MULTI-PURPOSE LAND INFORMATION SYSTEMS: TECHNICAL, ECONOMIC AND INSTITUTIONAL ISSUES

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ABSTRACT

Advances in computer, surveying, and mapping technology have had a marked impact on the economic barriers to multipurpose land information systems. This has opened the way for institutional innovations that may help to achieve the data sharing and spatial registration objectives identified in the 1980 National Research Council report on Multipurpose Cadastre.

INTRODUCTION

Since the appearance of the second National Research Council report on the multipurpose cadastre (1983), workers in the field have generally concurred as to the technical soundness of the overall concepts included in their recommendations (Wilcox, 1984; Chrisman and Niemann, 1985) These include: data layers or themes; the primacy of geodetic control and a base map; and a separate cadastral layer. Unfortunately, the technical aspects of the problem appear to be much more amenable to solution than the economic or institutional ones. Nevertheless, experience shows that advances in the first area can relax and sometimes remove barriers in the other areas. Continuing advances in computer, surveying, and mapping technology have had a marked impact on the economic barriers to multipurpose land information systems. This has opened the way for institutional innovations that may help to achieve some of the data sharing and compatibility objectives identified in the NRC report.

The purpose of this paper is to identify some technical, institutional, and economic aspects of the land records modernization problem: 1) a restatement of the land records modernization problem in terms of technical, institutional, and economic interactions, 2) an assessment of existing approaches to developing the cadastral layer and other map layers, 3) an examinination of promising technology for the development of the cadastral layer and multi-purpose land information systems (LIS), 4) an exploration of LIS implementation, particularly the economic barriers, 5) an examination of opportunities for institutional innovations, and 6) an integration of the findings on technological advances, economic barriers, and institutional innovations into observations on the land records modernization process.

PROBLEM

The troubled condition of land records in the U.S. has received widespread recognition. The National Research Council brought focus to the issue in their 1980 report, "Need for a Multipurpose Cadastre":

> "There is a critical need for a better land information system in the United States to improve land-conveyance procedures, furnish basis for equitable taxation, and provide much-needed information for resource management and environmental planning." (NRC, 1980)

Many agencies collect and use information about land -- its ownership, value, size, location, zoning, natural resources, and use -- in many different forms. Much of that land information, automated or not, is usually maintained by an individual institution for its own specific needs, without knowledge of or concern for its usefulness to others. This results in duplication of effort, higher overall costs, and limited utility and accessibility of the information to other agencies or individual citizens. Nevertheless, Portner and Niemann (1983) have shown that these deficiencies are the result of rational institutional behavior -- when each institution follows its own self-interest. These problems exist because traditional institutional arrangements were developed to meet the needs of a less complex society.

The advance of technology provides opportunities to automate land records processing. Yet, computerization of existing procedures is not, of itself, sufficient. A more "efficient," badly structured system is not what is needed. The whole process needs to be reconsidered and redesigned. In particular, the procedures used to develop assessor's maps need to be examined before it is decided to somehow transform them into digital records. It would seem unproductive to have highly precise copies of inaccurate maps, yet this is exactly what is happening in too many places.

EXISTING APPROACHES TO DEVELOPING THE CADASTRAL LAYER

Kjerne and Dueker (1984) describe two methods for developing the cadastral layer. The first method digitizes points and lines from existing maps, while the other calculates the location of points and lines from deed descriptions and survey measurements. Either of these two methods can be supplemented with base information (planimetry) derived using photogrammetric methods. This information provides visual evidence of roads, fences, *etc.* to aid in placement and fitting of points and lines, and allows the mapper greater confidence as to the location of poorly referenced property boundaries than mapping without such evidence. This kind of evidence, however, can only be supplementary to evidence gathered in the field.

Whether digitized or computed, all the points and lines in the cadastral layer need to be placed into a global spatial framework. Unless control was in place during the period within which the assessor's maps were built and maintained, a major reconstruction process and control densification is necessary to achieve a quality cadastral layer.

The network of control is also needed for spatial reference for other layers so the layers will maintain registration. The spatial registration of resource thematic data to the cadastral layer is an important issue for the management of land and the regulation of land uses. For example, open space planning requires the ability to determine relationships between open space boundaries and boundaries of land ownership in order to identify impacted parcels. Delineated flood plains must be related to the cadastral layer so planners can identify parts of land ownership parcels where buildings cannot be located. Assessors may need to relate the soils layer with the cadastral layer to determine the value of land based on the productivity of agricultural land. These examples show the need for relating the cadastral layer to resource thematic data layers. What are the problems? The 1983 NRC report identified a major problem as map compilation scale differences:

> Resource thematic data such as soils and floodplain boundaries, are normally compiled at map scales between 1:10,000 and 1:100,000. Transferring these already imprecise boundaries, whether by hand or by computer, to a cadastral mapping scale (1:1000 to to 1:5000) implies a higher accuracy than warranted, which may create erroneous information relating to specific parcels of land. (NRC, 1983)

Another problem relates to geodetic control. Separate data compilation scales requires a dense network of control to facilitate adjustment of data from a smaller scale to the larger scale layer. These technical issues affect the ability and opportunity to share data among various organizations. Solving the problems will ease the economic barriers to analysis and create new institutional approaches to the management of land.

NEW APPROACHES TO THE DEVELOPMENT OF THE CADASTRAL LAYER

Land records modernization taking place in a context of single-purpose systems. Major players such as utility companies and public works departments of municipalities are proceeding more rapidly than agencies actually responsible for land records. Rarely are they proceeding in concert. The organizations initiating these developments, however, often have lower spatial accuracy requirements, making their work of little value to those that follow. The "outside plant" spatial accuracy requirements of utilities are largely schematic. Consequently, their land base will not serve other users' needs and utility data will not register spatially to data from other agencies. Utilities refer to it as the "land base" because it is a picture or drawing of street rights-of-way, easements, and key natural features serving as a map base to which to register the distribution system. Generally, each user generates the land base anew as part of initial system setup. The costs of such duplication of effort, as documented by Larson *et al.* (1978), are substantial.

The land base constructed in this manner usually does not distinguish individual ownership parcels. Parcel center coordinates may be related to a parcel identifier relating the graphic object to the non-graphic data file containing parcel attributes. This approach, using parcel centroid coordinates linked to non-graphic data via a unique parcel identifier and a pictorial layer of property lines, predominates as the way to produce the cadastral layer. This method essentially uses the computer to produce a digital equivalent of a new paper map. Although the layer of property lines can be scaled, translated, rotated, and windowed, it is only relatable to other layers in pictorial form.

Figure 1 illustrates data structure options for mapping the cadastral layer. Options 1 through 4 represent the current state of the art, while options 5 through 7 are more powerful extensions. The choice among options will depend on the application. For urban planning and management applications, the parcel centroid usually suffices, while in rural areas with large ownership units and complex natural systems, parcel boundaries are essential. Meanwhile, surveyors need an option that uniquely describes corners and boundaries with the locational rules preserved.

To meet the surveyors's needs within an information system, topologically structured graphic data must be augmented with a record of the reference objects, procedures, and measurement values by which the property boundaries were established. Such a data structure enables a land information system to respond to a greater range of geometric and geographic questions (White, 1984), and is described in greater detail in Dueker and Kjerne (1985) and Kjerne and Dueker (1986).

A topological data structure for the cadastral layer would be expensive, particularly if it would produce only another "picture of a map." If user needs warrant the additional structuring of parcel data in topological form, consideration should be given to recording the evidence discovered by property surveyors so complete reconstruction of a portion of the cadastral map would not be necessary to update locations of cadastral objects.

LIS developments are driven by the need for finer resolutions and the requirement to include ownership considerations in public decisions and plans. The NRC's recommendation (1983) for a multipurpose LIS has achieved a convergence of approaches upon a layered system based on geodetic control and a cadastral layer(Chrisman and Niemann, 1985). A logical extension of the NRC recommendation is the need for a topological data structure that would uniquely record property corners, boundaries, and parcels and the spatial relationships of those objects, and would preserve the rules by which the objects are located. This graphic data structure would then be related to attributes of the parcel by a parcel identifier.

What appears to be a clear case for adopting the most elegant data structure for the cadastral layer is not as clearcut when economics are taken into consideration. As will be illustrated there is no clear strategy or simple solution to the complex technical, economic, and institutional problem of structuring the cadastral layer.

LAND INFORMATION SYSTEM COST ISSUES

The dilemma facing proponents of multipurpose land information systems is economic in nature. The benefits of compatible or spatially registered land data are difficult to identify and to measure. The benefits that can be identified are largely of an "avoided cost" nature (Epstein and Duchesneau, 1984). Additional and new uses of compatible data are largely undefined, though system proponents have "faith" that they will emerge through use of multipurpose land information systems. These new benefits will likely accrue to users of more sophisticated data structures that will allow topological overlays as well as graphic overplotting of layers.

Geodetic control and the resultant accurate base layer necessary to achieve the spatial registration to make data compatible are both expensive. As a result, single purpose systems are being developed, especially by utility companies, to meet their facility management needs, but not their engineering design needs. The schematic representation of their "outside plant" facilities is not relatable on the ground to other utility distribution systems or land features. Apparently, utilities' analyses of benefits and costs indicate that the additional benefits for engineering design do not warrant the additional cost of control. Although the cost to capture map data has been reduced by technological advances in turnkey automated mapping systems, similar cost reduction in control is only now becoming available through technological advances in global positioning systems. This technology, however, has yet to be incorporated into turnkey systems. It will occur as photogrammetric systems are optimized with respect to control densities and direct digital output. These are examples of technological opportunities that will reduce economic and institutional barriers.

The costs, particularly of control, are up-front while the benefits, in terms of avoided costs, lie in the future. It will take a large stream of benefits, discounted, to warrant the large up-front costs. Again, as an example, utility companies have opted to forego the cost of control, which enables them to implement a single purpose system more rapidly. Consequently, they recoup reduced costs faster.

Consortia approaches, as tried in Philadelphia (DVRPC, 1980) have proven difficult in terms of lining up all parties with respect to timing and budget. Questions of control of data also emerge as a major issue. In theory, dividing the cost of the base layer among a number of users makes sense. Accomplishing this has proven difficult for public agencies. Often it is not possible for the public sector to make the investment in data compatibility and share that cost among users. Similarly, utility companies are often precluded by federal or state regulatory agencies from investing in more spatial accuracy than they need, and from establishing an enterprise to sell their base layer.

The institutional and economic barriers are interrelated in terms of differing requirements of agencies and the high cost of additional geographic data detail and spatial accuracy. What may appear to be institutional barriers to a multi-purpose approach may in fact be legitimate differences in need for data detail and spatial accuracy. Similarly, so-called economic barriers may also be different demand functions or willingness to pay for data detail and spatial accuracy.

The economics of land information systems are difficult to assess, partly because many mapping system uses are in a governmental context where it is difficult to arrive at an accounting of costs and benefits. Nevertheless, organizations desiring to invest in a system and data conversion or to upgrade an existing system will want to perform analysis of the economic effects before coming to a final decision.

OPPORTUNITIES FOR INSTITUTIONAL CHANGE

The interrelationship between the economics of land information and the institutions that deal with land information, raise a number of issues concerning barriers and opportunities for institutional change. The principal issues are intergovernmental and interorganizational.

The high implementation cost of new, improved land information systems creates a difficult competition for resources within general-purpose governmental units. Assessors must compete with roads, police and health for resources within county government. Often these other units have problems that are more acute and visible than the assessor's need to modernize land records. Modernization of the mapping function and extension to an interagency multi-purpose LIS is discretionary and difficult to understand and promote. Even though the new system could possibly generate new revenue, this cannot be assured. The cost is more evident than the benefits.

The implementation of new systems will generate land information that will be in demand by other organizations. New mechanisms will be needed for sharing information and allocating the cost of information among organizations.Markets may be gained, lost, or shifted, and organizations will respond to shift by changing strategies and organizational form.

The opportunity for institutional innovations is twofold. One such innovation is the opportunity for public-private partnerships. Another is a growing state role in land records modernization.

Public-Private Partnership

A partnership of federal and state governments, local governments, universities, utility companies, and the private sector is needed. The state must provide progressive leadership, financial incentives, and technical assistance. Local governments and their constituents desire improved information to reduce costs of government. Universities must address important research questions and educate system designers, developers, and users. The universities can also help in facilitating change. Public utilities must be willing to explore longer term benefits of compatible data. If these actors do their job, the private sector vendors will respond to profit opportunities. Creating a viable market for their services may have to be nurtured.

Perhaps the biggest need is for the base layer. A private firm could sell the base layer without certain of the constraints operating on public agencies and regulated utilities. The uncertainty of this market and high capital costs, however, have prevented entrepreneurs from responding to this opportunity. The state, local governments, and utilities must assist in stabilzing this market to provide encouragement to vendors. They can do this by contracting to buy the base layer. However, the same problems that inhibit consortia exist here: it is rarely possible to line up all the clients at one point in time; some agencies or utilities are leading or lagging; budget cycles and needs are not synchronized.

Some doubt whether the private sector is ready to market base layer services, particularly whether the private sector would provide the necessary continuity over the life of a system. Can it easily be turned over to the public sector for maintenance and updating? Possibly some quasi governmental entity, in the form of a regulated monopoly, would be more reliable. A "base layer utility" would insure public control, insure a reasonable return on investment, and would have the same institutional stability as an electric utility.

Growing State Role

Institutional innovations might occur at the grass roots level, reshaping local governments into more effective managers of land information. However, innovation will likely need direction from state governments in order to achieve the desired standardization and compatibility needed for efficient application of technology. Also, an active state role will result from state interest in land related issues, particularly water and natural resource development issues, and transportation and economic development issues. The states will mandate or encourage programs to deal with those issues, and land information will be needed.

With respect to modernizing land records, states have either approached the problem in a broad and comprehensive way or in a narrower problem solving way. Massachusetts and Wisconsin are two states that have addressed the problem of land records in a comprehensive manner, by forming a study commission or committee. The commission in Massachusetts failed to achieve reforms. The comprehensive solution failed to achieve political support for the institutional change and financing of modernization. In Wisconsin, the committee process is still underway and its success in achieving institutional change to effectuate modernization of land records is still an open question.

A number of states have become involved in various forms of modernizing land records through programs of property tax equalization. These programs are often motivated by state school aid formulas requiring that local property tax effort be equal. Under the program, a state agency, usually the Department of Revenue, is empowered to oversee or conduct studies to evaluate the consistency of assessed values to true cash values. State have assumed the role of standardizing assessment practices and have organized the data reported to support those evaluations.

Other states, such as North Carolina and Oregon, have undertaken mapping programs to aid local governments to reconstruct cadastral maps. North Carolina was motivated to improve maps to reduce title conflicts and to ensure equitable taxation of property. Oregon was motivated by the lack, in a number of small counties, of technical expertise to maintain assessor's maps.

CONCLUSIONS AND RECOMMENDATIONS

Technological changes are occurring much more rapidly than institutional ones, reinforcing the tendency to opt for the pragmatic solution of implementing single purpose systems the costs of which can be quickly recovered. There is little incentive to investing in the institutional effort to make systems compatible and share, rather than duplicate, data. Unless the pace of institutional reforms is increased, multipurpose systems will not be achieved. To some extent technological advances will continue to obviate or relax the need for institutional reforms. However, the multipurpose LIS objectives make a purely technological fix insufficient.

The disparity between personal and societal perspectives and behavior forms another consideration. That is, an individual will tend to maximize his personal space and goods and minimize his contribution to the public good. In economic terms this is the "free rider problem" with respect to the provision of public goods. Investment in the multipurpose system is not in the interest of individuals and individual agencies. These short term interests are better met by single purpose systems. This must be offset by new and better institutional and individual incentives.

The technology to provide compatible land information has increased significantly, but institutional innovation has lagged. Institutional innovations in the private sector have been examined for clues for application to the public sector. We find that the public sector will have to act more like the private sector if institutional innovation is to be achieved. There is still considerable confusion surrounding the question of how to approach the modernization of land records. Some view it as primarily a technical problem while others consider it to be primarily institutional. The multipurpose objective both helps and hinders defining the scope of the modernization problem. It raises promises and expectations, but it inhibits the drawing of tight boundaries.

Although institutional and economic constraints impose significant barriers to its implementation, there has been general acceptance of the NRC's concept of the multipurpose LIS. Institutionally independent and spatially registered layers of data are the key.

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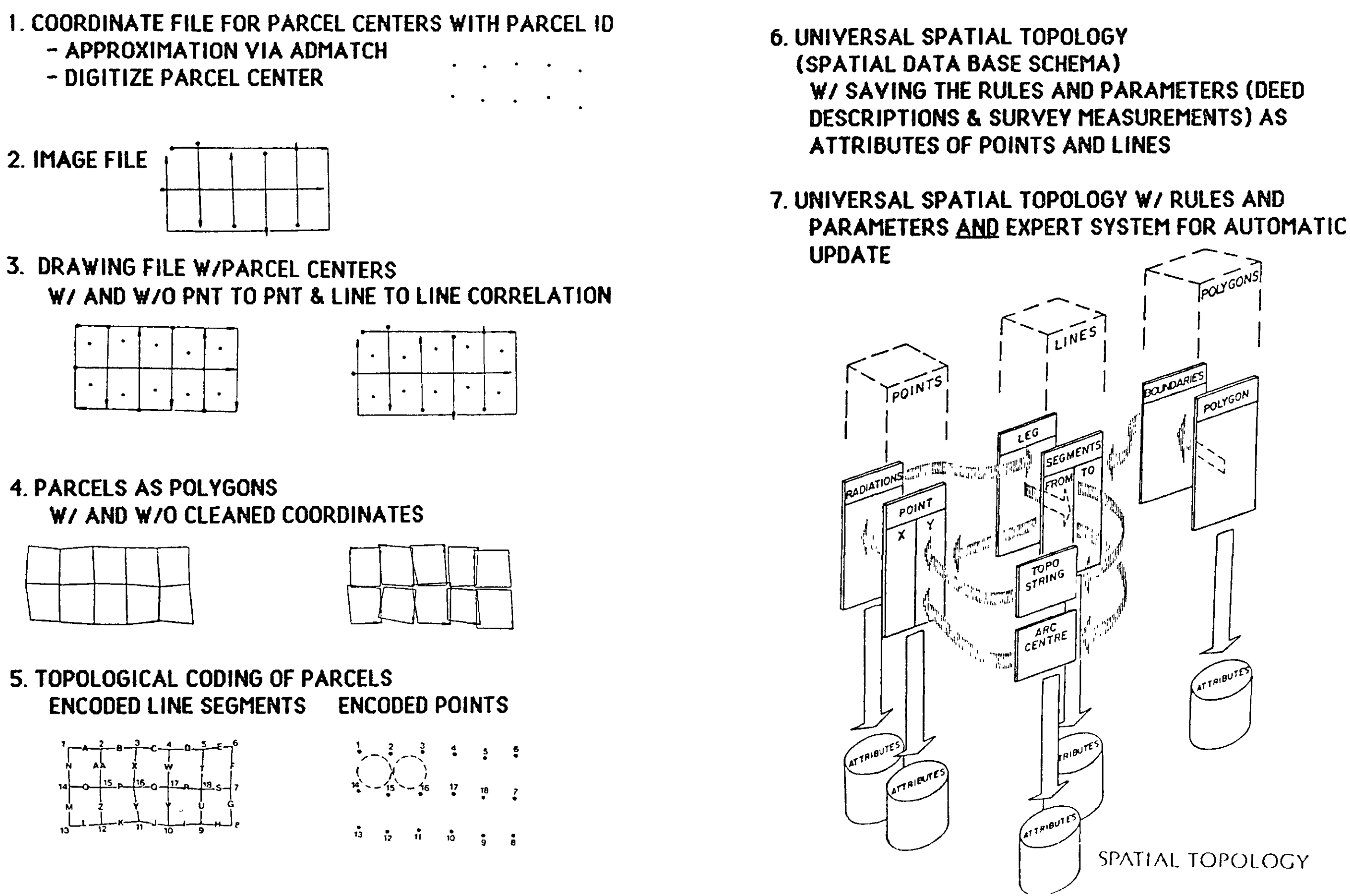

FIGURE 1. CADASTRAL LAYER DATA STRUCTURE OPTIONS