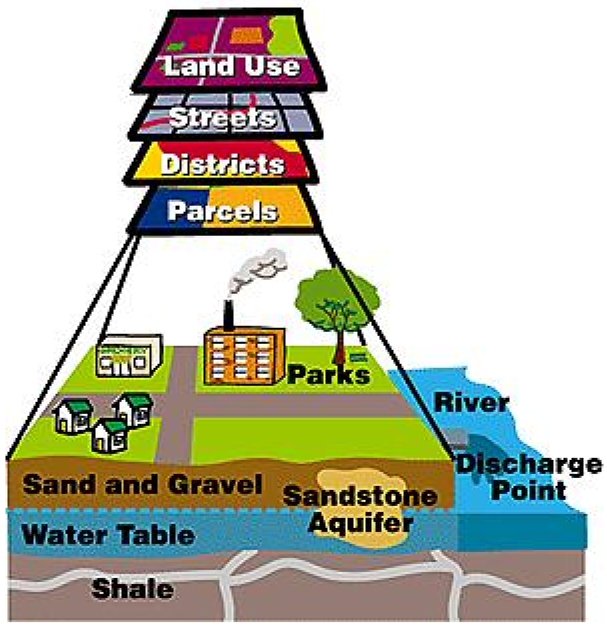
DATA MODELS

A GIS stores information about the world as a collection of thematic layers that can be linked together by geography. This simple but extremely powerful and versatile concept has proven invaluable for solving many real-world problems from tracking delivery vehicles, to recording details of planning applications, to modeling global atmospheric circulation. The thematic layer approach allows us to organize the complexity of the real world into a simple representation to help facilitate our understanding of natural relationships.



The thematic layer approach allows us to organize the complexity of the real world

GIS DATA TYPES

The basic data type in a GIS reflects traditional data found on a map. Accordingly, GIS technology utilizes two basic types of data. These are:

- **Spatial data** — describes the absolute and relative location of geographic features.
- **Attribute data** — describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is often referred to as tabular data.

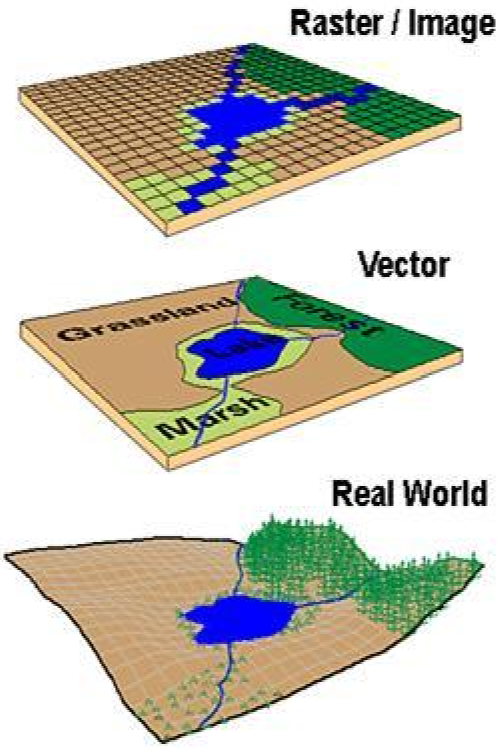
The coordinate location of a forestry stand would be spatial data, while the characteristics of that forestry stand, e.g. cover group, dominant species, crown closure, height, etc., would be attribute data. Other data types, in particular image and multimedia data, are becoming more prevalent with changing technology. Depending on the specific content of the data, *image data* may be considered either spatial, e.g. photographs, animation, movies, etc., or attribute, e.g. sound, descriptions, narration's, etc.

SPATIAL DATA MODELS

Traditionally spatial data has been stored and presented in the form of a map. Three basic types of spatial data models have evolved for storing geographic data digitally. These are referred to as:

- **Vector**;
- **Raster**;
- **Image**.

The following diagram reflects the two primary spatial data encoding techniques. These are vector and raster. Image data utilizes techniques very similar to raster data, however typically lacks the internal formats required for analysis and modeling of the data. Images reflect *pictures* or *photographs* of the landscape.



Representation of the real world and showing differences in how a vector and a raster GIS will represent this real world.

VECTOR DATA FORMATS

All spatial data models are approaches for storing the spatial location of geographic features in a database. Vector storage implies the use of vectors (directional lines) to represent a geographic feature. Vector data is characterized by the use of sequential points or *vertices* to define a linear segment. Each vertex consists of an X coordinate and a Y coordinate.

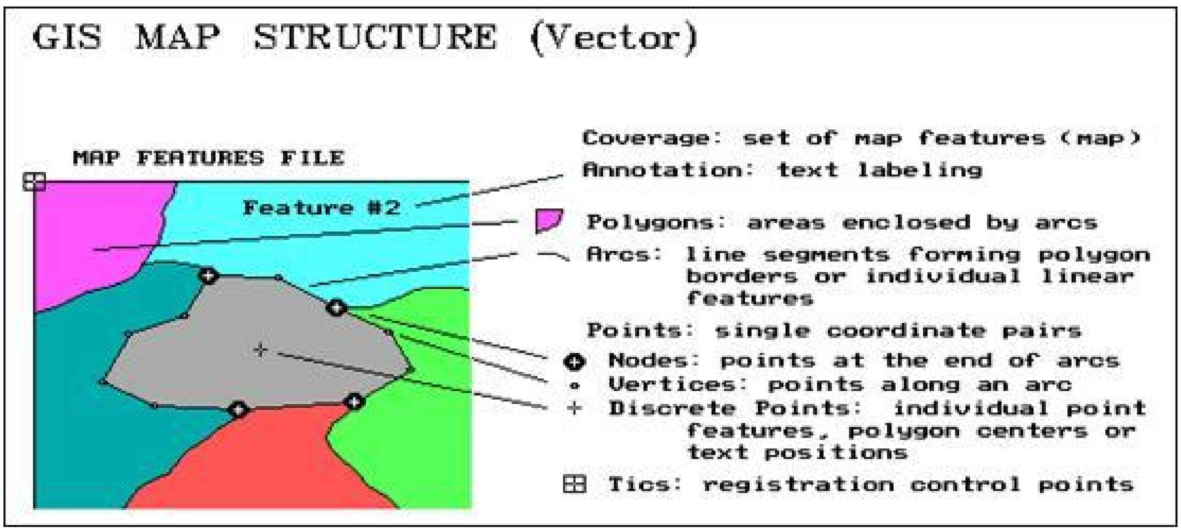
Vector lines are often referred to as *arcs* and consist of a string of vertices terminated by a *node*. A node is defined as a vertex that starts or ends an arc segment. Point features are defined by one coordinate pair, a vertex. Polygonal features are defined by a set of closed coordinate pairs. In vector representation, the storage of the vertices for each feature is important, as well as the connectivity between features, e.g. the sharing of common vertices where features connect.

Several different vector data models exist, however only two are commonly used in GIS data storage.

The most popular method of retaining spatial relationships among features is to explicitly record adjacency information in what is known as the topologic data model. Topology is a mathematical concept that has its basis in the principles of feature adjacency and connectivity.

The **topologic data structure** is often referred to as an *intelligent data structure* because spatial relationships between geographic features are easily derived when using them. Primarily for this reason the topologic model is the dominant vector data structure currently used in GIS technology. Many of the complex data analysis functions cannot effectively be undertaken without a topologic vector data structure. Topology is reviewed in greater detail later on in the book.

The secondary vector data structure that is common among GIS software is the **computer-aided drafting (CAD) data structure**. This structure consists of listing elements, not features, defined by strings of vertices, to define geographic features, e.g. points, lines, or areas. There is considerable redundancy with this data model since the boundary segment between two polygons can be stored twice, once for each feature. The CAD structure emerged from the development of computer graphics systems without specific considerations of processing geographic features. Accordingly, since features, e.g. polygons, are self-contained and independent, questions about the adjacency of features can be difficult to answer. The CAD vector model lacks the definition of spatial relationships between features that is defined by the topologic data model.



GIS MAP Structure - VECTOR systems (Adapted from Berry)

RASTER DATA FORMATS

Raster data models incorporate the use of a *grid-cell* data structure where the geographic area is divided into cells identified by row and column. This data structure is commonly called*raster*. While the term raster implies a regularly spaced grid other *tessellated* data structures do exist in grid based

GIS systems. In particular, the quadtree data structure has found some acceptance as an alternative raster data model.

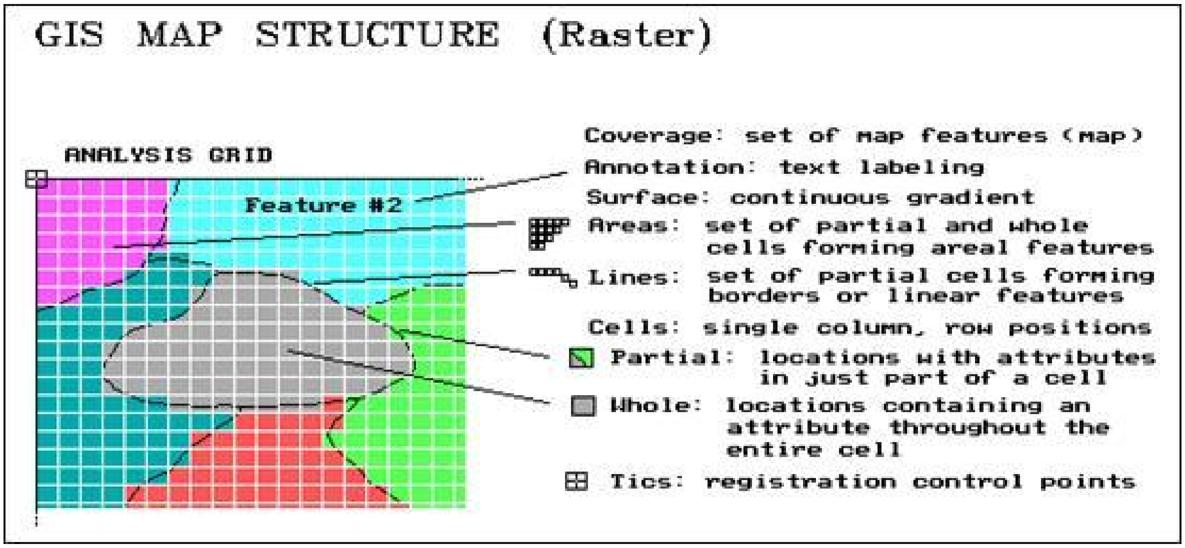
The size of cells in a tessellated data structure is selected on the basis of the data accuracy and the resolution needed by the user. There is no explicit coding of geographic coordinates required since that is implicit in the layout of the cells. A raster data structure is in fact a matrix where any coordinate can be quickly calculated if the origin point is known, and the size of the grid cells is known. Since grid-cells can be handled as two-dimensional arrays in computer encoding many analytical operations are easy to program. This makes tessellated data structures a popular choice for many GIS software. Topology is not a relevant concept with tessellated structures since adjacency and connectivity are implicit in the location of a particular cell in the data matrix.

Several tessellated data structures exist, however only two are commonly used in GIS's. The most popular cell structure is the regularly spaced matrix or *raster* structure. This data structure involves a division of spatial data into regularly spaced cells. Each cell is of the same shape and size. Squares are most commonly utilized.

Since geographic data is rarely distinguished by regularly spaced shapes, cells must be classified as to the most common attribute for the cell. The problem of determining the proper resolution for a particular data layer can be a concern. If one selects too coarse a cell size then data may be overly generalized. If one selects too fine a cell size then too many cells may be created resulting in a large data volume, slower processing times, and a more cumbersome data set. As well, one can imply accuracy greater than that of the original data capture process and this may result in some erroneous results during analysis.

As well, since most data is captured in a vector format, e.g. digitizing, data must be converted to the raster data structure. This is called *vector-raster conversion*. Most GIS software allows the user to define the raster grid (cell) size for vector-raster conversion. It is imperative that the original scale, e.g. accuracy, of the data be known prior to conversion. The accuracy of the data, often referred to as the resolution, should determine the cell size of the output raster map during conversion.

Most raster based GIS software requires that the raster cell contain only a single discrete value. Accordingly, a data layer, e.g. forest inventory stands, may be broken down into a series of raster maps, each representing an attribute type, e.g. a species map, a height map, a density map, etc. These are often referred to as *one attribute maps*. This is in contrast to most conventional vector data models that maintain data as *multiple attribute maps*, e.g. forest inventory polygons *linked* to a database table containing all attributes as columns. This basic distinction of raster data storage provides the foundation for quantitative analysis techniques. This is often referred to as *raster or map algebra*. The use of raster data structures allow for sophisticated mathematical modelling processes while vector based systems are often constrained by the capabilities and language of a relational DBMS.



GIS MAP Structure - RASTER systems (Adapted from Berry)

This difference is the major distinguishing factor between vector and raster based GIS software. It is also important to understand that the selection of a particular data structure can provide advantages during the analysis stage. For example, the vector data model does not handle continuous data, e.g. elevation, very well while the raster data model is more ideally suited for this type of analysis. Accordingly, the raster structure does not handle linear data analysis, e.g. shortest path, very well while vector systems do. It is important for the user to understand that there are certain advantages and disadvantages to each data model.

The selection of a particular data model, vector or raster, is dependent on the source and type of data, as well as the intended use of the data. Certain analytical procedures require raster data while others are better suited to vector data.

VECTOR AND RASTER - ADVANTAGES AND DISADVANTAGES

There are several advantages and disadvantages for using either the vector or raster data model to store spatial data. These are summarized below.

Vector Data

Advantages :

- Data can be represented at its original resolution and form without generalization.
- Graphic output is usually more aesthetically pleasing (traditional cartographic representation);

- Since most data, e.g. hard copy maps, is in vector form no data conversion is required.
- Accurate geographic location of data is maintained.
- Allows for efficient encoding of topology, and as a result more efficient operations that require topological information, e.g. proximity, network analysis.

Disadvantages:

- The location of each vertex needs to be stored explicitly.
- For effective analysis, vector data must be converted into a topological structure. This is often processing intensive and usually requires extensive data cleaning. As well, topology is static, and any updating or editing of the vector data requires re-building of the topology.
- Algorithms for manipulative and analysis functions are complex and may be processing intensive. Often, this inherently limits the functionality for large data sets, e.g. a large number of features.
- Continuous data, such as elevation data, is not effectively represented in vector form. Usually substantial data generalization or interpolation is required for these data layers.
- Spatial analysis and filtering within polygons is impossible

.

Raster Data

Advantages :

- The geographic location of each cell is implied by its position in the cell matrix. Accordingly, other than an origin point, e.g. bottom left corner, no geographic coordinates are stored.
- Due to the nature of the data storage technique data analysis is usually easy to program and quick to perform.
- The inherent nature of raster maps, e.g. one attribute maps, is ideally suited for mathematical modeling and quantitative analysis.
- Discrete data, e.g. forestry stands, is accommodated equally well as continuous data, e.g. elevation data, and facilitates the integrating of the two data types.
- Grid-cell systems are very compatible with raster-based output devices, e.g. electrostatic plotters, graphic terminals.

Disadvantages:

- The cell size determines the resolution at which the data is represented.;
- It is especially difficult to adequately represent linear features depending on the cell resolution. Accordingly, network linkages are difficult to establish.
- Processing of associated attribute data may be cumbersome if large amounts of data exists. Raster maps inherently reflect only one attribute or characteristic for an area.
- Since most input data is in vector form, data must undergo vector-to-raster conversion. Besides increased processing requirements this may introduce data integrity concerns due to generalization and choice of inappropriate cell size.
- Most output maps from grid-cell systems do not conform to high-quality cartographic needs.

It is often difficult to compare or rate GIS software that use different data models. Some personal computer (PC) packages utilize vector structures for data input, editing, and display but convert to raster structures for any analysis. Other more comprehensive GIS offerings provide both integrated raster and vector analysis techniques. They allow users to select the data structure appropriate for the analysis requirements. Integrated raster and vector processing capabilities are most desirable and provide the greatest flexibility for data manipulation and analysis.

Data Compression

DEFINITION

Data compression of Network GIS refers to compression of geospatial data within a network GIS so that volume of data transmitted across the network can be reduced. Typically, a properly chosen compression algorithm can reduce data size to 5~10% of original for images [1-2], and 10~20% for vector [3] and textual data [4]. Such compression ratios result in significant performance improvement.

Data compression algorithms can be categorized into lossless and lossy. Bit streams generated by lossless compression algorithm can be faithfully recovered to the original data. If loss of one single bit may cause serious and unpredictable consequences in original data (for example, text and medical image compression) lossless compression algorithm should be applied. If data consumers can tolerate distortion of original data to a certain degree, lossy compression algorithms are usually better because they can achieve much higher compression ratios than lossless ones. Some commonly used lossless and lossy data compression algorithms are listed in Table I.

Table I Lossless and lossy data compression algorithms

Lossless	Lossy
Huffman Coding	Differential Pulse Coded Modulation (DPCM)
Arithmetic Coding	Transform Coding
Lempel-Ziv Coding (LZC)	Subband Coding
Burrows-Wheeler Transform (BWT)	Vector Quantization
…	…

Raster data compression

Raster data compression algorithms are the same as algorithms for compression of other image data. However, geospatial images are usually of much higher resolution, multi-spectral and of significant larger volume than natural images. To effectively compress raster data in networked GIS, emphasis must be put on the following aspects:

Statistical properties of imagery in GIS may be quite different from other types of imagery,
Correlation among different spectrums,
Managing schemas [16] to deal with large volume of geospatial raster data,
integration of different other types of datasets (e.g., vector and 3-D data)

Non-raster data compression

Different methods can be utilized to compress non-raster data, such as 2-D and 3-D vector data (e.g. roads and borders), 3-D mesh models, and TIN.

For vector data, a survey of simplification algorithms can be found in [17]. Simplification aims at extracting a subset of original vector data according to predefined criteria. Resulting vector data is also compressed. Algorithms that derive binary coding for vector data [3] [18] also exist. Compression algorithms for vector data are far less than those for raster data. Researches on progressive vector transmission algorithms concentrate more on topological and semantic aspects than pure binary coding [9-11]. However, due to the complexity of this problem, existing solutions are far from satisfaction.

For 3-D mesh models, usually its structure and attribute information are coded separately. Structure information records how vertexes are connected and must be losslessly compressed. Attribute information records information of each single vertex and can be lossy compressed. Progressive mesh transmission algorithms [19] depends on how to decimate vertex one by one so that a given error criterion can be optimized.

Compression and progressive transmission of TIN is similar to 3-D mesh models [20].

2. LOSSLESS COMPRESSION

Lossless compressions are generally based on redundancy reduction and typically concentrate on more efficient ways of encoding the image data. More sophisticated lossless compressions will also transform the colour information, but only in order to store or deliver the image and always in a way that can be reversed. The key point to grasp about lossless compression is that no information is irretrievably lost in the process. Once decompressed, a lossless image will always appear exactly the same as the original, uncompressed, image. A commonly used lossless compression is the LZW (named after its developers, Lempel, Ziv and Welch). LZW operates by default within the GIF format and is an optional compression within the TIFF format. Like run-length encoding, LZW looks for recurrent patterns in the image's raster data. It replaces these with codes, giving the most common patterns the shortest codes and storing all the definitions in a separate dictionary. Although LZW is a very good compression, it has become subject to patent claims, so newer image file formats have avoided using it.

3. LOSSY COMPRESSION

Lossy compressions are based on irrelevancy reduction strategies but will usually also employ some redundancy strategies, particularly in their encoding. Lossy compressions transform and simplify the image information in a way that gives much larger reductions in file size than lossless compressions. The lossless LZW compression can be expected to cut the file size to three quarters or two thirds of the original – perhaps even halve it if the image has few colors, like a logo. In contrast, a lossy compression like the JPEG will reduce the file size to as little as 1% of the original, although anything less than 10% is likely to visually distort the image. The trade off, however, is that a lossy compression is by definition irreversible – it permanently disposes of information.

The JPEG is the best known lossy compression. Its irrelevancy strategy is based on the characteristics of human visual perception. JPEG is optimized for photographs and similar continuous tone images that contain many, numbers of colors [5]. Relying on the fact that people can more easily distinguish brightness (luminance) than colour (chrominance), JPEG concentrates its compression on the colour information within the image.

JPEG makes use of a mathematical transformation known as the Discrete Cosine Transform (DCT) to shift the image's colour values into a mode that can be more efficiently compressed and coded. The Discrete Cosine Transformation is not in itself lossy, but the next step in the compression process, known as quantisation, simplifies and rounds the colour values before they are encoded, throwing away real information. This is where the JPEG quality slider operates – it governs how much simplification occurs.

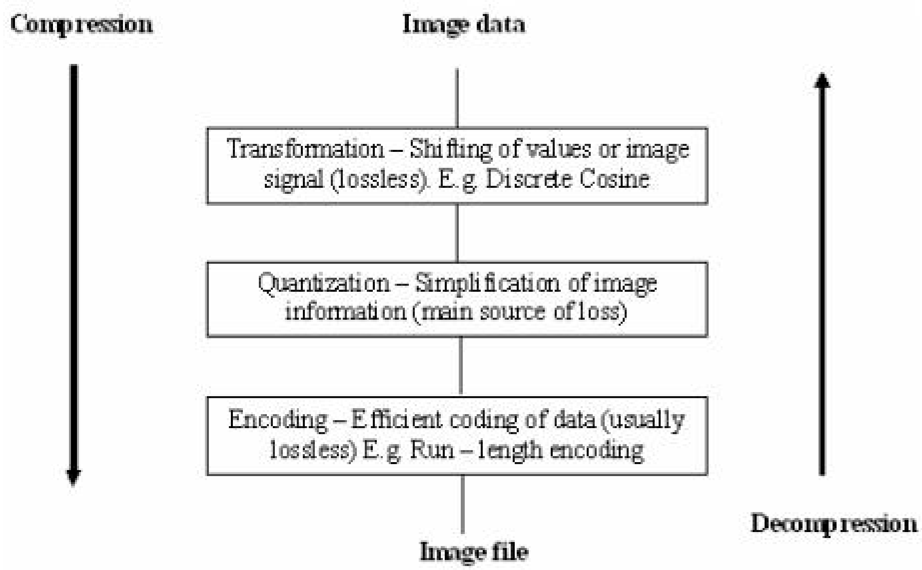


Figure 1: Steps Followed in a Lossy Image Compression Method

JPEG compresses small 8 · 8 pixel blocks of the picture at a time, working from top left to bottom right. Because the simplification (quantization) of each 8 · 8 (64 pixel) block is done independently, at a high compression (i.e. low quality) the boundaries between the blocks will begin to show, causing the 'blockiness' or 'blocking artifacts' often observed in JPEG images.

GIS Attribute data Analysis

Introduction

Geographical analysis allows the study of real-world processes by developing and applying models. Such models illuminate underlying trends in the geographical data and thus make new information available. A GIS enhances this process by providing tools, which can be combined in meaningful sequences to develop new models. These models may reveal new or previously unidentified relationships within and between data sets, thus increasing our understanding of the real world.

Results of geographical data analysis can be communicated with maps, reports, or both. A map is best used to display geographical relationships whereas a report is most appropriate for summarizing the tabular data and documenting any calculated values.

Analysis in GIS

Traditionally, geographic information systems are considered to perform four basic functions: input/updating, data conversion, storage/organization, manipulation, spatial analysis and output (presentation/display). Analysis module usually contain four important functions:

1. Selection is a rather simple operation, but it is important because all subsequent work is based on the results of the selection process.
2. Manipulation has to do with aggregation, buffering, overlaying and interpolation.
3. Exploration is the first step in discovering any kind of pattern or cluster in a data set. Explorative spatial data analysis (ESDA) uses the data in an inductive way to get new insight about spatial patterns and relations - "we let the data speak for themselves". Spatial statistics as Moran's I and the G statistics are important tools in explorative spatial data analysis.
4. Confirmation can be seen as tools for estimation of process models, simulation and forecasting,

From Clarke (1997) it can deduced that, what makes analysis in GIS different from other statistical analysis is that the attribute data have established links to maps for visual analysis. Any statistic we can think of to describe the data then automatically has geographic properties and as a result can be placed on map for visual processing.

Analysis Procedure

Before starting any analysis, one needs to assess the problem and establish an objective. It is important to think through the process before making any judgments about the data or reaching any decisions; ask questions about the data and model; and generate a step-by-step procedure to monitor the development and outline the overall objective (Modarres, 1998). The following steps outline the basic procedure for geographical analysis:

- Establish the objectives and criteria for the analysis. Define the problem and then identify a sequence of operations to produce meaningful results.
- Prepare the data for spatial operations. Prepare all map coverages for the proposed data analysis. Add one or more attributes to coverages in the database if necessary.
- Perform the spatial operations. Perform the spatial operations and combine the coverages, e.g. creating buffering zones around features, manipulating spatial features and performing polygon overlay.
- Prepare the derived data for tabular analysis. Make sure the feature attribute table contains all the items needed to hold the new values to be created.
- Perform the tabular analysis. Calculation and query the relational database using the model defined in step 1.
- Evaluate and interpret the results. Examine the results and determine whether the answers are valid. Simple map displays and reports can help in this evaluation.
- Refine the analysis if needed and repeat the analysis.

Figure 4.2. Analysis Procedure

GIS spatial analysis

According McGregor (1999) there is a strong link between humans and their environment and spatial analysis techniques and methods help to incorporate spatial elements into studies, so that we develop a clearer picture of human/environment link. Geographic Information Systems is a spatial analysis tool, which used in the Spatial Analysis to include a spatial perspective.

GIS data description answers the question "where?" GIS data analysis answers the question "why is it there?"(Clarke, 1997); *GIS Analysis* is the process of deriving information from one or more layers of spatial data (DeMers, 1997), it can involve multiple steps and processes and it is perhaps the most important capability of a GIS. Allows discovering relationships between various spatial data that might not have been apparent otherwise.

As Fischer, et al, (1996) put it, the heart of GIS analysis is the spatial/relational model, which expresses complex spatial relationships among map entities. The relationships can be stored in the data structure (topology) or derived through analysis. For example, the cascading relationships among members of same family can be encapsulated within a dataset. Spatial analysis is where the GIS rubber hits the road—where all the hard work of digitizing, building a database, checking for errors, and dealing with the details of projections and coordinate systems finally pays off in results and better decisions.

Spatial Analysis in GIS involves three types of operations: attribute queries (also known as aspatial queries), spatial queries, and generation of new data sets from the original database (Chou, 1997). The scope of spatial analysis ranges from simple query about the spatial phenomenon to complicated combinations of attribute queries, spatial queries, and alterations of original data (Fotheringham, et al. 1994). They characteristically include techniques such as single layer (horizontal operations) and multiple layer operations/vertical operations (analytical procedures that operate on multiple data layers) (Chou, 1997); they are based on the logical relationship among data layers.

These operations provide the most fundamental tools for the manipulation of the data organized on separate layers and the examination of the relationship among different features. They can be classified according to functionality into: overlay analysis (it involves the logical connection and manipulation of spatial data on separate layers); proximity analysis deals with operational procedures that are based on distance measurement between features on different layers; spatial correlation analysis is useful for revealing the relation between features of different types, spatial querying, point-in-polygon operation, buffering, and intersection, dissolving, etc.

4.5.5 Spatial Relationships

The term spatial relationships is the use of knowledge about the physical location of the objects, measure the distance between them and examine their attributes, it is achieved through cartography (cartography is to view maps as a form of visual communication--a special-purpose language for describing spatial relationships (Tomlin, 1990; Cartographic communication, 1999).

The types of spatial objects are points, lines, areas (for vector), raster cells (for raster); these object types are digital representations of phenomena and are defined by their dimensionality. An entity type is a type of phenomenon (e.g. building) and the same entity type may be represented by different types of objects at different scales e.g. a city may be a point at one scale, an area at another. In the database, several different types of entities may be represented by the same type of object e.g. points may represent both cities and buildings. An object class is a group of objects of the same type, representing the same type of entity e.g. cities and buildings are different classes of the same type of object (point). Also the number and meaning of attributes is the same for all objects in a class.

Object attributes may use various measurement scales (i.e. nominal, ordinal, interval, ratio). We think of a class of objects and its attributes as a table with rows corresponding to objects and columns corresponding to attributes. Classes of objects can be grouped into layers; sometimes only one per layer, depending on the system.

The power of a GIS comes from its ability to store relationships among and between objects. Relationships can be between objects of the same class, more often between objects of different classes; relationships can identify object pairs, which have their own attributes. There are a vast number of possible relationships in spatial data.

Relationships which are used to construct complex objects from simple primitives e.g. relationship between a line (chain) and the ordered set of points which defines it, relationship between an area (polygon) and the ordered set of lines which defines it

Relationships which can be computed from the coordinates of the objects e.g. two lines can be examined to see if they cross - the "crosses" relationship can be computed. Areas can be examined to see which one encloses a given point - the "is contained in" relationship can be computed, areas can be examined to see if they overlap - the "overlaps" relationship

Relationships which cannot be computed from coordinates - these must be coded in the database during input e.g. we can compute if two lines cross, but not if the highways they represent intersect (may be an overpass), some databases allow an entity called a "complex object", composed of "simple objects", e.g. objects representing "house", "lot", "cable", with associated attributes might be grouped together logically as "account".

Types of spatial analysis (Volusia, 1997) and (Chou, 1997) include: *Single layer operations* are GIS procedures which correspond to attribute queries, spatial queries, and alternations of data that operate on a single data layer, *Multiple-layer operations* are useful for manipulation of spatial data on multiple data layers, *Spatial modeling* involves the construction of explanatory and predictive models for statistical testing, *Point pattern analysis* deals with the examination and evaluation of spatial patterns and the processes of point features, *Network analysis*, designed specifically for line features organized in connected networks, typically applies to transportation problems and location analysis, *Surface analysis* deals with the spatial distribution of surface information in terms of a three-dimensional structure, *Grid analysis* involves the processing of spatial data in a spatial, regularly spaced form, spatial overlay, Boundary analysis, Proximity analysis, and Buffer analysis.

The raster data model supports a wide variety of analysis methods including: Neighborhood operations, Connectivity functions, Query, Classification and Measurement functions

Analysis functions with vector-based GIS are not quite the same as with raster GIS. There are more operations deal with objects and measurements such as area have to be calculated from coordinates of objects instead of counting cells as in raster GIS. In vector system most of the analyses like find are done by direct search in the database (DeMers, 1997) Compared with raster GIS, some of the vector GIS operations are more accurate (e.g. estimates of area based on polygons are more accurate than counts of pixels; and estimates of perimeter of polygon are more accurate than counting pixel boundaries on the edge of a zone), some are slower (e.g. overlaying layers and finding buffers) and some are faster (e.g. finding path through road network).

The idea of a vector representation is that we represent objects in the real world by points, lines and polygons in the GIS. By using a traditional kind of 2-D co-ordinate system, with a 'continuous' number system for the co-ordinate values, we can obtain a very high resolution very efficiently. Two numbers, x and y, and we have the location of a point. And we can store that position to zillionths of a millimeter in a database, if we wish.

4.5.6 Types of GIS Analysis

4.5.6.1 Spatial measurements.

GIS makes spatial measurements easy to perform. Spatial measurements can be the distance between two points, the area of a polygon or the length of a line or boundary. Calculations can be of a simple nature, such as measuring areas on one map, or more complex, such as measuring overlapping areas on two or more maps.

4.5.6.2 Information Retrieval

With a GIS we can point at a location, object, or area on the screen and retrieve recorded information about it from the Database Management System (DBMS) which holds the information abut the map's features.

In order for a GIS to answer the question "what is where?" we need to carry out retrieval. Retrieval is the ability of the DBMS or GIS to get back on demand data that were previously stored (Clarke, 1997). As Clarke put it "Geographic search is the secret to GIS data retrieval" so GIS systems have embedded DBMSs, or link to a commercial DBMS.

4.5.6.3 Searches by attribute

Most GIS systems include as part of the package a fairly basic relational database manager, or simply built on the exiting capabilities of a database system. All DBMS include functions for basic data display. Searches by attribute are then controlled by the capabilities of database manager. Find is the basic attribute search (Clarke, 1997). Find is intended to get a single record. Find can be browse or by searches. Examples include show attributes, show records, generate a report, find, recode, select, renumber, sort, compute allows the creation of new attributes based on calculated values, restrict, join, replace; all are examples of data reorganization.

Attribute queries are not very useful for geographic search as they don't or difficult to indicate location; so they just work as humble assistants in our geographical searching needs.

4.5.6.4 Searches by geography

In a map database the records are features. The GIS spatial retrieval is the generating maps, which allow searching for information visually and highlights the result, (Clarke, 1997). For example to generate a report; the spatial equivalent would to produce a finished map, the spatial equivalent of a find is locate. Spatial equivalents of the DBMS queries result in locating sets of features, or building new GIS layers. These include: Spatial searching, browsing the map and picking features, Spatial sorting to identify features that result from attribute sorting, Recoding features spatially, that is changing the scope of their attribute, is equivalent to spatial merge, Spatial select is to extract specific features. The form of select used most is buffer operation. Buffering is a spatial retrieval around points, lines, or areas based on distance, a join operation is the cross-construction of a database by merging attributes across flat files, in spatial terms it is called overlay. Thus overlay is a spatial retrieval operation that is equivalent to an attribute join.

Combinations of spatial and attribute queries can build some complex and powerful GIS operations, such as weighting e.g. dominant ethnic group in an area. Entire suites of geographic searches are searches and tests by relations of points, lines, and areas. Typical GIS searches are point in polygon, line in polygon, and point distance to line (Clarke, 1997).

4.5.6.5 The query interface

The user must interact with the data in appropriate way, to do that, we need the query interface. GIS query is usually by command line, batch or macro (Macro are files containing commands to be executed, one at a time) (Clarke, 1997).

The batch-type interaction with the data is usually linked to working with the operating system, the physical management of disk. This type of interaction dates back from the punched cards, in that all processes had to be thought out in advance and a file (or stack of cards) produced that could execute the different commands one at a time.

When interactive computing become commonplace, the command line as a query vehicle for data query took over. Commands were typed into the computer one at a time, under the control of the DBMS itself, and the software responded by performing the computations one at a time while the user waited for the command to be completed.

Most GIS packages are fully integrated with the WIMP (windows, icons, menus, and pointers) and use the GUI (graphical user interface) of the computer's operating system, such as windows to support both a menu-type query interface and a macro or programming language. And fairly recent trend is that most GISs also contain a language or macro tool for automating repetitive tasks; e.g. ArcView's Avenue, MapInfo's MapBasic, and Arc/Info's AML (Clarke, 1997).

SQL (standard query language) has been developed to be a standard interface to relational databases and is supported by many GISs. These use interfaces have specific characteristics (Montgomery, 1993 and Korte, 1992)

4.5.6.6 Spatial overlay

One basic way to create or identify spatial relationships is through the process of spatial overlay. Spatial overlay is accomplished by joining and viewing together separate data sets that share all or part of the same area. The result of this combination is a new data set that identifies the spatial relationships.

The power of spatial overlay is used in this study to compare the different demographic characteristics. 1) To identify the mixing/dominance of ethnicity in the study area; four layers of data are used in the analysis, Polygons or areas are assigned a rating based on ethnic type (Chinese, Malay, Indian, and others group). 2) The age composition, the layers of data used in the analysis are ethnicity layer from the above analysis and the different age cohorts. 3) Sex composition were the ethnicity layer is used in addition to whether or not they male.

Then the layers in each analysis are combined to create a new layer, which contain all the previous information. Finally, a comprehensive rating is determined by multiplying together the separate rating items. The result for each is a map showing the characteristics.

4.5.6.7 Boundary analysis

Boundary analysis, which is often referred to as districting, helps define regions according to certain criteria. This procedure is used to define area of specific demographic characteristic. Since districting is normally an iterative process involving the development of numerous scenarios based on various combinations of desired criteria, the computing power of the GIS proves to be a real timesaver. Rather than struggling with paper maps and adding machines, it is able to interactively define proposed boundaries and have related population totals automatically computed in a matter of minutes.

The redistricting of the study area is based on the majority ethnic group. The process involves the assignment of a certain number to each group. Prior to using GIS, developing of clusters is done using the statistical techniques.

4.5.6.8 Buffer analysis

Buffer analysis is used for identifying areas surrounding geographic features. The process involves generating a buffer around existing geographic features and then identifying or selecting features based on whether they fall inside or outside the boundary of the buffer.

This process is used to identify neighborhood for a specific ethnic group. The purpose of this; is to cluster households of the same ethnic group. The process involves representing each household on the map as a point. Each point is coded with information that pertained to the type of ethnicity, as well as the other demographic characteristics.

4.5.6.9 Neighborhood Operations

Neighborhood operations can evaluate the characteristics of the area surrounding a specific location: Identify all cells with value 5 (say people under 5 years old). Neighborhood operations include the following: Search (Average, Diversity, Majority, Maximum/Minimum, and total), Topographic, Interpolation (interpolation involves using known cell values to predict predicting the values of intermediate cells), and Contour Generation

4.5.6.10 Connectivity Functions

Connectivity functions involve traversing an area and accumulating values: Contiguity measures, Proximity, Network functions, Spread, Seek and Stream functions

Find operation

A raster GIS offers numerous ways to find items (DeMers, 1997). A simplest is to create a new coverage that eliminates all unnecessary data. To do this, all the other portions of the database are masked through a simple reclassification process e.g. reclassify everything else in the coverage as background, then output the result in table that allows to count the target points (grid cells) and background. Generally this will also allow to output percentage directly as well making possible comparisons of the amounts of the coverage occupied by the selected feature.

Network Analysis

Network analysis is used for identifying the most efficient routes or paths for allocation of services, and for evaluation of it. Identifying an efficient route or path is finding the shortest or least-cost manner in which to visit a location or a set of locations in a network. GIS can handle complex network problems, such as road network analysis. A GIS can work out travel times and the shortest path from A to B. This facility can be built into more complicated models that might require estimates of travel time, accessibility or impedance along a route system

Network analysis can also be used to optimize the allocation of resources. Such allocation is performed by identifying and creating areas of influence or service zones based on certain criteria. It is accomplished by assigning portions of a network to a location based on impedance.

Digital terrain analysis, GIS can build three dimensional models, where the topography of a geographical location can be represented with an x, y, z data model known as Digital Terrain (or Elevation) Model (DTM/DEM). The x and y dimensions of a DTM represent the horizontal plane, and z represent spot heights for the respective x, y coordinates.

Network (TIN), The data sets derived from a Digital Terrain Model can be used to analyze environmental phenomena or engineering projects that are influenced by elevation, aspect or slope. The visualization (display) power of the computer allows the terrain data to be visualized in three-dimensional form, often from any angle of view (this is known as point-of-view analysis).

INTEGRATED DATA ANALYSIS

Integrated Analysis and Compatibility

One of the main perpedus for GIS and in particular for spatial data interchange is the GIS's potential to combine data from various sources and different thematic fields, thus promoting data sharing by its very nature. This facility is particularly important for environmental analysis and problem solving which is highly interdisciplinary. In this fields there are many phenomena that are either difficult or expensive to measure e.g., evapotranspiration, soil erosion or potential natural vegetation. Deriving such information involves its modeling e.g., the combination of available data based on the rules of some deterministic or probabilistic model (Isaaks and Srivastava, 1989, p. 198ff). In the remainder of this paper such combinations of data sets are called *integrated analysis.*

Data assembling for integrated analysis is not only an issue of establishing a (technical) data interchange but raises compatibility issues on a higher abstraction level. What do we mean by this? Integrated analysis in GIS requires the data sets to be compatible with the GIS (i.e., to facilitate the correct decoding) *and* to be compatible *among themselves* (i.e., to establish comparability).

Figure 2 illustrates the two types of compatibility in an integrated analysis. The use of standard formats support the transfer and the correct decoding of the data e.g., the conversion from the interchange format to the GIS's internal data representation. The data sets present in a standardized environment provides compatibility from *a technical point of view* i.e., data are compatible with the GIS. Beyond that, the combination of those data sets within an integrated analysis requires the data to be compatible with each other e.g., to have comparable spatial, temporal, attribute and quality characteristics.

The next section will discuss the nature of those higher level compatibility issues, their importance, origin and relation to technical standardization.

Types of High-Level Compatibility

Integrated analysis is based on relations between data sets. Evaluation of such relations e.g., boolean, arithmetic or topological operations, requires common or similar' characteristics of the data sets involved e.g., identical spatial and/or temporal references and classification schemes. Table 1 gives an overview of common high-level incompatibility sources, which are mainly *contextual* issues.

When performing integrated analyses the high-level compatibility is often not given a priori but must be established first. The main problem hereby derives from the fact, that data are always collected in a particular context which determines its geometric, temporal and thematic dimensions. This context may vary considerably for each data set, and creates various problems for integrated analysis. Molenaar (1993, p. 26) gives an overview of contextual aspects to be considered for achieving high-level compatibility, such as the level of mapping (e.g., local, regional, national, or even global) and the task for which the data is used (e.g., monitoring, analysis of spatial processes and patterns, planning). These various contexts result on the one hand in different spatio-temporal references and resolutions and on the other hand in different levels of aggregation of the thematic

3. Polygon overlay, for example, operates on an intersection of the spatial references and therefore only requires similar spatial references.

[End Page 69]

information. In the following we refer to the context of data collection as to *original context*.

Beyond that, to keep costs low the same data are used for multiple analyses, which may require further *modification*. This (context-dependent) modification may cause considerable changes in the original context and its corresponding geometric and thematic descriptions of the enclosed objects. We thus carefully distinguish between the original context (when the data was collected), the intermediate context (when the original data set had been modified due to former use) and analysis context (defined by the integrated analysis) of a data set.

ACHIEVING HIGH-LEVEL COMPATIBILITY

In the previous section various types and sources of high-level incompatibility were shown. Some of these incompatibilities are addressed within current spatial data transfer standards by means of unified feature and attribute coding catalogues and several standardized ways of encoding data quality. Examples are the feature and attribute coding catalogue of DIGEST (Defense Mapping Agency,

[End Page 70]

1991), the normative annex to SDTS (SDTS, 1992) and the unified feature-coding presented in Peled and Adler (1993, p. 429). Those efforts support the correct encoding of transferred data, while preserving the meaning (i.e., the context) but do leave problems of high-level incompatibility. These remaining incompatibilities need to be resolved by transforming data in their original (or intermediate) context to the analysis context. Such transformations include various interpolation methods, resampling techniques, up- and downscaling procedures, reclassification, application of deterministic models and so on. These methods all have in common that they involve the prediction of unknown properties such as attribute values for additional spatial references or points in time. We call these methods for (contextual) transformation as *predictions*.

Prediction usually is based on the behaviour of the phenomena under consideration and the data characteristics, respectively. The data characteristics i.e., the semantics of the data are highly determined by the original context and their subsequent modifications. Reliable prediction thus requires the following knowledge about a data set:

[End Page 71]

- Information about the original context: Collecting data in a first step requires that some preliminary knowledge and a priori assumptions about the spatio-temporal behaviour of the phenomenon to be mapped are established. These properties and the data requirements of the original context determine the sampling strategy, a procedure which is sometimes referred to as *first abstraction* (Mackaness and Beard, 1993, p. 235).
- Information about context modifications due to former use of the data set. As each modification may introduce additional uncertainties they should be carefully recorded.

These types of information (which is sometimes referred to as lineage or data history), is addressed in current standards by meta-data *'which are data that relate to the substantive data being transferred'* (Moellering, 1991, p.12). However, the information about data semantics supplied with today's data interchange formats is often not sufficient to support prediction substantially. The next section concentrates on structured procedures for coping with incompatibilities.

CONTEXTUAL STANDARDIZATION

The previous section showed that high-level compatibility is a basic requirement for integrated analysis; and as this high-level compatibility is often not given a priori, contextual transformations must be performed. Usually a GIS-database has to serve multiple purposes i.e., various types of integrated analyses. That means that one might be confronted regularly with the problem of high-level incompatibility, thus being forced to perform contextual transformations repeatedly. It is therefore reasonable to overcome this high-level incompatibility by standardization (*contextual standardization*) in a similar way as lower level incompatibility is addressed by standardized data interchange formats.

However, the fact that current data interchange standards are restricted to a technical level indicates, that this extension may bear inherent difficulties. As data requirements for integrated analysis may vary considerably the contextual standardization must be based on an approach that provides high flexibility. In fact, current approaches towards contextual standardization suffer from a lack of flexibility. For example, a common approach is to transform all data sets into a pre-specified context (e.g. transformation of all data to a grid of a predefined resolution). This context is designed to be as general as possible to serve many applications. However, the flexibility usually needed cannot been achieved. The long life-time of many data sets contrasts to the shorter lifetime of integrated analysis with their specific requirements. It is therefore likely, that a pre-specified context appropriate for some initial applications becomes unsuitable on the long run. Consequently, data have to go repeatedly through transformations which finally limit the success of this standardization effort.

Another, more flexible approach based on adaptive contextual standardization will be presented in the next section.

Modelling in GIS highway alignment studies

Introduction

In the present Indian scenario there is a major shift in transportation system from railways towards the road sector, which has envisaged the Government of India to facilitate development of roads and highways as exemplified by the Golden Quadrangle Program etc. New roads and highways are being designed and built, as well as the existing highways are being upgraded to 4/6 lanes along with the super expressways. The technical know-how of present day road designing depends on various factors viz. socio-economic criteria, demographic analysis, landuse / landcover pattern, topography, etc.

In this context, terrain analysis may be considered as the prime requisite in the planning phase for providing an insight to the engineers regarding the landform features to overcome the potential engineering problems viz. The site-specific engineering aspect of a Highway passing through an alluvial terrain is different from a Highway passing through a degradational landform or a hilly terrain.

Core Business

In Highway / Super Expressway designing, location of a line is the most important criteria in terms of Geo-referenced Physiographic configuration which include, baseline information: viz.

Drainage Pattern	
Landform features (i.e. terrain characteristics)	
Physical/ Natural Processes (including dormant one)	
Hydrological condition	Spatial Datasets
Geomorphic Soil type	
Landuse / Landcover	
Existing Transport Network and Settlement characteristics	

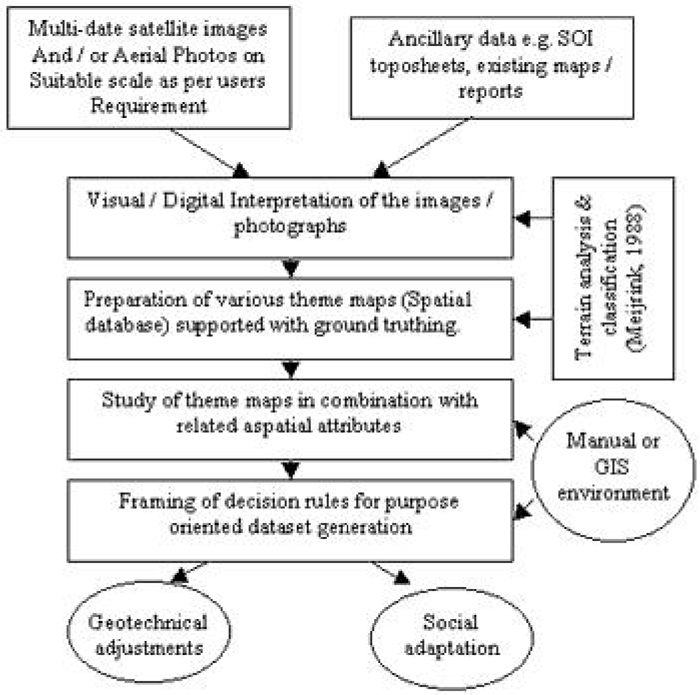
In this regard it may be mentioned that for cost modeling drainage pattern analysis helps in determining the number and type of bridges or culverts to be constructed, landform categories helps in determining the type of retaining wall or check dam to be erected and Landuse / Landcover study determines whether an alignment should be drawn over a double cropped area or a sparsely vegetated land.

Engineering properties of soil / subsoil conditions	
Surface & groundwater qualities	
Cultural / Aesthetic parameters	
Demographic composition	In
Historical packages	Aspatial terms
Traffic flow pattern statistics	
Disaster Management facilities	
Scenic qualities	

In this regard the spatial baseline information could be generated through terrain analysis and classification with morphogenetic approach (Meijrink, 1988) using Remote Sensing data. Space borne Remote Sensing and Geographical Information Systems are the most modern tool for generation of the aforesaid spatial data with temporal changes and subsequent integration and analysis of the aspatial data to conclude on "strategic datasets" (i.e. Geoinformation) giving emphasis on type of engineering work to be carried out. (c.f. Chakrabarti, 2000)

The Geoinformation provide vital information regarding 'vulnerable land units' for geotechnical adjustment (through structural means) and social adaptations (non-structural means) along the proposed Highway route (cf. Numan et al, 1995) (Fig.1). These new technologies could be utilized by the planners / executives for successful planning and execution of engineering activities and to increase the bearing strength of the road.

Activity Flow Chart



Case Studies

1 Flood Damage of the Panagarh - Moregram ADB road during the September 2000 devastating flood in West Bengal, India:

The ADB road is an important connectivity between NH-2 and NH-34 covering a distance of 150 Km. and passes across two major rivers of South Bengal namely Ajay and Mayurakshi. These rivers are characterized by a number of abandoned spill channels. It may be mentioned that flash flooding is a common phenomenon in the Ajoy River, which is also having a number of flood time spill channels and generally used as cropland now a days. The ADB Highway is passing over such a spill channel in and around Satkahania - Basudha area, Barddhaman district, West Bengal, India (Chakrabarti, Choudhury et.al. 2002). In this site only humes pipe are given as water pass way based on sparse information (cf Akinyedi, 1990) without giving insight to the factual data regarding the monsoonal activity of the spill channel. However multi-seasonal Remote Sensing data (IRS 1D, LISS III) reveals the presence of this loop channel (Photo 1a) locally known as Bidya River with its branch off point at Satkahania presently blocked by the embankment. During the September 2000 flood with breaches in the embankment at Satkahania point and rejuvenation of the aforesaid spill channel the road was damaged severely (Photo 1b) as the constructed water pass way was insufficient to accommodate the flood time flow - here lies the importance of terrain analysis with usage of Remote sensing data; some box culvert / small bridge may be constructed for avoiding such predicament.

2 Protection of Super Strada from Landslides in Southern Italy:

In Armento, Policoro province, Southern Italy the "Super Strada" (Super Expressway) passes through the Mediterranean schist phyllite and marl clay hills or 'Calinchi' prone to landslides. Detailed mapping using aerial photo and Remote Sensing data with field survey lead to the positioning of a number of "via ducts / check dams" (Photo 2 a,b,) as well as guard walls (Photo 2c) in the area to protect the "Super Strada" from damage due to frequent landslides. (Verstappen, 1988)

Conclusion

Comparative analysis of the case studies indicates the significance of Remote Sensing data for landform and drainage pattern analysis for safety of infrastructural designs in the planning stage itself. Usage of

Remote Sensing and GIS technologies may be considered as the essential prerequisite for careful physical spatial planning to make optimum use of the roads as communication links for all seasons as a great amount of money are invested in planning and construction activities of the roads.

Appropriate integration of different spatio-thematic information with aspatial data in GIS environment demand human resources development for handling and processing of the database of multidisciplinary nature to conclude on user orientation.

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Spill Channel
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Land Information System

INTRODUCTION

Problems concerning the optimal use of land resources and improved land management are important all over the world.

Since automation has greatly increased the ability to handle masses of data the challenge is to develop a good and comprehensive computerised *Land Information System* (LIS).

Information related specified land units is the cornerstone of LIS, since data concerning ownership and other property rights, boundaries, areas, land uses, market and assessed values, building, habitations, etc. are all interrelated.

Yl@tis-LIS is devoted to the problem of developing efficient information systems based on such land units and have proven knowledge of establishing LIS mainly based on experiences gained from integrating existing Cadastres, Land Register and Valuation Systems.

No countries are alike. *Yl@tis-LIS* should be understood as a framework of detail knowledge of the interrelations between areas related information. Our international experience has toughs us that traditional package solution seldom work since each country has its own infrastructure and administrative procedures.

The *Yl@tis-LIS* design has been developed in a modular fashion for LIS applications, and it has proven through the development of an integrated LIS for the Cyprus Government that *Yl@tis-LIS* can form a natural basis for comprehensive, multipurpose land information systems of great importance for improved planning management and control.

Furthermore, this modularity allows for a phased implementation plan, installing the individual modules only when legislation, organisation and work procedures are in place.

Yl@tis-LIS can be implemented by Yl@tis or by a locally selected software house backed by Yl@tis. In addition to the implementation of the system Yl@tis offers a number of consultancy services that can support the transition in the technical and administrative areas.

The Cyprus Land Information is a user-defined implementation of the Yl@tis LIS designed to fit Cyprus administration procedures and legislation. The system is at present running and can be demonstrated as the only computerised land Information System operating all basic interrelations on land units in one integrated system.

CONCEPTS

Several formal definitions of LIS have been proposed. Best known is one adopted by FIG (Federation International des Geometres)A land Information System is a tool for legal, administrative and economic decision-making and an aid for planning and development which consists one the one hand of a database containing spatially referenced land-related data for a defined area, and on the other hand of procedures and techniques for the systematic collection, updating, processing and distribution of the data. The base of a land information system is a uniform spatial referencing system for the data in the system, which also facilitates the linking of data within the system with other land related data.

A computerised Land Information System groups area related information and includes:

- Tools for legal, administrative and economic decisions
- Tools for physical planning and development

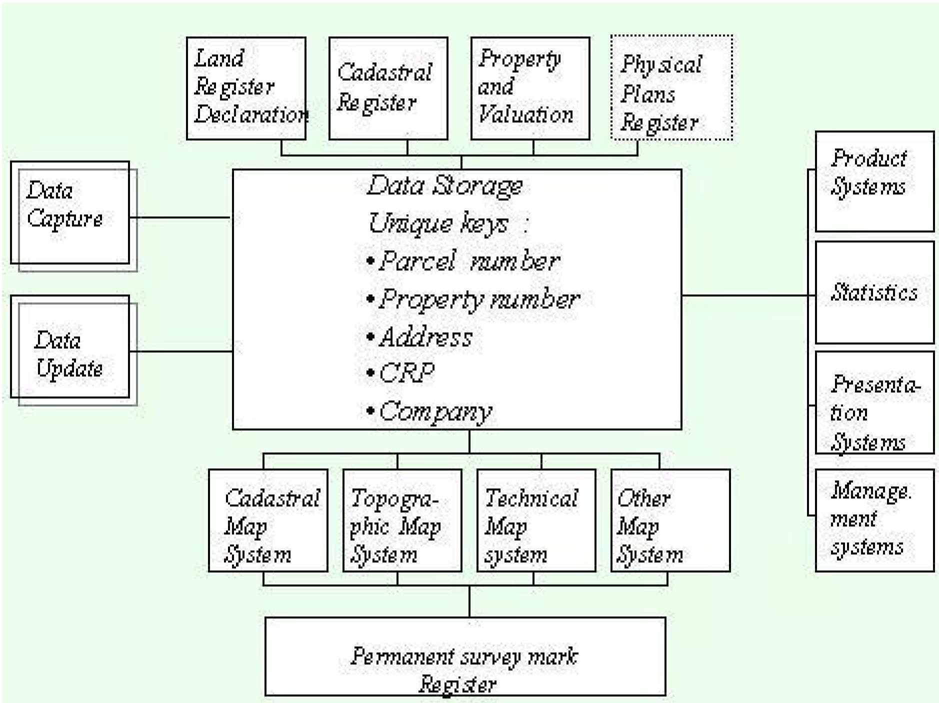
The cornerstone of Yl@tis-LIS is its modularity and data integrity, which is reflected, in well-defined modules providing the following major functions:

- Legal/Fiscal System
- GIS System

The legal/fiscal system can comprise of all area-related information but the core modules are:

- Cadastral Register
- Land Register of Declaration
- Property Valuation System

The links between these registers are unique keys such as property number, parcel number, person identifier, address code and company number. Those unique keys make it possible to collect necessary information across the different registers.



In order to support the administrative procedures involved with the case handling of land units a workflow system keeping track of all main transactions in the system is implemented as a shell enclosing the functional sub-systems. The present rules for the administrative procedures are laid down in the system.

KEY BENEFITS

The key benefits of Yl@tis-LIS are that the system provides:

- Secure management of public administration by transversely used analyses on the basis of information stored;

- High quality in public administration and reduction in public costs if data is reused;

- Better service to the public.

FUNCTIONAL FEATURES

Legal Fiscal System

1.Data Capture Models

The purpose of this module is to act as a tool for a fast conversion of the immense amount of land information data, which is stored in several manually kept registers. The module structure reflects the processes that are used by clerical staff when handling sales, transfer of owners, consolidations, acquisitions, valuation etc.

As the property entity is the basic entity in LIS, the most urgent task to deal with is the conversion of plots.

Converting the plots also means an automatically generated property number. When the conversion has been completed these modules will be unnecessary.

2.Register Core Systems

Cadastral Register Core System

The Cadastre is one of the basic registers in a Land Information System. Here new parcels of land are born and given identification, used by other registers of real properties.

The cadastre consists of four elements:
- The parcel register
- The Cadastral maps
- Measurements related to parcel framework (BTP)
- The register of Permanent Survey Marks (PSM)

The cadastral maps and the survey registers are described in the GIS section.

Alterations of properties are entered in the Cadastre based on measurements and documents worked out.

The Cadastral parcel number provides the link to other LIS sub-systems e.g. the Land Register and the Valuation of Property Register.

The core modules of the system consists of a complex of sub-module handling Cadastral alterations submitted by surveyors; valid checks of the alteration according to rules laid down in Cadastral regulations, update routines to other registers and temporary accumulation of data for statistical purposes.

Land Register of Declarations

The Land Register of Declarations mirrors the content of the current Land Register Pages, contain all the necessary information required to issue a legal Title Certificate for an Ownership, and reflect information on potential impediments.

The Land Register of Declarations forms the legislation of a property and keeps information about the following:

- Owner
- Address
- Area
- Tenure
- Declarations of transfer
- Mortgages
- Easements

Declarations includes:

- Mortgages and Bond.
- Forced Sales and Attachments
- Tenure
- Lease/License Notation
- Powers of Attorney

Land Register forms the basis on which all other satellite systems, like valuation and GIS, build additional data.

It controls all actions that are executed in relation to the properties as these are controlled by the law and are requested by the citizens.

The applications lodged by an owner or interested party for a particular property, is accepted and directed by the Legal department and is ending to it in order to finalize a specific transaction.

It is interrelated with the law of each country but the basic principles are common, like a division of a parcel, the sale of a property etc.

It controls the processing of the following transaction and not only:

- Maintain Contract of sale
- Maintain determination of boundary dispute
- Maintain Demarcation of Boundaries / Application for Replacing of Boundaries
- Maintain Compulsory Acquisition of Access

- Maintain partition
- Maintain amalgamation of titles
- Maintain Personal prohibitions
- Encumbrances
- Maintain Forced Sales
- Maintain Fixing/Varying Position of Access
- MAINTAIN GRANT OF LEASES
- Maintain Allocation of State Land
- Maintain Local enquiry
- MAINT LOCAL ENQ EXAM OF AN OBJ
- Maintain Mortgage
- Original Registration
- Readjustment of boundaries
- Maintain Registration by Inheritance
- Horizontal division
- Division of Units
- Maintain readjustment of Interest
- Maintain Transfer of a mortgage (Mortgagee)
- Declarations for transfer (Sale)
- Declaration of transfer (Gift)
- Declaration of transfer (Exchange)
- Maintain encroachments on state land
- Maintain exchange of state land
- Maintain Grant of State Land
- Maintain Power of Attorney
- Maintain Registration of Leases and Subleases
- Division/Grant of State Land
- Maintain Consolidation projects
- Maintain Acquisition by Grant
- Registration of a road
- Vertical Division
- Create / Maintain a legal Body
- Division and Partition under sec.29(8) Cap.224
- Maintain interests
- Maintain Division of Running Water
- Resurvey

Computer Aided Valuation

The fiscal info contains an informal part, as the government knows there is a house included in the property but it has not been informed by the citizen to the public administration.

Fiscal has a property, ownership part that can be altered Yl@tis-LIS Computer Aided valuation system comprises the following sub-systems:

- Computer Assisted Special Valuation System
- Computer Assisted Mass Appraisal System
- Real Property Enquiry System

Computer Assisted Special Valuation System

The *Computer Assisted Special Valuation System* is a standard registration system, which may be used to generate reports, and statistics in connection with Acquisitions, Rent Control, Land consolidations, Declarations etc.

Computer Assisted Mass Appraisal System (CAMAS)

The basic functions in CAMAS are:
- The Monitoring Phase
- The Property Value Calculation Phase
- The Exception Reporting Phase

The *Monitoring Phase* consists of a complex of modules, where the core is the calculation of the relation between: current capital value and analysed sale of property for sold properties.

The module complex comprises:
- Variable delimitation of geographical area
- Variable delimitation of administrative area
- Variable delimitation of period
- Delimitation of property types (residential, agricultural, forestry etc., i.e. use codes.
- Definition of the sale types which are to be analysed (optional sales, compulsory sales etc.)
- Definition of property values
- Control of the utility in the analysis of the defined data
- Calculation of distance percentage
- Calculation of average values

Additional statistical calculations in this phase can be performed ad hoc.

The *Value Calculation Phase*. In this phase predicted value for different property functions, based on different models are computerised. On the basis of the data determined in the monitoring phase the module complex of prediction calculate prediction for different kind of properties.

The *exception Reporting Phase*. Currently with monitoring phase and the predictive phase, these module sorts out properties to be handled manually according to rules laid down.

Valuation Parameters

The Valuation Parameters are an important LIS sub-system in relation to property valuation and physical planning.

The core modules of the system consists of the following sub-modules:
- Valuation elements alteration
- Stock of Buildings
- Historic information of all alterations carried out.

The valuation parameters are organised in different levels of registration:

- Property (comprising one or more buildings)
- Sub-property.

In general a sub-property is a building, which again can be divided in dwellings unit/Business premise so a building can comprise of one or more units.

The following type of information will typically be registered on each level:
Property: Type of ownership, water supply system, sewage disposal system, aggregated information on buildings.
Building: Purpose(s) for which the building is used, accessibility from road, year of construction or extension, construction characteristics, roof, wall material, different floor areas, number of stories, number of dwellings, installations.*Unit*:Purpose for which the dwelling/business premise is used, type of dwelling, floor area, bathroom and kitchen facilities, tenure.

Other property elements can be included according to the present legislation.

3.Update Modules

This complex of modules is the tool, which facilitates the updating of the tables in the database. The number of tables involved in the updating will not cause any table trouble and consistent rules are the key to consistent tables.

4.Product System

- *Enquiry System Module*

This complex of modules serves the purpose of acting as a decision-supporting tool. Daily routines where obtaining LIS information is crucial in several business matters, e.g. on citizen's or company's applications to local or central authorities about sales or valuation are supported by on-line functions. The modules are structured in such a way that any key known to applicants as - identification number, property number, parcel identifier, case file identifier, street code or address - is usable to access all legal/fiscal information about the property.

- *Property and Sales Statistics Module*

The importance of this complex of modules should not be considered as indispensable. The modules handle all types of sales information, which makes up the basis of the valuation with land and building information. Reported sales prices, loans, interests, rate of interests, number of settling days etc. make several calculations possible, e.g. rates, internal rate return, dispersion in general etc.

All modules involved contribute in producing output in the form of printed statistics. The statistics may be produced monthly and quarterly, half-year and yearly, currently accumulated.

- *Property Assessment Statistical Module*

Property Assessment Statistical Module forms the basis apprehension of mass assessments within the public authorities and produces various types of statistics e.g. property type, geographic and administrative areas, totals and deviations in land values as well as property values.

5.Legal/fiscal integration with GIS.

The legal/fiscal system is fully integrated with existing Geographic Information System. The database structure will enable review and presentation of legal/fiscal data in the geographic information system.

The system design is very flexible in the way that the GIS part can be implemented in a later phase of the Land Information System by using linkages to unique keys in the administrative part of the LIS.

WORK FLOW SYSTEMS

From an application to acceptance rules are laid down in the system. The WFS tracks all transactions in the system.

Upon the different subsystems a workflow system ensures the correct flow from data entry to acceptance or rejection of a case.

INTERFACES TO OTHER SYSTEMS

Yl@tis-LIS ensures the customer that LIS is implemented in such a manner that the communication to other systems will be possible. This implies of cause an accept from the other environments of the necessity of common application of unique keys within the following entities:

- Person
- Company
- Address
- Property
- Parcel

This could be system like:

- Inland Revenue Department
- Electoral Roll system
- Population Register Interface
- Tax Collectors Book System

LIS integration including GIS will rely heavily on the provision of the cadastral map system as the spatial underlay for the LIS.

On long-term basis, LIS/GIS can be available to other organisations wanting to make use of the facility.

For example utility organisations will use basemap/cadastral maps as underlay for all kinds of pipes and cables. The information about owner, land value etc. can be extracted covering the entire case handling.

SECURITY FEATURES

Application level:
- Access control
- Check out/in functionality
- Historic functionality.

Technical level:
- Back up procedure
- Disaster Recovery Plan

TECHNICAL PLATFORM

The system requires a relational database for data storage and retrieval and a standard Geographical Information System capable for integration to the relational database. The GIS and the relational database can support all hardware and operational software. The system can be implemented in both a central and decentralised environment.

PHASED IMPLEMENTATION

Yl@tis-LIS includes several modules. The modules comprise most ordinary legal, valuation and GIS functions as well as computer generated property numbers and other identification modules.

The modules can be implemented stepwise. This allows for particular functions to be implemented up front. Especially concerning valuation, the benefits from this strategy are obvious. It also facilitates the matching of available budgets.

Another good reason for recommending step-wise implementation is to give the organisation and staff sufficient time to adapt the modules. Every step must aim at the major goal for computer systems: to create integrated information that is easily accessed in different ways. The key to this requirement is integrated identification. Integrated identification of transactions, property, person, address and other entities involved in the transactions are supported by the core modules of Yl@tis-LIS.

CILIS an implementation of Yl@tis LIS

The Cyprus Land Information System is a Government System able to support all current operations in the Department of Land and Surveys as well as the increasing needs of the Department. The CILIS project was initiated in the end of 1995 and ended in spring 1999.

The Department of Land and Survey has the responsibility of:
- Keeping records for immovable properties and related ownership's updated;

- Control legal rights of properties
- Performing valuation of properties to secure the correctness of taxes related to properties;
- Performing Survey and Cartography of land;
- Serving the public on matters related to properties.

The Department of Land and Survey is organised in a central/decentralised structure. The central part of the department governs the technical instructions, the preparation of laws and the explanation of laws. The operations are carried out regionally in four districts. Each district is autonomous and is in a position to undertake all departmental functions. Every district maintains records for its own district only and is subdivided according to functions in three basic sub-departments each responsible for:

- Legal
- Fiscal
- Cartographic and Survey

CILIS is currently running in production centrally in the department and in one district. In beginning of next year the system will be rolled out to the other districts.

The CILIS includes all legal/fiscal; cartographic and surveys functions in one integrated system allowing access to aspatial and spatial data from all districts and can be used for online maintenance and retrieval of data as well current as history information.

Technical Platform

SUN Servers and Workstations running UNIX Solaris. Oracle Database. ARC Info GIS System. Running in a client server solution.

4.A.1 Adjudication

Adjudication is the process of final and authoritative determination of the existing rights and claims of people to land. This may be in the context of first registration of those rights, or it may be to resolve a doubt or dispute after first registration. Adjudication is also a standard procedure prior to the operation of a land consolidation scheme.

The process of adjudication should simply reveal what rights already exist, by whom they are held and what restrictions or limitations there are on them. In practice, of course, the mere fact of a final and definitive recording of these rights is a significant change in those jurisdictions where previously there had been uncertainty.

The process of adjudication may be sporadic or systematic, as with registration. Sporadic adjudication is a parcel by parcel approach, usually triggered by some specific event, like the sale of the property. Depending on the jurisdiction sporadic adjudication will then involve demonstrating that the title is basically sound before it is accepted and entered into the registration system. UNECE, 1996

4.B.1 Boundary / Perimeter

Périmètre (F); Perímetro (E)

The International Federation of Surveyors (FIG) defines boundaries as follows:

"Boundaries of parcels can be defined by physical demarcation on the ground or by a mathematical description usually based on a co-ordinate system. The accuracy and cost of cadastral surveys is dependent on the accuracy needed for boundary descriptions. The accuracy should reflect factors such as the value of the land, the risk and cost of land disputes and the information needs of the users of the cadastre." FIG, 1991

It is often the case that the boundary will be physically demarcated (e.g., by markers such as pipes, pegs, etc.) even when a jurisdiction uses a coordinate system to describe the position of the boundary. Coordinates tend to refer to physical objects on the ground and not to abstract positions.

A principal difference between boundaries is whether:

> the entire length of a boundary is demarcated by a physical feature (e.g., a river [centre or either bank], ridge, wall, or hedge, etc.)

> only the bend points of the boundary are demarcated by physical points (often referred to as monuments, beacons, etc).

This difference is often raised as the clash between "general" and "fixed" boundaries in a debate that has long plagued the English-speaking community. This debate often ignores the fact that so-called "general" boundaries such as rivers do exist in so-called "fixed" boundary jurisdictions. In one sense, fixed boundaries are no more fixed than general boundaries; they are merely delimited more precisely.

Regardless of the nature of the boundary, the documentation of the boundary position should be sufficient to allow the boundary to be relocated should it somehow be destroyed.

4.C.1 Cadastral administration

Administration du cadastre (F); Administración catastral (E)

The cadastral administration in any given jurisdiction is the organisation (or organisations) responsible for creating, maintaining and dealing with the cadastre.

There is a wide range of experience throughout the world. Although it is most common for the administration to be established and managed by traditional government departments, there are instances where such agencies have become self-financing, such as the Netherlands Kadaster. In some countries cadastral issues are the responsibility of local governments, in others they are national, but may be administered under one or more different ministries. The most common ministries with cadastral responsibilities are probably the Ministries of Justice, of Finance and of Agriculture. MANTHORPE, J., 1997

4.C.2 Cadastral register

Registre cadastral (F); Registro catastral (E)

The term “cadastral register” may include registers for any of the different types of cadastral system identified in the definition of the cadastre.

4.C.3 Cadastre

Cadastre (F); Catastro (E)

The International Federation of Surveyors (FIG) defines the cadastre as follows:

“Acadastre is normally a parcel based and up-to-date land information system containing a record of interests in land (i.e. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection.” FIG, 1991

Different countries use the term cadastre differently and this is a cause of real confusion. UNECE, 1996

4.D.1 Decentralised resource management

Instances décentralisées de gestion des resources (F); Instancias decentralizadas de administración de recursos(E)

Decentralised resource management is the principle of delegating policy-making in resource management to the lowest effective local levels of public authority.

The concept of decentralised resource management is one that has been significantly promoted as a result of the UN Commission on Sustainable Development’s Agenda 21, and is being taken up increasingly around the world.

4.D.2 Deeds registration

Deeds registration is a system of proof of property ownership and interests based on the registration of transfer and other deeds.

In an official deeds registration system, a copy of the relevant deed, for example a transfer deed, is deposited in the deed registry. An appropriate entry is then made into the register of the time, date, parties and transaction, as may be required by the particular jurisdiction. The documents generally require to be checked by a notary or an authorised lawyer to assure the validity of the transaction and entry.

This transaction reference, together with the supporting deeds, then provides evidence of the vendor's right to sell the property. The deeds registration system is limited in that it does not provide a guarantee of title. It does not provide the clarity, certainty or guarantee required for an ideal system. All that it typically provides is access into the chain of transactions that can be used to prove title.

4.L.1 Land Book

Registre ou livre foncier (F); Registro (E)

The Land Book system (Grundbuch), most commonly associated with Germany, is a system of title registration that is broadly followed in the German states, in Austria and Hungary and in those regions influenced by their respective former empires. The Grundbuch is under the administrative responsibility of the district judge, and is implemented by a full-time professional registrar. Each folio of the Grundbuch, as found in Bavaria, for example, consists of four parts, comprising respectively a description of the property, the name of the proprietor and how the parcel was acquired, details of any servitudes, and, finally, details of any charges such as mortgages. ROWTON SIMPSON, S., 1976

4.L.2 Land certificate

A land certificate is a certified copy of an entry in a land title system and provides proof of the ownership and of encumbrances on the land at that time.

4.L.3 Land charge

A land charge is a right in respect of land.

A land charge is registrable in England and Wales under the Land Charges Act, 1972. This is intended to reduce the number of interests affecting the land which would otherwise fall out of the registration system. The charges that are registrable include:

> *puisne mortagages (generally second and subsequent legal mortgages which cannot be protected by deposit of the title deeds because the first mortgage is secured by this right) and equitable mortgages*

(failing to comply with the legal formalities for creating a mortgage)

> *various forms of limited owner's and estate contract interests*

> *Inland Revenue charges for inheritance tax*

> *restrictive covenants and equitable easements*

> *registration of spouse's interests under the Matrimonial Homes Act*

CARD, R., MURDOCH, J., SCHOFIELD, P., 1994

4.L.4 Land commissions

Commissions foncières(F); Comisiones de bienes raíces (E)

Land commissions are formally constituted bodies to investigate land related issues, or to implement some aspect of land policy, such as adjudication.

4.L.5 Land dispute

Conflits fonciers (F); Conflictos de tierras / Problema de la tierra (E)

A land dispute is a disagreement over land. Aland dispute occurs where specific individual or collective interests relating to land are in conflict.

Land disputes can operate at any scale from the international to those between individual neighbours. At whatever scale, the dispute is likely to owe as much to the general nature of neighbourly relations as to actual problems relating to the land.

Land disputes may arise from a wide range of different situations and are commonly found where there is intense population pressure on land, where different types of land use abut or overlap one another, and where boundaries are not well demarcated. The following are cited as possible causes of land conflicts in HUSSEIN, K., 1998: over access to pastoral resources and damage to crops between herders and farmers; over grazing and watering areas between different groups of herders; where customary boundaries are poorly defined between neighbouring communities; between migrant and indigenous farmers; where expanding cities place pressure on peri-urban areas between the urban elites and peri-urban populations; where population pressure reduces the sizes of holdings below uneconomic levels; and where state allocations of land for forestry or large scale development schemes conflict with customary landholders interests. LEONARD, R., and LONGBOTTOM, J., 2000

Land conflicts may be resolved in a variety of ways. In parts of South Asia, for example, in Sri Lanka, land conflicts may be the subject of court cases that are inherited from generation to generation. In parts of the Highlands of Papua New Guinea, physical conflict between tribes may evidence land conflicts. In parts of Africa the land chief may have an important role in resolving land disputes.

4.L.6 Land Information System (LIS)

Système d'Information Foncière (SIF) (F); Sistema de información de bienes raíces (E)

Land Information Systems (LIS) have been defined by the International Federation of Surveyors (FIG) as follows:

"... a tool for legal, administrative and economic decision-making and an aid for planning and development. A land information system consists, on the one hand, of a databse containing spatially referenced land-related data for a defined area and, on the other, of procedures and techniques for the systematic collection, updating, processing and distribution of the data. The base of a land information system is a uniform spatial referencing system, which also simplifies the linking of data within the system with other land-related data." UNECE, 1996

4.L.7 Land register

Registre de la propriété (F); Registro de la propiedad / Certificado detradicióno libertad /Tracto sucesorio o sucesivo (E)

The land register is the definitive record of all registered properties, and comprises the registered details for each property.

In the land register for England and Wales, there are three registers or parts to the register; the Property Register, the Proprietorship Register and the Charges Register. These contain respectively:

> *a clear identification of the parcel and of the right owned, both in the parcel itself and in any other property, including a plan of the parcel*

> *the names of the owners and their addresses, together with any caution or restriction on the owner's right to dispose of the property*

> *any interests adversely affecting the property, including leases, charges, mortgages, restrictive covenants and easements over the property.*

ROWTON SIMPSON, S., 1976

4.L.8 Land registration

The International Federation of Surveyors (FIG) defines land registration as follows: "Land registration is the official recording of legally recognised interests in land and is usually part of a cadastral system. From a legal perspective a distinction can be made between deeds registration, where the documents filed in the registry are the evidence of title, and registration of title, in which the register itself serves as the primary evidence." FIG, 1991

The benefits brought about by instituting a system of land registration need to be viewed in context. "Land registration must be kept in perspective. It is a device which may be essential to sound land administration, but it is merely a part of the machinery of government. It is not some sort of magical specific which will automatically produce good land use and development; nor is it a system of land holding (land tenure); it is not even a kind of land reform, though it may be a valuable administrative aid to land reform. In short, land registration is only a means to an end. It is not an end in itself. Much time, money and effort can be wasted if that elementary truth is forgotten." ROWTON SIMPSON, S., 1976

4.L.9 Land registry / Registration office

Bureau de l'enregistrement des titres (F); Oficina de registro(E)

The land registry is the institution or office responsible for land registration. The title of the office and the responsibilities vary considerably between jurisdictions, as, accordingly, does the staffing and equipment of the office. Titles of the officer in charge of land registration include:

> Chief Land Registrar (England & Wales, Kenya)
> Keeper of the Registers of Scotland (Scotland)
> Registrar-General of Lands (New Zealand)
> Registrar-General, Registrar of Titles, Commissioner of Titles (variously in the states of Australia)

The responsibilities range from, for example, England & Wales, where the Chief Land Registrar has extensive judicial powers, to Kenya, where applications to resolve or correct problems must be referred to the court in the first instance. ROWTON SIMPSON, S., 1976

4.N.1 Notary

Notaire (F); Notario (E)

The notary is both a conveyancing lawyer and a public official responsible for seeing that the conveyance is properly undertaken. The notary is a vital part of the system of land transactions in many jurisdictions in continental Europe. It is not a feature of systems of title registration under the Torrens System. The notary is bound by a strict code of ethics, enforced by the relevant national bodies. ROWTON SIMPSON, S., 1976

4.P.1 Property files / records

Fichier immobilier (F);Fichero inmobiliario/ Archivo inmobiliario / Archivo de la propiedad inmueble (E)

Property files are more associated in an English context with real estate management than with registration activity. In such a context, each property will have on file a documentary record of accounts, correspondence, agreements, contracts and other pertinent matters in relation to its management.

4.P.2 Public access to information

Acceso público a la información (E)

Public access to information is a feature of public policy by which each society defines what information, particularly about private citizens and corporate entities, should be available to the public.

Public access is an important issue in relation to land information as such information can form a very significant part of decision-making for individuals, corporations and governments. It is an area of rapid development as computer and internet technology increase capabilities to access, distribute and analyse data.

Jurisdictions vary in their approaches to the ownership and protection of data within registries. The UNECE Land Administration Guidelines recommend that laws should contain the following:

> the extent of legal liability for the accuracy of the data;
> the extent of rights of privacy over land and property information;
> who owns the copyright to data within the registers;
> who may have access to data;
> who may alter entries in the registers

UNECE, 1996

4.P.3 Public notice

Publicité foncière (F); Edicto de bienes raíces (E)

Public notice defines the process and period by which the administrative system can be legally assumed to have properly informed the public, for example in connection with issues such as adjudication.

A characteristic of the processes of land adjudication and registration, and land consolidation schemes is that they involve the definition and redefinition of rights of owners of the parcel in question, and of other owners of adjacent parcels. A common characteristic of these processes is for there to be a period of public notice of adjudication or consolidation schemes in the area to allow any appeals before they are crystallised into the law. Public notice helps to ensure success of the scheme by encouraging public acceptance and support.

4.R.1 Register

Registre (F); Registro (E)

A register is a facility for recording specified matters.

A register may be a paper based record, kept in loose leaf files or bound into books. It has moved rapidly in the 1990's in sophisticated economies to electronically recorded data, using computer technology. It is becoming increasingly accessible by the internet, for example, for on-line conveyancing.

There may be several registers associated with land and property within one jurisdiction, including for example those related to land taxation and valuation such as the traditional cadastre, and those related to ownership, such as the land register or land book. In some jurisdictions these registers are being integrated with other land information to enable many purposes to be fulfilled.

4.R.2 Registration

Immatriculation (F); Matrícula inmobiliaria / Registro de la propiedad inmueble / Registro esporádico o sistemático (E)

Registration is the process by which rights and interests are recorded in registers. The process of registration in relation to land may follow a range of different options depending not least on the purpose and particular circumstances of the jurisdiction. These may include some at least of land registration, deeds registration, title registration, sporadic registration, systematic registration and registration of transactions.

4.R.3 Registration of transactions

Enregistrement des transactions (F); Registro de transacciones / Registro de instrumentos públicos (E)

Registration of transactions is the process by which transactional changes in rights and interests are recorded in registers.

Registration of transactions is often a legal requirement supporting a registration system. Without such compulsory registration requirements it is often argued that the system would become out of date and thus of progressively reduced value in fulfilling its tasks of maintaining an up to date record of ownership and related land rights. Registration of transactions will usually have a cost associated with it in fees, stamp duty and other transaction costs. In order for a registration system to succeed, whether it is "compulsory" or not, these costs must be sufficiently low to make the registration process viable for the registrant, otherwise alternative markets and unofficial transactions will occur and again undermine the registration system.

4.S.1 Sporadic registration

Sporadic registration of land is the process of registering land on a case-by-case basis usually as the result of a specific trigger such as the sale of the property. When introducing new systems of land registration or land titling it is usual to consider whether the most appropriate approach is for systematic or sporadic registration.

Sporadic registration is usually based on a specific action or actions of the owner of the property to trigger bringing it into the registration system. The most common action used to trigger sporadic registration is the sale of the property. This was, for instance, used as the main trigger for compulsory registration in defined registration areas in England and Wales after 1925.

Sporadic registration has the advantage that it may be less expensive in the short term than systematic registration and that it tends to target most economically active property first. It has the disadvantage that it will take much longer to achieve complete coverage of all titles within the jurisdiction. FIG, 1995

If the intention is to register all (or even most) parcels, then sporadic registration cannot be cheaper, and will likely be more expensive because of lack of economies of scale (e.g., neighbours all having to survey their parcels separately.)

Sporadic registration can also be criticised because the claims of each case are determined separately. Typically, public notice of the claim is a legalistic notice published in a newspaper. The process is not always very transparent. In contrast, systematic registration brings all claims in an area to light at the same time. It allows the population at large to scrutinise the claims being made.

4.S.2 Systematic registration

Systematic registration is the systematic approach to adjudicating, surveying and registering parcels on an area by area basis.

When introducing new systems of land registration or land titling it is usual to consider whether the most appropriate approach is for systematic or sporadic registration.

Systematic registration is relatively expensive in budgetary terms because of the typically large numbers of parcels being dealt with, although on a per parcel basis the average cost per parcel may be significantly lower than with sporadic registration as a result of economies of scale.

Systematic registration has the advantage that it will provide more comprehensive land information within a given time frame. It will also give more people improved rights more quickly, thus supporting the general development impact of increased security of ownership and reduced transaction costs. FIG, 1995

4.T.1 Title deed

Titre foncier (F); Título de tierras / Escritura pública / Título de propiedad (E)

A title is a right of ownership in real property. The title deeds of a property are the documents which evidence or prove ownership of the property.

Under a deeds system of conveyancing, the proof of title is through the demonstration of an unbroken thread of ownership through the sequence of deeds over the requisite number of years.

Under a title registration system, the land certificate may be referred to colloquially as the title deed, although in reality it is a certified copy of an entry in the title register.

4.T.2 Title insurance

Title insurance is an insurance service offered by companies to property purchasers under a deeds based system.

The title insurance underwrites any losses that may result after purchase of the property from discovered defects in the title. The purchaser pays a premium to the insurance company for this service. The service is available both to lenders under a mortgage arrangement, and to property purchasers.

4.T.3 Title registration

Title registration is a system for improving the quality of ownership and proof of title.

There are broadly speaking two parts of the register. The first is a map on which each parcel is demarcated and identified by a unique parcel identifier. The second is a text which records details about the title, the owner and any rights or restrictions associated with the parcel's ownership such as restrictive covenants or mortgages. Under a title registration system a transfer of the property simply results in a change in the name registered. A division of the land or alteration of the boundaries requires amendment to the plan and the issue of new documents or certificates. The official title registration record is definitive. UNECE, 1996

4.T.4 Torrens System

Système Torrens (F); Sistema Torrens (E)

The Torrens System is a system of title registration.

The concept of a "Torrens System" of title registration poses problems as there is no single such system, nor are its characteristics explicitly defined. Even in Australia, the home of the "Torrens System" there is a remarkable diversity of registration systems in the different states. The Torrens System of title registration is named after Sir Robert Torrens who introduced a system of title registration into South Australia in 1858.

The key features of title registration are security, simplicity, accuracy, expedition, cheapness, suitability to its circumstances and completeness of the record.

Three fundamental principles for the success of a title registration system proposed by Ruoff, RUOFF, T., 1957, and generally accepted are:

> The mirror principle **-** that the register reflects accurately and completely all of the current facts material to the title.

> The curtain principle **-** that the register is the sole source of information necessary for a purchaser.

> The insurance principle - that anyone who suffers a loss should be compensated.