DIGITAL CADASTRAL INDEX MAPS

FOR A LAND INFORMATION SYSTEM

IN TRINIDAD AND TOBAGO

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ABSTRACT

The need for Land Information is much more critical to developing countries than to the developed. The former have to maximise the returns from resources already available in the country. This paper explains the LIS concept, the essential components, and major functions. The difference between a multipurpose cadastre and LIS is clarified. A parcel based LIS with a data base structure capable of growth is advocated for developing countries whose present land data sources are akin to those in Trinidad and Tobago. The digital form of the Cadastral Index Map is seen as the linking device between subsystems. Transformation techniques based on the least squares and colocation principles are given to refine the existing cadastral index diagrams in order to improve their metrication properties.

LAND INFORMATION SYSTEM CONCEPTS

The concept of Land Information system appears to have been vaguely described and misunderstood in the surveying community. Computerised land based data which were originally contained in files , registers, card indexes and maps is concieved to constitute a land information system or subsystem. This is incorrect and some clarification is appropriate.

A Land Information System (LIS) is defined by the Federation des Geometris (FIG) as follows:

"A Land Information System is a tool for legal, administrative and economic decision-making and an aid for planning and development which consists on the one hand of a data base 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 data. The base of a land information system is a uniform spatial referencing system which also facilitates the linking of data within this system with other land related data." (Eichorn, '82).

It is evident from the definition that LIS is a facilitating system for generating decisions with the view to initiating, planning, developing and controlling the use of land based resources. Information is different from data and the distinction is important. Data are values not necessarily numerical, assigned to attributes of entities that are not used in the decision process. By contrast, information consists of classified and interpreted data required for decision-making. For example, market values of land parcels residing in land registry records constitute data. These figures when classified by geographical regions, over predetermined periods and vendor-vendee relationships, provide information, for decision on land valuation.

A system implies the existence of a number of subsystems. Geographical positioning, Legal cadastre, Fiscal cadastre, Utilities and Building cadastre, Topography, Land Use, Demography are examples of subsystems of a LIS. Each of the subsystem may be composed of further subsystems. A co-ordinated network of subsystems is characterised by its synergy, that is, all subsystems or elements are more effective in the system taken as a whole, than, if they were functioning independently. In other words, decisions made on the basis of information from all relevant subsystems is likely to be better than those made from each taken separately. This, however, implies the existence of a defined policy, a procedure, a rule, or a set of guidelines for decision making, formulated, on the basis of ranking goals. Lack of such decision making guidelines will no doubt result in negating the purpose of an information system and reducing it to a data source.

The key word in the definition of a LIS that distinguishes it from a multipurpose cadastre is 'data base '. This term evolved with advances in computer data storage and became current in the late 1960's. It is used to refer to a collection of interrelated data stored to serve many applications. The basic components of a data base are:

(i) A data bank - which is a collection of data relating to a given subject.

(ii) A data base management system (DBMS) - a system enforced through a software to update, add and/or retrieve attribute values of identified data elements.

(iii) A data dictionary - which is a catalogue of all data elements giving their names and structures.

The distinguishing characteristics of a data base are:

(i) Logical data independence - which refers to the ability to change the overall structure of the data base without changing the application programs instituted to process information.

(ii) Physical data independence - this refers to the independence of the physical location of the data and the logical relationship betwen them or the application programs.

It is therefore evident that a computerised land data system does not necessarily constitute a data base, unless it contains the identified components and characteristics. Physical and logical data independence enables growth of data bases which property is not available in manual or non-data base subsystems. The latter permit increase in attribute data values but not new attributes or data elements.

The essential components of a LIS may therefore be summarised as:

(i) One or more Data Banks of attributes of land in a form that can be integrated or related to each other.

(ii) Data Base Management System.

(iii) A series of application programs prepared to process data on the basis of identified procedures and policy guidelines to provide information.

(iv) Procedures, and techniques for the systematic collection and validation of data as well as the updating of the data bank.

(v) Feedback mechanism to assess and improve application programs and data requirements.

INTEGRATION OF SUBSYSTEMS

The growth of computer technology and the demand for improved and efficient transaction processing in the industrialised nations have contributed greatly to computerised land data systems. This is evident from a study of operational systems in Austria, New South Wales, South Australia, Sweden and West Germany (FIG 82; Hamilton, '85). These were iniated to improve the processing of transactions at the land registry. The Land Registry in Britain has recently embarked ona similar venture (Sharman, '86). The Wyandotte County, local authority in USA operates a system directed towards improving its fiscal cadastre, and reports cost effectiveness resulting from efficiency in collection of land and building taxes (Rhodes, '85). Attempts are in progress to update most of the above systems which are land parcel oriented to LIS. On the other hand the Maritime Provinces and Alberta State both in Canada and Victoria State in Australia are progressing systematically towards the formulation of LIS, based on geographical positioning subsystems. The basic entity in the former group of data systems is the legal land parcel with the exception of Wyandotte County which uses rateable land parcel. The latter group however may have points, strings, polygons or even solid figure entities.

Updating, land parcel based systems to LIS involves the need to establish a linking mechanism which is capable of relating data in the various subsystems. This integration process is obviously facilitated by the spatial referencing of all data. If however, all the data is parcel based then some measure of integration is possible if they bear a one to one relationship with one or more land parcel. The limitation is essentially in respect of point and string data. The usefulness of such data is reduced through generalisation when associated with a polygon. Raster type or statistical data can however be used with little or no loss of precision. Further, statistical analysis or study of spatial variations of data, an essential requirement of information, is restricted or complex. Therefore the systems potential as an information source is constrained. The use of spatial reference of a single point in each land parcel helps to overcome these defects to a great extent. The assumption here is that all data can be attributed to the chosen points. Where parcels are large or constitute long corridors this assumption may not be valid and can result in distortion of information. Partitioning of such parcels is an adequate solution, but spatial referencing of parcel boundaries improves the system capability considerably.

A resource that is available in many developing countries. but seldom used effectively for spatial referencing,.is the cadastral index diagram. They are used at present by land registries and national survey organisations as indexes to record ownership, plan reference, title or deed documents storage location etc. Such diagrams are generally on the scale of 12 ch to 1 inch (1:9504). Larger scales are used in urban areas. These diagrams have been maintained for over a century. They are compiled by reducing larger scale cadastral plans to the nominal scale and positioning them in the diagram by ensuring visual coincidence with boundaries already shown in the diagram, or through co-ordinates, derived from smaller scale topographical maps. The cadastral surveys though of sufficient precision are on independent coordinate systems and are seldom connected to the national reference frame. Therefore the orientation and positioning of the surveys in the cadastral index diagram is of questionable accuracy. It may therefore be appropriate as an initial step in the direction of formulating a LIS, to consider refining these diagrams, with the view to improving their metrication properties. This suggestion may also be viewed in the light of other land data sources.

Physical features of the landscape and thematic resource data are recorded in topographical maps which were generally on the scales of one mile to an inch (1:6360). The introduction of the metric scale and larger scale topographical maps rarely contributed to rationalisation of sheet boundaries to accord with index diagrams though they were redesigned on scale of 1:10,000. Data from index diagrams were seldom reconciled with topographical maps or vice-versa. Reasons for these may be sought, in the lack of co-ordination of the techniques and personnel, involved in mapping and cadastral surveys, of developing nations.

Demographic and other socio-economic data are on the basis of the smallest administrative unit of the country. Their correspondence with topographical map boundaries or index diagrams is rarely established. Local Government, Planning, Valuation, Utilities, and other land data source organisations adopt their own systems and methods to record data. Some use topo maps or cadastral diagrams as their base map but the methods employed to add data are so inaccurate that they require extensive validation.

Much of the lack of integration of land data may be attributed to the absence of sufficiently large scale base maps showing parcel boundaries. Cadastral index diagrams continue to function as reference diagrams only. The precision of individual surveys that constitute the diagram has increased over the years, sometimes disproportionate to the needs, but, the diagram as a whole has not acquired the status of a map. Simultaneously with the refining of cadastral index diagrams correspondence of details appearing in topographical maps requires to be established. Land data source organisations may then validate and transfer data to these base maps. Spatial referencing may thereafter be achieved by digitising these maps. The maps in themselves are valuable analogue data sources for decision making when contrasted with the present recording in files, registers and diagrams.

REFINING CADASTRAL INDEX DIAGRAMS

In Trinidad cadastral index diagrams (referred to as Ward Sheets), 140 in number are on the scale of 12 chains to an inch (1:9504). They are nominally on the Cassini projection. Urban areas are covered by 17 section sheets on the scales of either 1:1250 or 1:2500. The data on the index diagrams are being transfered photographically to 191, 1:10,000, UTM sheets. This implies a change of scale and orientation as a whole to visually match three or four plotted positions. Problems of sheet edge matching is solved by compromise and the art of the draughtsman. The ward sheets may be characterised as giant jig-saw puzzles of reduced legal survey plans The legal survey plans are generally on scales varying from 1:500 to 1:500C, the latter scale is for rural agricultural land.

Two approaches are suggested for improving the metrication property of cadastral index diagrams of Trinidad. They were carried out in a test area and the results are given, (Table 1).

The first approach uses the principle of a two dimensional conformal transformation. The transformation parameters are computed using the national coordinates of identifiable points on the index diagram. These are similar to ground control points used in photogrammetric mapping or control extension.

The transformation model takes the form:

$$\begin{bmatrix} e \\ n \end{bmatrix} = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} E \\ N \end{bmatrix} + \begin{bmatrix} e \\ d \end{bmatrix} \qquad (1)$$

The quantities on the left of the equation refer to digitised coordinates of stations their national coordinates are (E,N). a, b, c and d are the transformation parameters, they are functions of the scale, orientation and origin of the digitiser frame. With sufficient control points a least square solution is possible. The transformation model is then inverted to determine the national coordinates of other points whose digitised coordinates are measured.

The assumptions in this approach are:

1. Distances and directions in the index diagram are based on the same standard or reference direction.

2. There is no scale variation over any one refined index diagram.

3. The nominal scale of the index diagram does not correspond to he scale of the refined diagram.

4. Factors arising from non-uniform shrinkage of the index diagram are controlled.

The first assumption is strictly valid in so far as the points are in respect of the same cadastral plan, where they are from different plans errors arising from non-standardisation of distance measurement may be ignored considering the scale of the diagram. Use of different reference directions cause the largest errors. However it must be stated that a measure of uniformity in reference direction is obtained on the diagrams by the need to ensure coincidence of boundaries of abutting surveys. Use of the grid north derived from applying a convergence correction to magnetic north is also helpful.

The second and third assumptions relate to the map projection and the inability of the method to model scale variations prevalent in an orthormorphic projection. This may be ignored considering the purpose for which the refining is attempted.

The residual errors obtained at the control points are measures of the extent of deviation from these assumptions. They may be used to review the fixation of relevant cadastral plans.

The second approach is an attempt to use the Colocation principle to model the errors inherent in the assumptions of the first method. The mathematical model takes the form

$$O = AX + S + n \quad \ldots\ldots\ldots\ldots \quad (2)$$

where O represents the observed digitised values, X the transformation parameters, A the national coordinates, S is called the 'signal' and n the 'noise'. (S + n) represents the residual in the least squares transformation. The 'problem of refining cadastral index diagrams is here reduced to one of determining X, the transformation parameters and the signal corresponding to any digitised value. The solution is dependent on determining the covariances between signals of control points and between observations and the signals.

The covariances were derived from residuals obtained at the control points when the least squares method was applied. Attempts to fit a continuous function for the covariances was unsuccessful and the derived discrete values were used.

The reader is referred to the report on the method of colocation (Moritz, '72)for a detail account of the principles and proofs.

The validity of both methods were checked by comparing computed national coordinates with known values. The difference is identified as the error and tabulated in the table along with the linear displacement of the points. It is seen that the mean linear displacement for the first method is 7.7m, and 5.5m for the second, while the least plottable error is 1m. The method of colocation, generally gives better results. The mean displacement may be identified as a measure of the accuracy of the refined index diagram.

The choice and distribution of the control points for the computation of the transformation parameters and the covariances requires further investigation. A suitable continuous covariance function is likely to improve the results further.

CONCLUSIONS

Information consists of classified and interpreted data for decision making. A collection of a variety of data, requires, a set of objectives and stated goals for processing and providing information. However, data collected from a number of sources may not be integrated unless they are linked and their correspondence is established. The cadastral index diagram used by most developing countries is seen as a useful resource to integrate land based data. The need to improve the metrication property of these diagrams is proposed, two approaches are suggested and demonstrated.

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TABLE I

TRANSFORMATION AND VALIDATION DATA
WARD SHEET NO. 13D/23A

TRANSFORMATION PARAMETERS		
PARAMETERS	LEAST SQUARES	COLOCATION
a	0.0098527	0.0100258
b	0.0000108	-0.0000218
c	-6553.520	-6618.893
d	-11757.260	-11783.519

CHECKS AT POINTS WHERE NATIONAL COORDINATES ARE KNOWN					
STATION NO.	DIGITISED COORDINATES CMS	ERROR EAST NORTH	DISPLACEMENT	ERROR EAST NORTH	DISPLACEMENT
		LEAST SQUARES		COLOCATION	
D 13 - 303	32.05 18.84	02.9 -11.3	11.7	-06.3 00.0	6.3
D 13 - 304	34.51 18.50	07.1 -10.0	12.3	01.5 -08.3	8.4
B - 215	37.28 42.14	-04.2 -04.4	6.1	06.7 -02.2	7.1
B - 219	40.41 50.60	05.1 -05.5	7.5	02.1 -07.3	7.6
B 222	43.57 56.02	07.2 -03.1	7.8	-00.4 03.5	3.5
B 225	45.80 59.32	09.5 02.5	9.8	03.3 00.4	3.3
B 227	46.01 61.61	04.5 03.8	5.9	-02.8 -02.7	3.9
B 229	48.73 63.32	05.9 02.1	6.3	03.6 02.8	4.6
B 230	48.79 66.22	-00.2 -02.0	2.0	-04.5 00.1	4.5

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