to ensure the savings are obtained.
Complex Technology	☞ While the front end of many GIS are becoming more simplified and easy to use for the casual user, it is important to realize the technology behind the GIS is becoming increasingly complex. *This should not be ignored.* ☞ The organization needs to acknowledge that certain skill sets identified in this GIS Strategic Plan will be required to keep the system at a certain level of operation. ☞ If these skill sets are not available, then the benefits again are likely not to be obtained. The GIS Strategic Plan will become an important component in establishing the required skill sets to sufficiently maintain the enterprise GIS and it must be done by organizations wanting to deploy GIS

Figure 4: Conceptual View of an Enterprise GIS Solution



J GIS Tools

57. There are various GIS Software available in the market and these are given below

Table 7: GIS Applications Across Types	
GIS Application Name	**Details**
Desktop GIS	
GRASS	☞ Originally developed by the U.S. Army Corps of Engineers, open source: a complete GIS. Most widely used.
SAGA GIS	☞ System for Automated Geoscientific Analyses- a hybrid GIS software. SAGA has a unique Application Programming Interface (API) and a fast growing
Quantum GIS	☞ QGIS is a user friendly Open Source GIS that runs on Linux, Unix, Mac OS X, and Windows.
MapWindow GIS	☞ Free, open source GIS desktop application and programming component.
ILWIS	☞ ILWIS (Integrated Land and Water Information System) integrates image, vector and thematic data. uDig
Kalypso (Software)	☞ Kalypso is an Open Source GIS (Java, GML3) and focuses mainly on numerical simulations in water management.
gvSIG	☞ Open source GIS written in Java.
JUMP GIS / OpenJUMP	☞ (Open) Java Unified Mapping Platform (the desktop GIS OpenJUMP, SkyJUMP, deeJUMP and Kosmo emerged from JUMP
SavGIS	☞ A free and powerful Desktop GIS available in 3 languages (English, French, Spanish) for Windows (XP, Vista), developed since 1984 by the Institut de Recherche pour le Développement, a French public research institute
Web Based	
MapServer	☞ Web-based mapping server, developed by the University of Minnesota. Most Widely used.
MapFish	☞ MapFish is an easy-to-use and extensible web 2.0 mapping application framework. ☞ MapFish is composed of two parts: MapFish Client and MapFish Server. MapFish Client is a JavaScript framework based on OpenLayers for the mapping part, and on ExtJS for the GUI (widgets) part. MapFish Server is responsible for server side treatments and composed of several modules which can be implemented in several languages such as Python, Java, PHP.
GISNet	☞ A web-based GIS system developed by MRF Geosystems Corporation.
Google Earth	☞ Google mapping web based solution, visit Google site for more information
Commercial Software (Multiple Types)	
ESRI	☞ Products include ArcView 3.x, ArcGIS, ArcSDE, ArcIMS, and ArcWeb services.
MapInfo	☞ Products include MapInfo Professional and MapXtreme. integrates GIS software, data and services.
MapPoint	☞ Proprietary GIS product developed by Microsoft.
Oracle Spatial	☞ Product allows users to perform basic geographic operations and store common spatial data types in a native Oracle environment.

Table 8: Comparison Between Open Source and Commercial Web GIS Software[4]

Feature	Map Server	ArcIMS	GeoMedia WebMap	MapXtreme
1. Product Characteristics	☞ Open Source	☞ Commercial Web-based	☞ Commercial Web-based	☞ Commercial Web-based
2. Support for different web browsers	☞ Browser independent	☞ Browser independent	☞ Browser independent	☞ IE and certain versions of Netscape
3. Availability of code examples in the documentation	☞ Yes	☞ Yes	☞ Yes	☞ Yes
4. Ability to connect to, display, and perform analysis on data from various data sources	☞ *Raster[5]:* TIFF/GeoTIFF, EPPL7, MrSID, IMG, Jpeg, and OGC web coverage server among many other formats through the GDAL library. ☞ *Vector[6]:* ESRI shape files, PostGIS, ESRI ArcSDE, Oracle Spatial, MySQL and many others through its OGR library.	☞ *Raster:* TIFF/GeoTIFF, EPPL7, MrSID, IMG, Jpeg, among other formats. (OGC web coverage is not supported) ☞ *Vector:* ESRI shape files, ESRI ArcSDE, ArcInfo Coverages, CAD files, Commercial RDMS engines among other formats.	☞ *Raster:* TIFF/GeoTIFF, MrSID, Intergraph Raster files, JPG ☞ *Vector:* ESRI Shape files, ArcInfo Coverages, MapInfo tables, CAD files, Oracle spatial, and MS SQL among other formats.	☞ *Raster:* BMP, JPG, TIFF/GeoTIFF, BIL, SID, PNG, IMG, PSD and ECW files ☞ *Vector:* ESRI shape files, MapInfo Tables, OGC GML, Commercial RDMS engines among other formats
5. Technical support	☞ Technical support is basically provided free of charge through online user communities, online documentation and tutorials, and developer communities. ☞ Commercial technical support which provides a professional service level is also provided through some companies such as DM solutions.	☞ A free of charge knowledge base is available online for users to review solutions to previous problems solved by the technical support team. ☞ Users can also log a problem, however in this case responses are not guaranteed to be punctual.	☞ A free of charge knowledge base is available on the support website, and is searchable by any visitor to the website. ☞ Logging a problem is only possible for customers paying annual maintenance fees.	☞ A free of charge knowledge base is available online, and is searchable by the general visitors of the website. ☞ A free discussion area is also provided for the users where they can exchange information and experience.

[4] Compiled for NCRPB by Ramesh S Arunachalam and at request of **Mr Karna, Director, Administration and Finance**
[5] Raster data type consists of rows and columns of cells where in each cell is stored a single value, Raster data types usually refer to *image* style data.
[6] Vector data type uses geometries such as points, lines (series of point coordinates), or polygons, also called areas (shapes bounded by lines), to represent objects

Table 8: Comparison Between Open Source and Commercial Web GIS Software[4]				
Feature	**Map Server**	**ArcIMS**	**GeoMedia WebMap**	**MapXtreme**
		☞ Another form of subscription support is also available and guarantees prompt support. Product updates and patches are also available on the website free of charge.		☞ As with the other commercial software providers, professional support is provided to paying customers.
6. The documentation addresses different skills of developers	☞ Yes	☞ Yes	☞ Yes	☞ Yes
7. The server software does not require extreme hardware requirements	☞ Can be installed on most common personal computers.	☞ Has a hardware requirement for each server software application, but all requirements are easy to fulfil.	☞ No information was available on the product web page.	☞ Can be installed on most common personal computers.
8. The server software comes with an installer and does not require compilation	☞ A compilable version as well as a couple of installer versions is available for windows operating systems.	☞ Yes, comes with an installer.	☞ Yes, comes with an installer.	☞ Yes, comes with an installer.
9. The software does not require users of the website to install additional plug-ins	☞ No additional plug-ins are required	☞ No additional plug-ins are required	☞ Different plug-ins (active-x control or java applet) are provided with the software for vector rendering depending on the design and architecture of the website.	☞ No additional plug-ins are required
10. The software can be installed on a variety of web servers	☞ Apache, IIS, any HTTP web server.	☞ There is a separate release for Apache, IIS, Oracle application server, sun java	☞ IIS Only	☞ The website states that it is compatible with all popular web servers, but does not

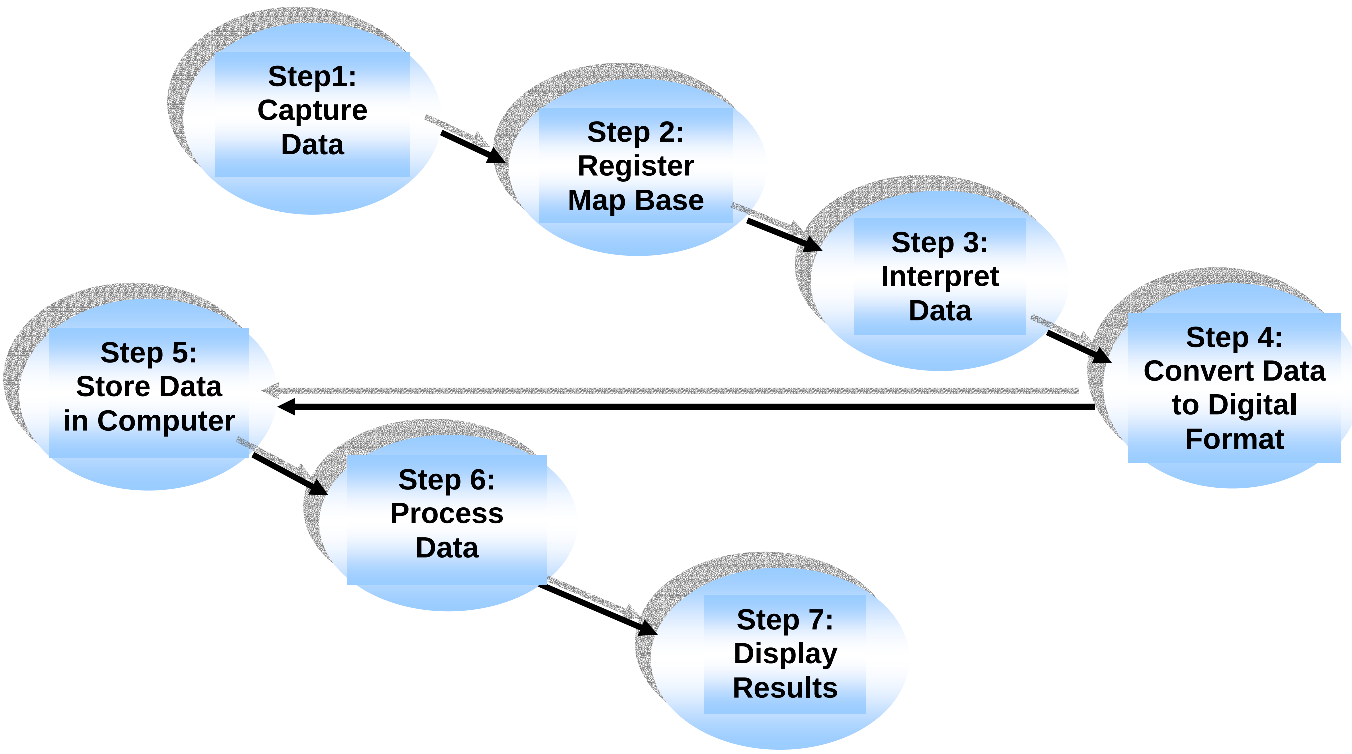
Table 8: Comparison Between Open Source and Commercial Web GIS Software[4]				
Feature	**Map Server**	**ArcIMS**	**GeoMedia WebMap**	**MapXtreme**
		system, web logic, Websphere.		state which.
11. The performance of the software remains high even as the number of users increases	☞ No information was available on the software websites/documentation regarding this aspect of the softwares investigated.			
12. The software is compliant with technology standards	☞ Compliant with OGC standards (WMS (client/server), non-transactional WFS (client/server), WMC, WCS, Filter Encoding, SLD, GML, SOS)	☞ Compliant with OGC specifications (WMS, WFS)	☞ Compliant with OGC standards (SFS, WFS, WMS)	☞ OGC WMS
13. The software supports providing and consuming web services	☞ Yes	☞ Yes	☞ Yes	☞ Yes
14. Spatial Analysis	☞ Most of the spatial analysis is performed using the libraries for raster and vector analysis including thematic maps[7], spatial queries[8] image rendering, and text annotation.	☞ Thematic Maps, Image rendering, Spatial and attribute Queries, Data Extraction, Address and Coordinate Geocoding[9], find address, buffer zones, text annotation	☞ Thematic maps, Spatial and attribute queries, Address and Coordinate Geocoding, Aggregation, Analytical merge, functional attributes, table joins, find address, buffer zones measure length and angle, text annotation	☞ Gradient fills, pie charts, buffer zones, thematic maps, advanced text labelling, spatial and attribute analysis
15. Programming languages	☞ PHP, python, Perl, Ruby, Java, and C#	☞ JSP, ASP, .NET, Cold Fusion	☞ . NET, JavaScript	☞ .NET, HAHTsite, ASP, XML and Oracle OCI)

[7] Thematic maps provide a colour coded representation of the features displayed in the map; the colours represent distinct attributes or range of attributes of the features.
[8] Spatial queries help answer questions with a spatial dimension, such as what is the closest hotel to a certain lake.
[9] Geocoding refers to the presentation of textual coordinate or street address data as a graphical representation on a map.

K Generic Process of GIS Implementation

58. The generic process of implementing a GIS is as follows:

Figure 5: Process of GIS Implementation



L Ten Stage GIS Planning Good Practices Methodology

59. **Overview of the Method:** This ten-stage good practices GIS planning methodology was evolved from years of experience in planning large and small implementations in public- and private-sector companies. The size and nature of the organization will determine which of the component stages are most relevant. **A full enterprise-wide implementation would almost certainly require going through all the stages in full, while for a smaller project, some steps may be completed quickly or even skipped.** Regardless of the size of the undertaking, all situations are unique; it will be good to understand all of the steps in the process before adapting the methodology to the specific circumstances/context.

60. The suggested ten-stage good practices GIS Planning Methodology is given below:

- **Stage # 1:** Consider the strategic purpose
- **Stage # 2:** Plan for the planning
- **Stage # 3:** Define specific GIS requirement
- **Stage # 4:** Describe the information products
- **Stage # 5:** Define the system scope
- **Stage # 6:** Create a data design
- **Stage # 7:** Choose a logical data model
- **Stage # 8:** Determine system requirements
- **Stage # 9:** Consider benefit-cost, migration, and risk analysis
- **Stage # 10:** Plan the implementation

Table 9: Ten Stage GIS Planning Good Practices Methodology	
Stage	**Description**
Stage # 1: Consider the strategic purpose	☞ Start by considering the strategic purpose of the organization within which the system will be developed. *What are its goals, objectives, and mandates?* ☞ This stage of planning ensures that the GIS planning process and final system fit within the organizational context and truly support the strategic objectives of the organization. ☞ This stage also allows assessment of how the information created by the GIS will affect the business strategy of the organization.
Stage # 2: Plan for the planning	☞ *GIS planning should not be taken lightly.* Forget about actually implementing a GIS for the moment. Just planning a GIS takes a commitment of resources and people. Organization must be prepared to provide enough resources for the planning of GIS. ☞ Making the case means understanding what needs to be done and what it will take to get it done. The result of this stage is a project proposal that makes that case and explicitly seeks approval and funding to launch the formal planning process. ☞ Commitment to the planning process is essential to a successful GIS implementation, especially in public-sector organisations. The project proposal helps secure this senior management and administrative commitment.
Stage # 3: Define specific GIS requirement	☞ Once the project plan is approved, the in-house GIS planning team can be activated to begin its most important endeavor: ***identifying exactly what the organization needs from a GIS.*** ☞ Defining the specific GIS requirements is the primary task of the planning process. One must meet with the customers or clients of the GIS (those who will use the system or its output) to begin gathering specifics about the organization's needs from the user's perspective.
Stage # 4: Describe the information products	☞ Knowing what the organization wants to get out of the GIS is the key to a successful implementation. And what it wants usually comes in the form of information products: maps, lists, charts, reports, whatever is needed to inform decision making and streamline workflows. ☞ This stage must be carefully undertaken. This will involve talking to users about what their job involves and what information they need to (successfully) perform their tasks. Ultimately it would be important to determine things like how each information product should be made and how frequently, what data is required to make it, how much error can be tolerated, and the benefits of the new information produced. In other words, each person needs to be assisted in declaring a specific need for such information from the GIS and thus, they must be helped to write an *information product description (IPD).* ☞ This stage should result in a document that includes a description of all the information products that can be reasonably foreseen, together with details of the data and functions required to produce these products.
Stage # 5: Define the system scope	☞ Once the information products have been described, one can begin to define the scope of the entire system. This involves determining what data to acquire, when it will be needed, and how much data volume must be handled, then charting all this on a *master input data list (MIDI).*

Table 9: Ten Stage GIS Planning Good Practices Methodology	
Stage	**Description**
	☞ One will also have to assess the probable timing of the production of the information products. Here, one may discover it's possible to use one input data source to generate more than one information product, and this can be built into the development program. Each refinement helps clarify the needs and increases the chance of success.
Stage # 6: Create a data design	☞ In GIS, data is a major factor because spatial data is relatively complicated. In the conceptual system design phase of the planning process, one will review the requirements identified in the earlier stages and use them to begin developing a database design.
Stage # 7: Choose a logical data model	☞ A logical data model describes those parts of the real world that concern the organization. The database may be simple or complex but must fit together in a logical manner so that one can easily retrieve the data one needs and efficiently carry out the analysis tasks required. ☞ Several options are available for designing the system's database and the advantages and disadvantages of each approach could be reviewed at this stage, while considering various issues affecting the design: data accuracy, updation requirements, error tolerance, and data standards.
Stage # 8: Determine system requirements	☞ Here, one has to envisage the system design in its entirety by examining as a whole what is required of the system: the GIS functions, user interface, communications bandwidth, and core capacity. This is the first time in the planning process that one will examine software and hardware products. ☞ One will also have to review the information product descriptions and the master input data list in order to summarize and classify the functions needed to make these products. This will enable the organization to inform vendors of what is required in the way of software functionality. One will also have to consider issues of interface design, effective communications (particularly in distributed systems), and platform sizing in order to determine the appropriate hardware, software, and network configurations to meet the organizational needs.
Stage # 9: Consider benefit-cost, migration, and risk analysis	☞ Following conceptual system design, one will need to work out the best way to actually implement the system that has been designed. This is where, preparing for how the system will be taken from the planning stage to actual implementation, would need to be spelt out ☞ As part of that preparation, one may need to conduct a benefit-cost analysis to make the business case for the system. To convince management to fund the GIS implementation, key staff and others involved will probably be called upon to show how various risk factors weigh in, such as migration from the old system to the new and other factors
Stage # 10: Plan the implementation	☞ Until now, the focus of the planning methodology has been on what needs to be put in place to meet the requirements. The focus at this stage switches to how to put the system in place-acquisition and implementation planning. Now one will have to address such issues as staffing and training, institutional interactions, legal matters, security, existing legacy hardware and software, and how to manage change (which is most critical). The plan that results from this last stage of the methodology will contain the implementation strategy and benefit-cost analysis. This plan

Table 9: Ten Stage GIS Planning Good Practices Methodology	
Stage	**Description**
	becomes the final report which can be used both to secure funding for the system and as a guide for the actual implementation of the system. ☞ The final report equips the organization with all the information needed to implement a successful GIS. It will become the GIS planning book to help the organization through the implementation process. ☞ Developing the final report should be the result of a process of communication between the GIS team and management so that no part of the report comes as a surprise to anyone. The report should contain a review of the organization's strategic business objectives, the information requirements study, details of the conceptual system design, recommendations for implementation, time-planning issues, and funding alternatives. ☞ The purpose of this GIS planning methodology-is to guide one through these various stages of thinking. It can also be used to give senior management the context for the questions they must ask about GIS in their organization; it can also inform planners or GIS managers on how to answer those questions from senior management

M Scalable Vector Graphics (SVG): The Future

What is SVG?

61. Scalable Vector Graphics (SVG) is a new graphics file format and Ib development language based on XML. SVG enables Ib developers and designers to create dynamically generated, high-quality graphics from real-time data with precise structural and visual control. With this powerful new technology, SVG developers can create a new generation of Ib applications based on data-driven, interactive, and personalized graphics.

Box 1: SVG what is it? And why is it Preferred

Scalable Vector Graphics (**SVG**) is an XML specification and file format for describing two-dimensional vector graphics, both static and dynamic (interactive or animated). The SVG specification is an open standard that has been under development by the World Wide Web Consortium (W3C) since 1999. SVG images and their behaviours are defined in XML text files. This means that they can be searched, indexed, scripted and, if required, compressed. SVG files can be edited with any text editor, but specialist SVG development environments are also available. These offer a wide range of specialised and general-purpose features.

All modern web browsers except Microsoft Internet Explorer support and render SVG markup directly. To view SVG files in Internet Explorer (IE), users have to download and install a browser plug-in.

Since 2001, SVG has progressed from version 1.0 to 1.2 and has been modularised to allow various *profiles* to be published, including SVG Print, SVG Basic and SVG Tiny. Being an efficient, widely understood and flexible image format, SVG is also well-suited to small and mobile devices. The SVG Basic and SVG Tiny specifications were developed with just such uses in mind and many current mobile devices support them.

Why SVG?

62. **Data-driven Graphics:** SVG creates powerful, dynamic content because it tightly integrates front-end graphics to back-end business processes and data including e-commerce systems, corporate databases, and other rich sources of information. SVG files use existing and proven Ib standards such as Cascading Style Sheets (CSS) and Extensible Style Sheet Language so that graphics can be easily customized.

63. **Reduced Maintenance Costs:** By dynamically changing image attributes, SVG eliminates the need for numerous image files. For example, a navigation button that normally requires a minimum of two raster files can be replaced by a single SVG file? Roll over states and behaviors are specified via easily scriptable attributes such as color, shape, size, text, or opacity. And because SVG is text based, production teams can utilize version control systems to track and manage all changes made to a file.

64. **Reduced Development Time:** In a traditional Ib workflow, content (data), presentation (graphics), and application logic (scripting) are developed sequentially. If a change is made to content after a project is complete, entire graphics must often be re-created. SVG separates these three elements, allowing them to be developed in parallel, reducing development time and distributing the work more efficiently. By separating such workflow elements, SVG enables developers to develop and designers to design.

65. **Scalable Server Solutions:** SVG can reduce server loads by allowing client platforms to perform the graphic rendering. If the client platform has limited processing resources (PDAs and cell phones, for example), the server can pre-render and optimize content before delivery. In both cases, the source content is the same. Client-side rendering can also dramatically improve the user experience. For example, zooming in on an SVG-enabled map is extremely fast and can instantly provide additional details such as streets names, building addresses, and topographic information.

66. **Easily Updated:** As data changes, so do the graphics, with no additional work on the part of the developer. Unlike other proprietary formats, SVG separates design from content, making updates to either relatively painless.