SPATIAL CADASTRAL BOUNDARY CONCEPTS AND UNCERTAINTY IN PARCEL-BASED INFORMATION SYSTEM

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ABSTRACT:

Parcel-based information system (PBIS) is a geo-information system based on land parcels as spatial units. These spatial units are spatially and uniquely referenced to a common geodetic reference system. It has capabilities to collect, store, analyze and supply reliable land information for decision makers. It also links many kinds of other land related geo-information through an appropriate infrastructure network environment depending upon responsibilities and needs for an organisation.
This paper concerns mainly uncertainty issues related to land registration and cadastre in a parcel-based information system. Such system basically consists of spatial description based on a survey measurement including aerial photographs, containing the division into land parcels of an area, a descriptive component which record legal facts (deeds) or legal consequences (title) and other attributes such as use and economic value. The objective of this paper is to analyze definition of spatial boundary concepts of cadastral parcel data. Different spatial data capture approaches are briefly discussed to identify uncertainties in data and processes. Then the analysis are made on the basis of cadastral requirements to look at the approaches for the clients' satisfication in relation with land management activities. The concepts of general and fixed boundaries are elaborated with particular reference to legality and quality aspects. Then they are further analyzed in view of applications. Finally the uncertainty issues are highlighted within the context of land management.

1. INTRODUCTION

There are several phases for execution of land registration and cadastral surveying in an organisation. They are usually adjudication, demarcation, surveying and recording. The primary goal of carefully designed procedures is to provide certainty on land ownership and boundaries for the land parcels. Before a land surveyor can survey and record cadastral boundaries, adjudication and demarcation are conducted for the definition of cadastral parcel boundaries. Then he or she performs the field measurements, and store them in spatial database as accepted by the land owners and neighbouring owners, and by the appropriate authorities as prescribed in the rules and the regulations. Although much time is spent on these phases, there are still many cases where reliable information could not be captured and supplied to the citizens with minimum uncertainty. This causes delays and backlogs in the development activities.

There is still not a systematic way to handle uncertainty of cadastral boundaries in the conventional cadastral mapping system due to the constraints imposed by the map scale and the way the maps are prepared and stored. The precision with which boundaries must be determined depends not only upon the legislation, but upon local circumstances and the size and type of monumentation and data capture methods that are adopted. It is essential to understand and clarify the relationship between '*de jure*' and the '*de facto*' positions of spatial referenced boundaries. The disputes could be in the whole parcels or at the boundaries of cadastral parcels.

Many organizations in the developing countries are now adopting new information technology using computer, because this new tool is expected to help them to reduce the uncertainty and risk on land disputes beside other advantages of speed, cost and efficiency.

2. DEFINITION OF SPATIAL OBJECTS

The heart of a parcel based information system is cadastral parcel object. It is basically an continuous area object of land within which unique and homogeneous interests are recognized in a real world whether it is for legal, ecological or for use. For legal cadastral purposes such a parcel reflects a homogeneity in legal interest and on behalf of land use purposes such a parcel reflects a homogeneity in use (Henssen, 1995b).

The size of such spatial object ranges from many square kilometres , in case of farms or estates, to a square meters in case of small area occupied by an electricity substation. In the case of cadastre, a bundle of rights are identified on each of cadastral parcel object owned by a person, persons or institution (private or government). Cadastral parcel also describes the public as well as private landed property

including buildings and structures located within it. However, in this paper, the discussion is mainly focused on land parcel.

For each cadastral parcel object, the following classes of basic information can be distinguished:

- Spatial description
- Ownership or stewardship
- Use and resources
- Economic value
- Subject (person, persons or institution)

Spatial description relates to location and shape of parcels including topological information. Conventionally this information is normally gathered and presented in a large scale cadastral map where unique parcel identifiers are indicated. In some countries, the field sketches for each parcel are also included and attached to a deed or a title.

In digital database environment, parcels are digitised or constructed through coordinate lists, and modeled in topological relationships. Each parcel is constructed from three or more boundary lines. The boundary line is made by joining two boundary corners who locations are known in term of local or national geodetic coordinate reference system. In addition to these information, in some forms of cadastre, we need information regarding distances and azimuths for each boundary lines, and topological information. Restrictions such as minimum parcel size imposed by planning rules or boundary restrictions imposed by construction rules are also recorded.

Ownership or stewardship consists of detailed description of legal rights, freehold, leasehold, easement, mortgage, use rights, or any restrictions on these rights.

Landuse and resources are another important elements for the cadastral parcels. Sometime it only concerns present landuse (or permitted land use established by planning rules). Environmental information such as pollution, hazard, etc is also possible.

Parcel values are indicated for assessment of economic resource. The values are normally computed based on an appropriate valuation model. In a fiscal cadastre tax rate and value are also included.

The subject is the one who owns and enjoys the rights on the one or more cadastral parcels, and also suffers to all consequences that follow on the parcels. This class can be specialized into three subgroups namely individual, institution and government. Individual can be further classified into single person and group of persons. Institution represents such as trust, public and private institution, tribe, community, etc. Government implies any state enterprises and offices. The information such as name, address, date of birth/date of establishment, profession, etc. are included in the database.

3. BOUNDARY CONCEPTS

There have been always a debate or confusion between general boundaries and fixed boundaries in the processes of adjudication, demarkation, surveying and information managment.

In defining parcels, uncertainty or problem arises due to the non-contiguous areas, non-clarity on administrative boundaries, changes in natural features, differences in tenure and use, delimiting limited interests and delimiting public lands.

3.1. General boundary

In this concept a boundary line between adjoining parcels is left undertermined. The English system relies mainly on physical boundary features, man-made or natural. The precise position of the boundary within the physical features depends on the "general" land law of the country. Physical boundaries could be one side of hedge or fence, or the other side, or down the middle. There is , in effect, a strip of unspecified width and uncertain ownership left between each parcel. For instance, in Kenya, parcel boundaries are deliberately kept vague to prevent argument and the proverbial splitting of hairs. The advantage of general boundaries lies primarely in the less demand of standard in surveying. In this way, land registrar can have a possibility to ignore small changes in the position of a boundary agreed between two parties, whilst guaranteeing the title. This means that there has been a way to handle fuzziness of the spatial boundary.

In many countries access to land are getting more and more difficult especially in urban areas. Recent trends have been observed in such areas that even a small piece of land is valuable due to the tremendous increase of land prices. Thus the requirements with which the boundaries should be defined, have to be compatible to the client's needs and satisfications.

3.2. Fixed boundary

The term fixed boundary is often used when a land surveyor surveyed accurately so that any lost boundary coners can be recovered from the survey measurements accurately. Legally it also means that boundary points become fixed in space when agreement is reached at the time of adjudication or alienation of the land. Then the location of boundaries cannot change without some document of transfer (Dale and Mclaughlin, 1989). This is the principle that is adopted under the Torrens system. The advantage of such system is the confidence which land holders can have as to the precise extent of their properties.

The choice between "general" and "fixed" boundaries depends on the pace of creating or updating the system, the existence of physical features, disputes to be expected, the amount of necessary security and

the costs.

3.3 Demarcation and surveying

Demarcation is usually carried out in two approaches involving legal and technical surveying aspects.

In the first approach the boundaries are recognized on the ground, surveyed or identified on aerial photographs but neither legally fixed nor permanantly demarcated if this is not requested by the parties.

In the second approach the exact positions of boundaries are fixed on the ground in the presence of the parties, and permanently marked with pipes, stones, concrete beacons etc. if existing fences, hedges or ditches are not considered sufficient demarcation.

Depending on the choice of boundary concept, one can have many alternatives on the data capture methods. If one would consider a large area for systematic adjudication, aerial photography might be most economically appropriate.

For example, in Kenya, enlarged aerial photographs are adopted for preliminary index diagram where the boundaries of each parcel are marked and verified in the field. In Thailand, rectified enlarged photographs are used to identify parcel boundaries in the flat areas. The problem on such method is that photographs are not rectified to correct relief displacement. Secondly the areas derived from such documents would not be appropriate. Thirdly boundaries would not be retracable in case of disputes, because there were not measurements recorded. If database is to be established from such documents, digital monoplotting would be recommended provided that auxiliary data (such as digital elevation model, orientation parameters and ground control points) are available in the light of low cost approach.

An alternative approach is to prepare a large scale topographic database using photogrammetric techniques and cadastral boundaries are then marked on these digital topographical maps in the field using physical features as control points. Then a simple method of digitizing or construction procedure can be effected in the database.

There are many countries where the ground survey methods such as compass or optical square and tape measurments, compass-angle instrument, theodolite and stave, and electronic distance measurement (EDM) and theodolite, are being employed. Now-a-day global positioning system (GPS) is also a popular data capture method for cadastral purposes.

In some developing countries (eg Nepal and Bhutan), planetabling technique is still used to prepare cadastral maps in the field. In such cases quality is limited to map scale, map quality, accuracy of control points used, and skills of the surveyors.

In Zambia, the freehold parcel boundaries are usually surveyed using theodolite and either steel tapes or EDM with high standards of measuring accuracy ranging from 1:4,000 (rural areas) to 1:12,000 (urban areas) for the traversing with complete measurement of parcel dimension in the field. In other situation, a simple sketch plan is made for a short term leasehold land and no boundaries exist or marked on the ground.

In general the quality of such spatial cadastral boundary data depends on:

- the choice of boundary concept,
- the method of identification of boundary,
- identification errors,
- method of data capture and conversion,
- data structure or storage and
- etc.

Further elaborations on quality issues will not be dealt in this paper.

3.4. Uses of PBIS

The parcel database should be suitable for use in many of land related applications apart from the basic land registration and cadastre already discussed above.

Some of main land related applications are Property convenyancing, land reform, utilties, valuation and taxation, land consolidation, development planning and management, statistical analysis, environmental protection, etc. These applications uses cadastral parcels by combining with other spatial objects specified in their models.

In this connection, it is quite interesting to see description given by H Couclelis (1996) on "a typology of perspectives on boundaries" from the user views.

4. UNCERTAINTY ISSUES

In GIS there are many research publications and literatures, which treat uncertainty aspects. The intention of this paper is to relate and highlight some of these concepts within cadastral application domains. The following figure shows data elements which are influenced by the uncertainty, because they are either due to the concepts that were adopted, method of data capture and conversion, classification schemes, the way data are organized and stored, or interpretation on the data for many cadastral applications.

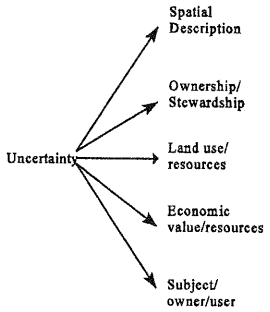

Figure 1: Uncertainties in Cadastral object

In the practical situations, four basic principles, namely the booking principle, the consent principle, the principle of publicity, and the principle of speciality, are followed in a land registration in order to avoid or reduce uncertainties in the use of information.

In GIS system environment, Molenaar (1994) provides three categories of statements in the handling uncertainty aspects namely "the assignment of object classes, the assignment of object attribute value, and the assignment of spatial description to objects".

In cadastral world these statements are extremely important to satisfy the users of PBIS. PBIS handles not only legal cadastral parcels but also other spatial objects like forest parcels, mining parcels, agricultural farms, polluted areas and so on.

For example, to simplify data acquisition for taxation purposes, cadastral objects are often classified as urban, subrural and rural. Alternatively cadastral parcels are classified according to present or permited land use. First approach of classification does not really serve to convince a tax payer, because his piece of land may be situated in the fuzzy region. Second approach does give some more concrete ideas, but still give problems on the class values in the valuation models. Thus appropriate classification techniques are to be formulated to avoid any ambiquity and confusion. Secondly the assignments of attribute values are to be made using appropriate data acquisition methods. Similarly in the case of land consolidation or land reallocation, classification is usually based on soil classes for valuation models. These are only few examples of cadastral applications in this paper with regards to the assignment of object classes and attribute values.

Again the treatment on the spatial description has been interestingly described by Molenaar (1994). This could well be applied in the parcel objects which can be fuzzy in the general boundary concept described above.

Well formulated uncertainty information can be documented in the deeds or titles of cadastral parcels.

5. CONCLUSIONS

The scope of this paper is to identify and underline uncertainty issues in cadastral parcel boundary concepts. The parcel boundary problems are reviewed against the systems of land registration and cadastral surveying. It then describes the uses of parcels and consequences, if certainty is failed to describe in the system environment. Since this is initial phase of works, solutions presented seem rather vague. However the approaches proposed for handling uncertainty in parcel-based information system seem promising.

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