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Cover: A cartographic image (scale 1:250,000) depicts the State Trunk Highway System throughout 12 northeastern Wisconsin counties. Pavement Distress Index (PDI), a measurement of pavement condition, is indicated by color. Each color represents a level of distress, with magenta (red-purple) indicating the most distress.

PDI is one of the primary inputs within the Wisconsin Department of Transportation’s Pavement Management Decision Support System (PMDSS). The system provides an easy-to-use interface consisting of pull-down menus and various options for user enhancements. Data integration, user interfaces, and spatial display and hardcopies for PMDSS were designed and implemented by two full-time staff in less than six months using GIS technology. For more about the Wisconsin Department of Transportation’s use of GIS, see p. 59. (Cover map courtesy of WisDOT Geographic Information Services Section.)
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The refereed section of URISA Journal strives to share new knowledge in the technical, social, economic, and institutional subject areas that support information systems technology. It is the intent that this section of the Journal contain papers that are representative of URISA's membership and the broader information systems community. We encourage the participation of system designers, implementors and users as well as the educational and research community.

We hope that the refereed section will provide reliable information and new insights resulting from experience, research and scholarship. We also hope that this section will link academia, industry and the user community through the sharing of critical investigations and organized knowledge. To this end, we are seeking three forms of work: (1) Reports of current research and development pertinent to the overall information systems community; (2) systematic literature reviews of research for the research and development community; and (3) systematic reviews of applications which explain successful systems and procedures to the overall information systems community.

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Kenneth J. Dueker
Upgrading Real Property Boundary Information in a GIS

Raymond J. Hintz and Harlan J. Onsrud

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Abstract: One difficult issue facing geographic information system (GIS) developers in the United States today is the current inability to create spatially accurate, legally supportive and operationally efficient land ownership databases. Solutions providing strong legal foundations for GIS are not simple. Often repeated attempts at digitizing inconclusive cadastral data and cross-referencing title information are stopgaps at best. Methods for supplying comprehensive and officially sanctioned cadastral data are currently being investigated.

This paper describes technology for establishing a measurement-based management system at the local government level. The audience will gain an understanding of how sophisticated surveying computations, least squares analysis, statistical techniques, and blunder detection methods have now been packaged in an automated black box. Tools which were available previously to only highly specialized surveying experts are now potentially useable by surveying technicians. Through use of these powerful tools, maintenance over time is readily achievable for cadastral measurements in a GIS database.

Many current and potential users of automated geographic information systems are ultimately interested in use, control, or management of real estate or the resources associated with it. Thus, almost all current and future users of GIS eventually ask: Who owns the land and what are the limits of that ownership?

In practice, methods for providing a reliable link between legal ownership interests in land and the physical location of those interests are largely nonexistent in the United States. The availability of tax assessor maps has made them the convenient choice as the cadastral base for most local geographic information systems now being assembled in the United States. However, tax assessor maps were never intended to provide highly accurate, legally defensible descriptions of individual parcels in a jurisdiction. The danger in using conventional tax maps as the basis for the cadastral layer in an automated land information system is that data derived from or dependent upon this layer will give a false impression of high accuracy, and that derived data appearing on the computer screen could be sanctioned by the local government. Derived data are likely to be relied upon in situations where they should not be used and as a result cause damages.

Ownership rights in real property under the U.S. legal system are defined by the owner's deed and the chain of instruments that precede that deed. Therefore, it is desirable to utilize the boundary description in the cadastral layer, if possible.

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A problem arises in that many deed descriptions, although clear on their face, are unclear when attempts are made to precisely locate the described parcel on the physical earth. Land surveyors professionally interpret the evidence called for in individual conveyance instruments in carrying out property surveys. As a result, the best available evidence for precisely locating the deed-described bounds of a parcel typically consists of the measurements made by land surveyors (Dansby and Onsrud 1989).

Figure 1 provides a model for a useful multipurpose cadastral system. Surveying measurements tied to ownership parcels provide the crucial link between those land attributes determined primarily through physical observations and those attributes determined primarily through resort to legal system considerations and definitions.

Providing Strong Legal Foundations

Solutions in providing strong legal foundations for GIS are not simple. In developing an ideal land ownership database, several major needs become immediately evident.

- **The land ownership database must be spatially accurate**—down to the precision that surveying measurements allow. If a future user of the GIS wants to overlay the cadastral layer with a building layer which has been mapped photogrammetrically, the GIS should be able to indicate allowable setback distances to the property lines. In other words, if a firm tie to legal rights in land is desired, the spatial accuracy of the cadastral parcels should be as good or better than that required by any other layer.

- **The ideal cadastral database should be operationally efficient.** An example input system is shown in Figure 2. A secretary should be able to enter data into the system and a surveying technician should be able to operate it. The system should identify any blunders that the secretary might make, as well as identify blunders in measuring that land surveyors feeding data into the system might make. While various types of numerical blunders must be identified, it is also very important to identify various types of station labeling problems. Two examples of the latter include different points having the same name and a single point having more than one name.

- **The database should be legally supportive.** In other words, the land ownership database should be based upon the documents the legal profession will resort to in the event conflicts between adjoining parcels arise.

Objectives for an Automated Measurement Management System

In the authors’ view, such a database is supportable most efficiently through an automated measurement management system. The ideal automated measurement management system should carry out a great deal of sophisticated measurement analysis. However, that sophistication should remain invisible to the typical user. The system should provide valid answers but ask very few questions of the user.

The ideal cadastral database contains measurements.

There should be no derived data, adjusted data, or massaged data in the system. Only directly observed data should be contained in the database. The management system should handle all computations leaving little for the surveyor to do beyond identifying property corners on the ground and reporting measurements.

A well-designed measurement management system should identify any blunders in measuring or labeling that the surveyor may have made in the field. For instance, if a measurement is reported as 44.35 when it should have been 44.53, the system will indicate a probable blunder in that measurement.

Without human intervention, the system should automatically compute the coordinate values of all parcel corners in the system. The system should indicate graphically and numerically the reliability of each derived corner location.

The system should be established such that each time additional measurements are fed into the system, it must be verified that the new data are consistent with the existing data. If new measurements appear to be less accurate than previous measurements to the same monuments, warnings should be output to the operator. If old measurements in the system are found to be blunders or substantially less accurate than new measurements, similar indicators must clearly identify the situation to a user.

Land records are housed and administered primarily at the
Figure 1.
Model of a Multipurpose Cadastre

Model of a Multipurpose Cadastre

- Buildings and Streets
- Topography
- Soils
- Surveying Measurements
- Deed Described Parcels
- Zoning
- Digital Terrain Model
- Real World

c Sample land attributes determined primarily through physical observations
$d$ Linkage layer
f Sample land attributes determined primarily from legal system considerations and definitions.
county or local government level in the United States. Therefore, the centralized automated measurement management system should be operated by the GIS cadastral layer manager at this facility. Private sector users would access information via modem. They should have the ability to add data for subsequent verification and input, and also retrieve data in a localized area of concern. The accessibility of the information is required for success of the measurement management system.

An Operational Automated Measurement Management System

A prototype system meeting many objectives just described has been developed (Hintz, et al. 1988). The system is currently being used and tested by the U.S. Bureau of Land Management and several private surveying firms. The system has also been used to establish cadastral survey control networks for the city of Altamonte Springs, Florida and Orange County, Florida. The system has recently been updated to input and analyze survey measurements collected on a hand-held PC equipped with data collector software. This collector can be interfaced to any commercially available total station. Use of the system in practice is explained through a series of simplified figures.

Presume that a measurement based cadastral layer in a GIS is to be established. The parcels illustrated in Figure 3 are the first four parcels which will be entered into the database. Presume for purposes of this initial example that the deeds of the adjoining owners describe the same corner monuments and that conflicts between the ownership lines do not exist.

Figure 4 shows the survey traverse network completed around each land parcel. The accompanying table shows how conventional terrestrial survey measurements were recorded. Unlike traditional traversing, notice there is no need to keep track of the order in which survey measurements were collected. In addition, the survey measurements could have been made by radial survey rather than by traverse. There is no difference in the data entry procedure for this type of data collection. A different file structure is used for vectors derived from use of the Global Positioning System (GPS).
After entering the data into the computer by keyboard entry, or by automatic file transfer from a data collector or vectors from GPS processed files, blunders in the data are automatically isolated in a user-friendly pre-least squares routine (Vonderohe and Hintz 1987). After any exposed blunders are corrected by the operator, automated initial coordinate generation occurs for added points in the system (Vonderohe and Hintz 1986). Then least squares analysis occurs. Blunders undetected in the pre-analysis stage may now be identified by several quality control procedures. Post-least squares processing completes the tasks of calculating coordinate standard errors, error ellipse information, residuals for all measurements, post-adjustment traverse misclosures (automatic and/or user-defined routes), adjusted bearings and distances for desired lines, coordinate lists and drawing files that are in a format readable by other software systems (Onsrud and Hintz 1989).

Figure 5 shows the error ellipses (one sigma) that may be automatically generated and drawn by the system. Error ellipses represent the magnitude of the uncertainty of coordinates in 2-D space, and can be automatically determined at a user-prescribed confidence level. Notice the map scale for the error ellipses is different from that of the traverse legs. For instance, the major axis length for the error ellipse at property corner L is approximately 0.075 feet whereas the distance from K to L is approximately 428 feet. In all examples, stations D and H
had fixed (constrained) coordinate values from a previous survey. In a readjustment of a larger data set that contains the shown data, it may be desirable to constrain stations other than D and H (possibly geodetic control stations), but constraints on measurement data need to be handled on a case-by-case basis. Since measurement information is retained, the adjustment becomes a verification of data quality and not a determination of final coordinate values.

Presuming that the error ellipses are small enough for any immediate purposes intended, best estimates of the bearings and distances for all the parcel boundaries may be generated. If a survey plot is desired, additional labels, tables, and headers can be easily added in a CAD or GIS environment to which the measurement management information has been digitally imported. The resulting plat is illustrated in Figure 6. Thus, the system developed so far shows that it is possible with very little human intervention to generate a final plat with little more than angles, distances, and labels as input into an automated measurement management system.

In Figure 7, an additional land parcel has been added to the cadastral base (i.e., Cook) and another has been subdivided (i.e., Hintz into Hintz and Zhao). The additional survey measurements are added to the database and the resulting network hubs are illustrated in Figure 8.

The software described previously is run once again and error ellipses are generated as illustrated in Figure 9. Notice that because of the additional

FIGURE 5. Error Ellipses

FIGURE 6. Cadastral Plat
measurements the reliability of the derived position of point L has increased and the major axis of the error ellipse at that point has decreased to approximately 0.045 feet.

Once again, in Figure 10, the final plat is generated digitally. Notice that some distances and bearings have changed slightly from those in Figure 6. This is due to the added measurements and increased resultant reliability of the derived corner positions. Thus, the database upgrades itself over time. This upgrading of information solves many of the temporal problems in survey measurement maintenance. At some point in time, the positions of the property corners become known to an adequate degree of reliability for almost all land ownership purposes. At that point, it is no longer necessary to add further measurements to the database except perhaps as a check on those new observations. If a survey monument is destroyed and the position needs to be relocated, the information in the measurement management system is easily accessed to reliably relocate the original position.

If a well-planned labeling scheme is employed, it is possible to let numerous "islands" of survey networks grow in a community over time. Perhaps none of these islands will be tied to geodetic control initially. For instance, each island of parcels might assume an independent coordinate system. Over time, as measurements are added to the database which links islands together, larger islands are formed. Eventually islands are encountered that have been tied
to geodetic control monuments or contain GPS observations. At that point, interconnected links can be automatically referenced to the absolute coordinate system.

It is important to recognize that the entire measurement management data set need only be completely readjusted fairly infrequently (Hintz, et al. 1988). This is crucial as readjustment of the entire data set could require the simultaneous solution of tens of thousands of equations for data in a metropolitan area. This would be very time consuming on a PC-based system. Local adjustment of data occurs frequently as data are added and need to be verified.

Further Developments

It is not suggested that massive remapping or resurveying programs should be promoted to secure validity of the information in the cadastral layer of a GIS. Such programs are generally unwarranted. When a real property conveyance takes place in the United States, survey measurements usually are made of that parcel. If a systematic means can be devised to capture the data already being collected, the cadastral database desired by many potential GIS users will become a reality.

Use of the described system to compile and maintain ownership line locations in a GIS does not suggest that property lines digitized from tax maps should be thrown out. That information is sufficient for many intended purposes. The current challenge for the surveying and GIS academic community is to develop a means of
upgrading the spatial information derived from tax maps to spatial information derived from real property surveys.

Because both approximate cadastral information from tax maps and accurate cadastral information from surveys are envisioned as being contained in the same GIS, means of identifying which category the data belong to must be developed. Numerous tagging methods are possible. Perhaps just maintaining two separate cadastral layers initially may be satisfactory for some purposes.

The above described system goes a long way in solving the temporal problem for surveying measurements in a GIS. However, it doesn't begin to address the temporal problems associated with the characteristics of the real property parcels (i.e., changes in land use, zoning, vegetation cover, erosion, etc.).

Another problem is how to upgrade other layers in the GIS that are dependent on the cadastral layer. For instance, presume that the initial cadastral layer in a GIS was formed by digitizing lines from tax maps. A sewer line is known to run down the center of a street and is shown in another layer of the GIS. When the cadastral layer is updated using survey measurements rather than the digitized tax map information, the sewer line may now appear a substantial distance from the center of the street. GIS developers may want to consider developing methods of inputting data that will tie it to the cadastral layer. As the cadastral layer is updated, those other layers may then also be automatically updated (Kjerne and Dueker 1988).

The last issue raised is that providing accurate measurements between corners described by conveyance instruments does not in itself resolve boundary conflicts between adjoining real property owners. Developing a survey-based cadastral layer is likely to show the location, extent, and nature of such conflicts. For instance, in Figure 1, the cadastral layer clearly shows that the deed-described parcel owned by Onsrud and the deed-described parcel owned by Hintz are in conflict with each other. This conflict must be resolved as it always has been by resorting to the laws established by the U.S. legal system. The surveyors' role in this area will always remain to explain facts, provide evidence, express opinions, and aid the adjoining landowners in resolving the conflict in a legal forum for reaching a property line agreement.

References


Use and Value of a Geodetic Reference System*

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Abstract: A control reference system, consisting of a set of physically monumented points on or near the earth’s surface and the geometrical data indicating their horizontal or vertical locations, allows detailed dependent measurements of the locations of land features to be made and adjusted. When the control reference system is established with prescribed precision and accuracy, it becomes a geodetic reference system (GRS). Traditionally, investments to establish and maintain a GRS are seen to provide benefits in the form of reduced costs for dependent measurements. This paper views a GRS as the source of information which is an input into a process whose outcome is a decision about growth, resource, and environmental management. The particular contribution that a GRS makes is the compatibility imparted to the location of features measured and adjusted relative to the system. Using this view, we have developed and tested a method for measuring the benefits of investments to upgrade, maintain, and use a GRS. These benefits are the costs avoided in establishing the compatibility of data when this has to be done at the time of decision-making. A test of this method in a particular jurisdiction shows a benefit-to-cost ratio considerably greater than one.

A control reference system consists of a set of points on or near the earth’s surface and the geometric data indicating their horizontal or vertical locations. The geometric data are frequently expressed in the form of plane-coordinates relative to a datum which is the reference or base for measurements (National Geodetic Survey 1979, p. 21).

These data become the basis for a framework allowing detailed dependent positional measurements to be made and adjusted. The control reference system becomes a geodetic reference system when the points, often identified by physical objects, are located with a prescribed precision and accuracy (geodetic precision) that is greater than that required for other dependent measurements (National Geodetic Survey, p. 18).

A geodetic reference system (GRS) is classified according to standards for precision and accuracy, which must be satisfied by the geodetic data. The designation given to survey measurement work of the highest prescribed order is first-order (National Geodetic Survey, p. 31). This paper describes the role of a GRS in a particular process or use. That process is the use of geographic and land information products and services in decision-making involving growth, resource, and environmental management issues.

It is generally understood that a GRS significantly increases the cost of accurate land measurement and surveying (National Research Council). However, the contributions (benefits) of the system to the development, maintenance, and use of geographic and land information systems is not well defined. Identification and description of such contributions are the goals of the work described in this paper.

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A GRS is described in a National Academy of Sciences panel report as necessary in order to:

Create an integrated land-records and information system. This system permits spatial reference of all land data to identifiable positions on the earth's surface. It can be used to form a common index for the land-records and resource information when that information contains a coordinate reference to the earth's surface. (National Geodetic Survey, p. 45)

Our research views the information products of a GRS as vital inputs to a process whose final outcome is a decision about growth and resource management. The perspective that GRS products serve as inputs to a decision-making process is crucial to our approach. In this view, the reference system is seen to be, not an end product itself, but the source of information and data for other processes whose outputs are desired and valued. Ultimately, our attention to use and value is focused on the demand for useful products to which reference system information contributes (Mackaay 1982). In short, the demand for a GRS and such information products flows from their ability to contribute to decision processes.

Identification and description of the role of GRS, however, present difficulties. These arise whenever one is forced to identify and monitor the flow of data and information. The research described in this paper identifies the contribution of GRS products and services to the process of growth, resource, and environmental-management decisions. It results in a method for assessment of the benefits and costs to upgrade and utilize a GRS in that process.

Information Concepts

Information has several features that distinguish it from other traded commodities (Mackaay 1982). A critical feature of information is that it has characteristics of a public good (Barlowe 1978). In economics, a public good means that use of the product by one person does not curtail use by another. In the contrasting case of a private good such as a car, use by one person denies use at the same time by someone else. Maps and geographic information are often produced as a public good by governments. A GRS is another example. Another distinguishing feature is that it is difficult to measure the quantity of information actually acquired. A final distinguishing feature concerns the ability to assign property rights to information (Mackaay 1982). A precondition for operation of a market is that property rights be created and protected by law. In the absence or limitation of such rights, suppliers either find it unprofitable to produce the product, or, if produced, tend to underproduce it. If the producer cannot prevent use of the product in the absence of payment, then the ability of market processes to generate the optimum amount of the product is compromised. For information products, there are varying degrees of ability to assign property rights. For example, the patent or copyright system assigns property rights to knowledge in order to create incentives for its production. The limited ability to maintain property rights in information products raises the question as to the extent to which market processes are workable for these products.

The Analytical Framework

Our analysis focuses on the contributions (benefits) of GRS information to growth, resource, and environmental decision-making. This requires that we adapt the definition of a reference system to the scope of that process.

We distinguish between site-specific control, described as local control or simply control, and a "global" reference system based on a geodetic reference system. Site-specific control consists of the points and associated data used for land measurement within a limited area or for a specific project. Site-specific or local control is the basis for a site-specific datum used to support decision-making involving activities such as subdivision, road, bridge, building, marina, or other project development confined to a limited, well-defined area. It is often established at the time of the project development.

A global reference framework supports actions and decisions involving a more varied set of activities. For example, regulatory and environmental decisions require that data and information be assembled not only for the
site-particular project, but also for a much larger impacted area. This requires data and information about not only the relative locations of features within the project area (the relative accuracy), but also the position of the various features that constitute the entire area (positional accuracy). More importantly, the independent data and information for specific projects must be compatible such that they can be combined into an appropriate information package for the whole.

This distinction between local and global reference system allows us to distinguish between primary and subsequent users of the products of a geodetic reference system. Primary users of spatial reference are those who make site-specific or project-specific measurements. These are typically surveyors, mappers, engineers or other land measurement professionals. Their basic needs are most often for local control.

The subsequent users of maps, measurements and geographic information related to a reference system are citizens, planners, public officials, lawyers, judges, developers, bankers, and similar decision-makers, often without expert knowledge of or experience with the spatial products or the scientific measurements they represent. These users seek data and information, at reasonable cost, as a means of reducing uncertainty associated with decisions involving growth, resource investment, and environmental issues. Frequently, they need a variety of comprehensive data and information from several sources about several sites that must be combined into an information package useful for their specific decisions. Their needs generate a demand for universal compatibility in spatial information.

The relationship depicted in Figure 1 suggests a need for universal compatibility in spatial information. While universal compatibility is often not a critical need for primary users of spatial information, it is a major need for many of the secondary and tertiary users.

While Figure 1 illustrates a variety of applications, it is not intended to be a complete representation of usage. The four columns each represent a primary activity that generates or utilizes spatial information products in a singular activity. Although the material is depicted vertically, we recognize that, in reality, overlaps and connections exist among the four activities. As a means of simplifying the exposition, we assume that, in each primary
activity, ten spatial information products are produced. For example, for construction activities, C1, . . . , C10 represent individual information products used in decision-making for construction.

Our observations as to how the needs for spatial information are typically satisfied can be shown by reference to the construction column in Figure 1. The typical pattern is that spatial information products needed for decisions involving construction activities are produced in a manner and context mainly, if not solely, determined by the primary mission construction. This should not be surprising. For example, the typical highway department produces information it needs with a local control system that yields the accuracy and compatibility required for its purposes. Consequently, the information products will be compatible, but only for the specific site or project. This scenario tends to be repeated in the other columns. Individual activities or organizations generate the type of spatial information needed for their specific mission, which means that data tend to be compatible on only a local basis.

Each primary activity has little need to draw upon spatial information products generated by others. In other words, data associated with each primary activity tend to be isolated and there is little reason for the data to have what we describe as universal compatibility. This is a logical outcome within an organization. The need for universal compatibility does not tend to be a pressing concern within a specific primary activity, unless the site development process requires decisions of a wider scope than those associated with the site itself.

The demand for universal compatibility arises mainly from activities and decisions that require large amounts of diverse spatial information across a large number of primary activities. These needs typically arise from secondary or tertiary uses of the original information products generated within each primary activity. In Figure 1, such uses are shown as land-related decisions which utilize information products from each of the four primary activities. The ability to integrate and combine these information products requires that the products and the underlying data have the attributed universal compatibility. We wish to emphasize that it is the secondary and tertiary users who create the main demand for universal compatibility. Unlike primary users, secondary and tertiary users find universal compatibility to be an important attribute of information products.

In practice, limited resources within an organization often limit the production or maintenance of spatial information with the attribute of universal compatibility. Organizations often produce spatial information only sufficient to meet primary and immediate needs with little or no consideration to the needs of secondary or tertiary users. However, it is the demand for spatial data compatibility by these non-primary users that is the origin of the demand for a global geodetic reference system. Spatial information generated by the system ensures that the needs will be met of both those who execute a site-specific activity and, more importantly, the secondary and tertiary users who require compatible data and information.

When a GRS is used to produce information products such as C1, . . . , C10 and LV1, . . . , LV10, those who combine data from each primary activity can proceed with relatively minor additional adjustment or expense. For example, if a secondary user needed an information product defined as C2LV8, use of a geodetic system ensures that the two databases can be easily combined with a high and known degree of accuracy.

Local compatibility may be totally adequate for decisions in a single, primary activity. However, users at a higher level of aggregation must be able to relate independent sets of information. These users require the presence of universal compatibility—a characteristic imparted when a geodetic reference system is used to make site- or project-specific measurements.

Thus, the unique product of a geodetic reference system is universal compatibility of data and information. The output is not monuments, nor data about the location of monuments. These are inputs. Previously, we emphasized that economic value flows from the demand for the output or product. In this context, the benefits attributable to the investment in a GRS arise from the demand for universal compatibility.

The following major points have been made:
• The economic value of a geodetic reference system is found in the unique product it yields.
• The unique product is universal compatibility.
• Demand for universal compatibility arises mainly in the case of secondary and tertiary users of spatial information products.
• Agencies and organizations that initially produce much of the spatial information tend to have little concern for the need of universal compatibility by secondary and tertiary users.

Attributes of a Geodetic Reference System

Traditionally, a control system is understood to be a set of physical objects in the ground and the data that describe their locations in a mathematical form (National Geodetic Survey, p. 18). These objects and the descriptions of their locations are the basis for measurements of the locations of various land features.

The major contribution of a GRS is its ability to impart the attribute of universal compatibility to what would otherwise be independent data and measurements. The process by which a GRS makes such a contribution is illustrated in Figure 2.

The relation between a GRS and the various land data files is commonly depicted as in Figure 3.

Prospectively, and without elimination of the traditional view, a GRS can be seen as the information pins that hold together otherwise incompatible spatial data. A genetic reference system means compatibility.

A GRS that provides universal compatibility to a variety

FIGURE 2.
The Role of a Geodetic Reference System in Compatibility Creation

FIGURE 3.
The Relation Between a GRS and Land Data Files

LAND PARCELS
TRANSPORTATION NETWORK
UTILITIES
ZONING DISTRICTS
CENSUS TRACTS
POLICE DISPATCHING
FLOOD PLAIN MAPPING
NOISE IMPACT
SEISMIC RISK
FIRE ZONES
FLIGHT PATTERNS
SUBSIDENCE
NEIGHBORHOODS
SOILS
GEOLOGY
VEGETATION/WILDLIFE
HYDROLOGY
HISTORICAL/ARCHAEOLOGICAL FEATURES

GEODETIC REFERENCE SYSTEM
of data files has the following elements:

- Density
- Accuracy
- Spatial Extent
- Mathematical Language
- Operational Effectiveness

Density and accuracy have the meanings commonly associated with control systems (National Geodetic Survey, p. 2).

Spatial extent means adequate distribution throughout a community sufficient to encourage common reliance by primary and subsequent users. The reference system must provide for a common mathematical language for measurement data and for spatial referencing and analysis of all land-related data. Finally, the information about the spatial reference system must be made widely and conveniently available to the various users and thereby be operationally effective.

The Benefit Stream: Avoided Costs

Measurement of economic value is reflected by the amount of money consumers would be willing to expend to acquire various amounts of a product. In the case of a private product, market transactions provide the basis for quantification of value or benefits and the demand relationship can be estimated. In the case of a product, such as a GRS information product, the principle is the same, but market transactions are not available to serve as a means of identifying the demand curve. Alternative means must be used to quantify the benefit stream flowing from the system (Wunderlich and Moyer 1984).

Because economic value is a demand-initiated concept, a GRS is properly viewed as an input, which, in combination with other inputs, is capable of producing various outputs or products. Economic value of the GRS is derived from the level of demand for these outputs. If no demand existed, no economic value could be assigned to the reference system. In other words, because a GRS is available and numerous products based on the system are technically possible, it does not automatically lead to the conclusion that public expenditures designed to densify and maintain the system and/or to promote greater usage of the system represent an economically efficient use of resources. Such a conclusion requires an assessment of the magnitudes of benefits and costs.

This research assesses the benefit and cost streams resulting from use of an existing GRS. While their density and accuracy may vary, geodetic reference systems exist in all areas of the United States. Expenditures to create a GRS at some level have already been made; these are the result of past decisions. They are, in more than one sense, a "sunken" cost. The expenditure is history. The important decisions for benefit/cost analysis are those that are prospective. The relevant prospective decision focuses on the benefit-cost levels resulting from using scarce resources to alter the attributes of a GRS.

Our analytical approach rests upon a basic principle: measureable benefits generated from an investment include the costs avoided as a result of the investment. These savings are properly interpreted and treated as benefits. The rationale, in terms of demand and expenditure, is that one would be willing to pay an amount equal to the cost savings in order to obtain the savings. The magnitude of the avoided costs, while not reflecting the complete demand relationship, represents a minimum estimate of economic benefits. These are tangible benefits.

The principle of avoided costs can be applied to our attempt to assess the economic value of using a GRS. Assume that a particular decision must be made and that it requires spatial information indicating the position of three physical features. Most importantly, the decision requires the three pieces of spatial information to be combined and represented in a manner that allows the user to relate each feature to the others, and that this is done by placing the information on a single map. In other words, the three pieces of information must be universally compatible and capable of being placed in a single information file.

The manner by which a GRS leads to avoided costs (benefits) is illustrated by contrasting two situations: (1) the three pieces of spatial information exist and are based upon a GRS; and (2) the information exists, but each piece is based on a separate and unrelatable measurement or reference system. In the first case, universal compatibility exists. But in the second
situation the information products lack universal compatibility. The needs of the decision-maker, in our example, can only be satisfied by incurring additional costs to attain the required compatibility. However, these additional costs are avoided in the first situation because a GRS was originally used to generate the three information products. Thus, they represent part of the benefit stream attributable to a GRS. The avoided costs are properly viewed as a minimum estimate of the benefit stream.

The following discussion attaches a more operational meaning to the framework. However, we want to emphasize that use of a benefit/cost framework to assess the value of a GRS leads to a dramatic change in the traditional perspective. In this context, the system is viewed as an input, with its economic value dependent upon the demand for its output: information products with universal compatibility.

Earlier economic studies of a GRS focused on the effects of a more dense distribution or more accurate location of control stations (Johnson 1972; Brown 1977). The GRS was viewed as a self-contained unit without a focus on the unique outputs obtainable from the system. This basically led to a limited search for economic benefits. The major benefit resulting from greater density of the system was identified as savings in traverse time and lower costs in bringing control into a specific site. Such savings are important, but require careful interpretation as to whether they represent an economic benefit.

In the analysis presented here, traverse time is viewed as simply a cost of using the reference system to produce an output. Any cost saving due to greater density simply reduces the denominator of the benefit/cost ratio, i.e., reduces the cost of producing the output. In other words, a saving in traverse time is not an output of a GRS and these cost savings are not properly viewed as benefits. Prior analysis, by not distinguishing between inputs and outputs (supply and demand elements), failed to identify the most important source of benefits (universal compatibility) attributable to a GRS. Our framework incorporates the earlier work, but changes the perspective from a point-specific focus to a focus on a system and the demand for the system output.

This section defined the critical elements of the analytical framework used to identify and assess the benefits arising from the existence of a GRS.

The following major points have been established:

- Universal compatibility is the unique product obtained from use of a GRS.
- Economic benefits arise from the demand for universal compatibility by secondary and tertiary users of spatial data.
- Universal compatibility allows secondary and tertiary users of spatial information products to integrate various information products without additional expense.
- The relevant policy issue concerns the benefits and costs of using an existing GRS, not whether such a system should be created.

Development of the Benefits Model

Decisions about land planning, investment, impact assessment, and development are present in the public and private sectors in every community. In some areas, little change in growth or resource development is anticipated and investment in a GRS to support land-related decisions may not be appropriate. But for many areas facing rapid growth and resource use, the cost of utilizing spatial data and information required for land-related decisions may be reduced when compatible data are gathered in anticipation of decision-making needs.

Land planning and development activities involve phases, each requiring a significant number of decisions. Within each phase a subset of decisions require spatial information products. Each decision creates a demand for universal compatibility in the required spatial information products. This demand is indicated in Figure 4.

The process depicted in Figure 4 begins with the need for spatial information products that support decisions. Decision-makers assess the adequacy of existing data files to serve their needs. If existing data are adequate and compatible, further data collection is not necessary. If not, either because the data do not exist or they are not compatible, the decision-maker's needs can only be satisfied at additional effort and cost. The failure to use a GRS to generate spatial data and information causes secondary and subsequent
FIGURE 4.
The Land-Related Decision Process

Spatial Information with Universal Compatibility Required?

YES

Files of Data Exist?

NO

Data Files Suitable for Decision Making?

YES

Existing Data Files

Established, Maintained and Based on a Geodetic Reference System

NO

Supplemental Data Collection Required

Geodetic Reference System not Utilized

users to incur additional costs to meet their needs. Initial use of such a system leads to avoidance of these costs, the basis for quantifying economic benefits.

We have emphasized the following points:

- The demand for universal compatibility by those who are not surveyors, mappers, or geodesists is extensive.
- This demand, arising from a vast number of land-related decisions, appears to be expanding.
- These decisions require the integration or combination of large amounts of diverse data information.
- Integration of such information can be accomplished without additional cost when a geodetic reference system is the basis for initial collection of the data.

Public and private decisions often use existing files of compatible data and information. Decision-makers act with confidence based on these data and avoid costly ad hoc field measurements otherwise necessary to make data compatible. As illustration, consider the case of a need to obtain the relative location of two (or more) subdivisions as a water-related project is planned and built. Often, each parcel within a subdivision has been accurately located and described. However, the subdivision may not be accurately located relative to a reference system. Thus, it is necessary to measure, ad hoc, the relative locations of the subdivisions. This measurement and the associated costs are avoided when the subdivisions are accurately tied to a common reference system, an act which imparts compatibility to the individual subdivision data.

It is also important to note that measurement of the relative location of two subdivisions for a project development often disappears into the chaotic, unorganized local land records, making the measurement inaccessible and, therefore, unknown to subsequent users who desire the data.

Ad hoc and duplicative measurements imply avoidable data-collection costs. They also impose the costs of delays in decision-making. This latter cost is an important consideration when the argument is made that modern spatial-measurement techniques provide inexpensive, ad hoc measurements. For example, advanced surveying and mapping techniques will reduce some of the costs for location and representation of wetlands or the ordinary high-water mark and similar natural features. However, if a decision based on that location is required, the data are not available, and it is Janu-
ary in a cold area, then a delay may occur until information is obtained. The delay imposes costs upon individuals, the community, or both.

It is possible, as we shall demonstrate, to measure at least a portion of the avoided costs generated by GRS investment yielding compatible data. These avoided costs include much of the wasteful repetitive data collection effort required to impart compatibility when a GRS is used in the original collection effort. They do not include intangible benefits that come from avoiding poor decisions made with poor data. Neither do the avoided costs include intangible benefits arising from the ability to creatively combine compatible, existing data.

A community investment in a GRS that supports compatible data and their representation as maps is an investment in the ability to make satisfactory map overlay combinations from existing files. Each subsequent overlay combination can be made to the community standard of quality from existing files of compatible data without recourse to ad hoc measurements. The alternative to this process is the creation of compatibility by ad hoc measurements. We are able to estimate these ad hoc costs with the assumption that they result from measurements made with conventional surveying and mapping techniques. We do not assume that data files or maps must be redone, but rather that they must be made compatible. The avoidance of the cost to create or re-create compatibility is a benefit attributable to the GRS.

There will be circumstances where portions of project-specific reference systems used to create maps or files remain in place. Here, the necessary ad hoc measurements are those that establish the relative location of some of the points within the separate sites in order to make the maps compatible. This is a best-case scenario. In other circumstances, nothing remains of the site-specific control used to create the map. Only the map itself remains. In this worst-case scenario, more extensive ad hoc surveying and mapping is required to create compatibility. In our estimation of the avoided costs of ad hoc measurement we consider this range of possibilities.

The costs to create a system, built upon a GRS that sustains compatible land data include the establishment and maintenance costs for the GRS and for that portion of the data collection and maintenance necessary to make the data compatible.

The model for evaluation of the investment in a geodetic reference system is summarized as follows:

\[ \Sigma (\text{Avoided ad hoc costs to create data compatibility}) \]
\[ \Sigma (A \text{ priori costs to upgrade and maintain the GRS, and to maintain the compatibility of data files}) \]

The decision to upgrade and maintain a GRS is inseparrable from the decision to plan accurate, compatible data. That is, if compatible data are to be available when needed, then there must be a GRS.

The last part of the denominator recognizes that maintenance of the entire system requires periodic updating of data files and their representation as maps. A portion of this maintenance cost is devoted to measurements that insure that the updated data remain compatible.

Reference system attributes impose unavoidable field-measurement costs when data files and maps are periodically updated. The greater the reference system density and accuracy, the less the cost of creating data file compatibility. Increased reference-system density and accuracy are not seen as a benefit but represent lower costs for operating an information system that satisfies the demand for decision-making data, and an increase of avoided costs.

Testing the Model

The benefits model has been applied in a specific test area that has invested in a GRS and uses it to sustain data and information for local planning and development (Bauer 1982). The test area:

- Contains a regional planning commission encompassing several counties and municipalities.
- Exists within a Public Land Survey System state.
- Encompasses more than 2,000 square miles.
- Has economic activity reasonably balanced among residential,
### TABLE 1.
Land-use and Community Development Plans

<table>
<thead>
<tr>
<th>Question</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography and surface drainage</td>
<td>Topography, Wetlands, Roads, Buildings, Sewers (sanitary and storm), Water supply</td>
</tr>
<tr>
<td>Soil suitability</td>
<td>Soils, Parcel boundaries, Buildings, Topography, Wetlands</td>
</tr>
<tr>
<td>Existing land use</td>
<td>Parcel boundaries, Land cover (woodlands, etc.), Wetlands, Soils</td>
</tr>
<tr>
<td>Zoning</td>
<td>Parcel use, Environmental corridors</td>
</tr>
<tr>
<td>Community utilities</td>
<td>Water supply, Sewers (sanitary and storm), Wetlands</td>
</tr>
<tr>
<td>Community facilities</td>
<td>Parcel boundaries, Boundaries for schools, parks, etc.</td>
</tr>
<tr>
<td>Roads</td>
<td>Roads, Geodetic reference system</td>
</tr>
<tr>
<td>Property</td>
<td>Parcel boundaries, Building locations, Easements</td>
</tr>
</tbody>
</table>

industry, commerce, and agriculture.

Many of the local jurisdictions within the area have:

- Resurveyed, remonumented, and established geographical coordinates for a significant proportion of the Public Land Survey System (PLSS), corners and quarter-corners.
- Used the measurement data to prepare large-scale maps for an extensive portion of the area.
- Developed accurate, compatible data by reference of measurements to the PLSS or parcel corners which are part of the geodetic reference system.
- Used existing, compatible data files for land planning and development decisions.
- Developed common regional standards of data quality for decision-making.
- Remained true to NAD27.

The area is balanced economically in that there are important industrial and commercial activities as well as extensive agricultural areas. There is a major metropolitan area with more than one million people and several smaller cities with

more than 100,000 people. Population growth and economic development are moderate.

While the area is typical in many ways, it is atypical in its degree of reliance on high quality data for land planning and development decisions. Many local governments have invested in a GRS according to an area-wide common standard and produced spatial information products with the prospect, often realized, of avoiding subsequent and costly ad hoc field measurements. The use of spatial information based on a GRS throughout a region of several counties establishes the basis for a test of the model.

The regional planning commission director identified the following as major activities which are frequent and require accurate and compatible data:

- Land-use and community development plans.
- Watershed and related water studies.
- Facility development, especially highway construction.

### Land-Use and Community Development Plans

These plans project future land use based upon current conditions, projected changes in population and uses of land, and the physical capacity of the land. The plans require answers to questions that require combinations of data about the location of a variety of features. The list of features that are important in the case study area are itemized in Table 1.
Water Related Activities

These involve flood hazard management, sewer and water supply planning, and natural area conservation for specific sites and for entire watersheds. The following features are routinely considered and data on these features are combined from existing files for a water-related study:

- Topography
- Surface Water
- Soils
- Land use
- Land cover—woodlands, etc.
- Natural areas—habitat, etc.
- Water supply
- Sewers (storm and sanitary)
- Community facilities
- Roads
- Wastewater sources
- Parcel boundaries
- Building location
- Easements
- Precipitation
- Population
- Wetlands

Facility Development

For facility development, especially highway construction, several data needs arise. These include centerline location, grade and topography, right-of-way location, parcel boundary location, land use, building location, natural areas, and environmental corridors. Several needs are resolved by appropriate combination of accurate, compatible data. The context is not only physical construction but also a broader one such as the environmental impact of the project in our test area.

Highway construction is not the sole responsibility of the regional planning commission or local governments. However, state and local agencies within the test area do rely extensively upon the files of accurate, compatible data created and maintained by the commission and local governments. Unfortunately, these highway agencies do not typically maintain records of the land-feature data combinations and the source of these data for the various decisions that are made. Thus, we are unable to include this stream of decisions in the benefit analysis. We are assured by state highway department officials that such data are used, but they do not have the retrospective records to measure the use of such data. Thus, our estimate of the GRS benefits is low because the avoided costs associated with highway construction cannot be measured.

Estimating Costs

The calculation of benefits and costs include the situation where maps or files exist but are not compatible (or not compatible to the degree desired) because they are not tied to a GRS. Here, one of two possible types of ad hoc measurements must be made. These are:

1) The original control is no longer available because it was not maintained or was specifically designed not to be permanent; or
2) The original control is available (as in the use of site-specific control), but is not tied to a geodetic reference system.

Both require field measurements to establish the compatibility between various data files. The former situation involves more measurement than the latter. Thus, the benefits from a geodetic reference system constitute a range which depends upon the balance of conditions existing in a jurisdiction.

As an example, consider existing topographic data generated from local control data rather than from GRS data. It is now desired to combine the topographic data with other land feature data. There are two possible circumstances:

1) The original local control monuments are gone because they were not maintained or were temporary by design. The location of topographic features must now be integrated with other features of the ground configuration. This requires the activities of ground survey, aerial photography, computation, and drafting based upon a photogrammetric model.
2) Some portion of the original local control monuments remain. The necessary tasks require connection of the remaining local control to the GRS by ground measurements and to recompute and draft the results to produce a new spatial product. It is typically not necessary to repeat the photogrammetric modeling.

Jurisdictions in the test area rely on the existing, compatible data to avoid the cost of field measurements. The cost of these avoided measurements can be estimated. Estimates, made for both situations described above, represent upper and lower limits of the avoided costs.

Estimates of the avoided field measurement costs were made for the test area based
upon the following resources:

1) Identification by local personnel of major activities that require and use existing compatible data.
2) Estimates by local personnel of the annual rates of major activities in the area.
3) Planning documents as retrospective records of actual data use.
4) Planning documents and interviews with local officials to determine decisions made with spatial information.
5) Interviews with surveyors, mappers, and photogrammetrists to estimate the cost of avoided field measurements that would have been necessary to produce compatibility of the existing data.

The general problem of estimates is illustrated by the example of topographic data. For one case where topographic data exist (often in the form of topographic map) but nothing remains of the local control used to generate the data, measurements must be made that tie the topographic data to the geodetic reference system. All data must be tied to the system. This problem requires ground survey, aerial photography, modeling and plotting. For the other limiting case where the topographic data exist and some or all of the local control remains, measurements must still be made but less effort is

| TABLE 2.  
Estimated Cost of Making Land Feature Data Compatible  
(costs expressed in dollars per square mile in 1983 dollars)* |
<table>
<thead>
<tr>
<th>Feature</th>
<th>Original Control Destroyed</th>
<th>Cost</th>
<th>Original Control Recoverable</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td>Aerial photography</td>
<td>$200</td>
<td>Ground survey</td>
<td>$400</td>
</tr>
<tr>
<td>Plot (model)</td>
<td>$1,200</td>
<td>Compute, draft</td>
<td>$400</td>
<td></td>
</tr>
<tr>
<td>Ground survey</td>
<td>400</td>
<td></td>
<td>$800</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$1,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roads</td>
<td>Aerial photography</td>
<td>$200</td>
<td>Ground survey</td>
<td>400</td>
</tr>
<tr>
<td>Plot</td>
<td>$200</td>
<td>Compute plot</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Ground survey</td>
<td>400</td>
<td></td>
<td>$600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewers (storm and sanitary)</td>
<td>Ground survey</td>
<td>400</td>
<td>Ground survey</td>
<td>200</td>
</tr>
<tr>
<td>Compute and draft</td>
<td>100</td>
<td>Compute and draft</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$500</td>
<td></td>
<td>$300</td>
<td></td>
</tr>
<tr>
<td>Parcel boundaries (Registry work done)</td>
<td>Ground survey</td>
<td>2,600</td>
<td>Ground survey (compute)</td>
<td>100</td>
</tr>
<tr>
<td>Graphics</td>
<td>200</td>
<td>Graphics</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$2,800</td>
<td></td>
<td>$300</td>
<td></td>
</tr>
<tr>
<td>Building location</td>
<td>Aerial photography</td>
<td>200</td>
<td>Ground survey</td>
<td>400</td>
</tr>
<tr>
<td>Plot</td>
<td>800</td>
<td>Compute, plot</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Ground survey</td>
<td>400</td>
<td></td>
<td>$600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$1,200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easements</td>
<td>Ground survey</td>
<td>2,600</td>
<td>Ground survey</td>
<td>200</td>
</tr>
<tr>
<td>Compute, graphics</td>
<td>200</td>
<td>Compute, graphics</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$2,800</td>
<td></td>
<td>$400</td>
<td></td>
</tr>
<tr>
<td>Soils**</td>
<td>Graphics, plotting</td>
<td>$200</td>
<td>Graphics, plotting</td>
<td>$200</td>
</tr>
</tbody>
</table>

*Cost estimates are consensus figures based on industry fee schedules.
**These and other features are ambulatory. The major effort to maintain these files is field measurement. The indicated values are the avoided compatibility costs when data about features are regularly maintained in compatible form.
required. Although no aerial photography is required, ground surveying and some computation and redrafting are necessary.

We have estimated the avoided costs of obtaining compatibility for the set of independent, compatible files typically maintained and used by jurisdictions in the test area. Clearly there is a range of estimates that depends upon the measurement techniques employed and the accuracy desired. We have assumed the use of current, standard surveying and photogrammetric techniques. In addition, we have assumed the high standards of data accuracy and compatibility demanded by the jurisdiction that serves as our test area. An indication of these standards is given by the fact that the area has established the geographic coordinates of corners in its Public Land Survey System to an accuracy corresponding to traditional second-order standards. The jurisdictions typically prepare base and thematic (land feature) maps for the decision-making process.

Table 2 contains cost estimates using methods described in the example for topographic data and applying the standards of the test area.

For land-use and community development plans, the combinations of land feature data in Table 3 are routinely made within the test area jurisdictions.

Each combination for a particular decision must be considered even though features appear several times in the entire process. The process demands a set of independent decisions, each involving an independent set of combinations. These independent decisions are used in decision-making with the ultimate goal of a land-use plan. Because each combination must be made independently, it thus generates an independent set of avoided costs.

For watershed studies a single combination involving a large number of features must be made. This list and the avoided costs are listed in Table 4.

For facility development, especially highway construction, no data were available because records are not maintained that would allow a retrospective calculation.

**Calculation of Benefits and Costs**

We are able to calculate the avoided costs of field measurements to create compatibility for the major activities. These avoided costs represent a partial benefit stream from utilizing GRS.

It was estimated from records in the regional planning...
TABLE 4
Watershed Study Costs
(costs expressed in dollars per square mile)

<table>
<thead>
<tr>
<th>Features</th>
<th>High Cost</th>
<th>Low Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topography</td>
<td>$1,800</td>
<td>$800</td>
</tr>
<tr>
<td>Surface water</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Ground water</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Soils</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Land use</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Land cover (e.g., natural habitat)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Water supply</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Sewers—storm</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Sewers—sanitary</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Community facilities</td>
<td>2,800</td>
<td>300</td>
</tr>
<tr>
<td>Wetlands</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Sewers</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Roads</td>
<td>800</td>
<td>600</td>
</tr>
<tr>
<td>Wastewater sources</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Precipitation</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Parcels</td>
<td>2,800</td>
<td>300</td>
</tr>
<tr>
<td>Population</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Buildings</td>
<td>1,200</td>
<td>600</td>
</tr>
<tr>
<td>Easements</td>
<td>2,800</td>
<td>400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$16,100</strong></td>
<td><strong>$6,300</strong></td>
</tr>
</tbody>
</table>

Commission files that the commission prepares land-use and community development plans for local units of government at a rate of about 36 square miles per year.

Watershed studies are done for entire watersheds and project conditions for a 15- to 20-year period. Based on the number of studies and their area, the commission prepares studies at a rate of 120 square miles per year.

Benefits = [(avoided costs for planning, watershed, and construction activities)].

Benefits = [(rate) (avoided costs for planning activities) + (rate) (avoided costs for watershed activities) + (rate) (avoided costs for construction activities)].

commission, the county surveyor, and others responsible for corner destruction. The commission and the surveyor take positive action to monitor actions that lead to reference system damage, and recover restoration costs from offending parties. In some cases, one public agency compensates another for the costs of restoration, an indirect public cost. The costs of maintaining data compatibility can be estimated. This can be done because the jurisdiction maintains the reference system and periodically updates dependent data files. The updating process involves aerial photographs, feature identification, and plotting. Ground activities are unnecessary except those minimally necessary to flag ground points. We estimate these avoided costs as $2,000/mi² for each updating process, which typically occurs in 5-year intervals.

The GRS established to support these planning and related decisions now covers about 1,344 square miles. Thus:

\[
\text{Cost} = \left(1,344 \text{ mi}^2 \times \frac{2,000}{\text{mi}^2}\right) + \left(\frac{16,000}{\text{mi}^2}\right) + \left(\frac{2,000}{\text{mi}^2}\right).
\]

Finally, the ratio of benefits to costs is:

\[
\frac{\text{Benefits}}{\text{Costs}} = 4.5/1.7
\]

(upper limit/lower limit).

The estimates of the benefits of investment to upgrade and maintain a geodetic reference system to support land decision-making are conservative for several reasons. First, data are
Summary and Conclusions

A methodology designed to measure the benefits and costs of the effort to upgrade and utilize a GRS has been developed. The analysis reveals that the benefits arise because there is demand, especially but not exclusively, at local levels of government for compatible data in decision-making processes involving land planning and development issues. The GRS provides the means for making it possible to combine existing data files to satisfy information needs without resorting to the expensive, ad hoc field measurements. These avoided efforts generate the stream of benefits.

Benefits and costs were estimated for a test area. Jurisdictions in the area have invested in a geodetic reference system, developed land information based upon the system, and used the information in decision-making for land-related activities.

The results of an application of the model to a test area demonstrate large benefits compared to the costs of the system. These positive net benefits are conservative; they include only a portion of the actual benefits generated because complete records were not available. If these additional, unmeasured benefits were included, then the full extent of the value of investment in a geodetic reference system would be revealed.

References


Modeling Cadastral Spatial Relationships Using Smalltalk-80

Daniel Kjerne and Kenneth J. Dueker

Abstract: This paper describes research on modeling location in cadastral maps using ParcPlace System's Smalltalk-80 running on an Apple Macintosh II. We have developed point and line object classes that store their location methods, measurement values, and reference objects, and automatically update their location when changes occur in the measurement values or the location of reference objects. The paper discusses the transferability of these class definitions to object-oriented database systems. Finally, certain tools available in this language—e.g., delegation, multiple inheritance, and dependency—allow extension into other GIS and multipurpose cadastral problem areas, specifically that of sharing information about polygon boundaries among different data layers.

The work reported follows on some previously described (Kjerne and Dueker 1986; Kjerne 1986; Kjerne 1987) exploring the object-oriented paradigm as a tool with which to model location of objects in maps. As our work continued, we made use of a more powerful hardware and software system and devoted time to looking at development and utilization issues. Our interests, abilities, and resources led us into three areas:

- The use of an object-oriented language, Smalltalk-80 (referred to hereinafter as Smalltalk), to model cadastral location using the object-oriented paradigm.
- Study of the development of spatial information systems, such as engineering design and computer-aided design (CAD) database systems based on object-oriented ideas, to see how that approach might be useful for developing a mapping system.
- Finally, the conceptual exploration of how an object-oriented approach might facilitate linkages of location among layers of a land information system.

The remainder of this paper reports on these three areas of inquiry.

Modeling Cadastral Location

Principles of object-oriented systems

Object-oriented (o-o) systems are based on a paradigm of objects responding to messages, rather than (as is the case with procedural languages) on one of operators performing actions on operands (Goldberg 1983). Here is one of the most succinct and comprehensive explanations of this environment that we have found (Ketabchi and Wiens 1987):

In an object-oriented environment, anything which is to be represented within the system is an object. An object consists of a private memory with a public interface. Each object within the system is identified by a unique system-defined object identifier. This identifier does not change even though properties of the object may change.

An object's private memory cannot be directly accessed or manipulated by other objects. Any operation upon an object's private memory can only be effected by sending an appropriate request to the object. Since each object has a well-defined interface, and sole con-
Horwood Critique Articles

In 1985, URISA established the Horwood Critique Prize in memory of Dr. Edgar Horwood of the University of Washington, who founded URISA in 1966. The objective of the prize is to challenge information systems professionals to more critically interpret developments in the field. The prize is given annually to the author(s) of a paper published in the previous annual URISA Proceedings representing the best critical analysis of an urban, federal, regional or local system design, implementation or application; technology policy or issue; or contextual environment.

Papers are judged on their candor, critical insights, and conclusions and methods employed in the critique. All papers appearing in the Proceedings are judged in the competition. To share these outstanding papers with a wider audience, we are featuring an adaptation of Daniel Kjærne’s 1987 prize-winning paper, “Modeling Location for Cadastral Maps Using an Object-Oriented Computer Language” (1986 URISA Proceedings, Vol. 1, pp. 174-189). The article appearing in this journal, “Modeling Cadastral Spatial Relationships Using Smalltalk-80,” is a more current report of the research effort and was originally published in the 1988 GIS/LIS Proceedings, Vol. 1, pp. 373-385.


In keeping with the critical intent of these papers, we invite comments and responses to all four Horwood Winners (1986-89). The 1989 Horwood winner, “Adapting and Applying Existing Urban Models: DRAM and EMPAL in the Seattle Region” (Watterson, Vol. IV, p. 78), will be featured in the next issue of the URISA Journal. Two responses to the Kjærne and Dueker paper, “Modeling Cadastral Spatial Relationships Using Smalltalk-80,” appears in this issue on p. 36.

The Editors

trol over its own private memory, an object actually functions as an abstract data type.

Many objects within the system exhibit similar behavior. These objects are grouped together in classes. Each object within a group is said to be an instance of the class of that group. Classes are arranged in a super-class/subclass hierarchy. The behavior defined within each class is inherited by its subclasses.

Each class defines the behavior of its instances. However, the instances are not identical. Instances are distinguished by their unique identifiers and the contents of their private memories. The set of classes is not fixed. Users can create new classes as well as new instances of current classes (p. 44).

It might only be added that, instead of classes, some object-oriented languages use a proto-typing mechanism, cloning and modifying instances to add new types of objects (Ungar and Smith 1987). And it should be noted that the description above is not completely true for procedural languages that have been extended to handle abstract data types, such as C++, Object Pascal, etc.

The o-o paradigm and conceptual modeling

Object-oriented languages are based on a very different way of viewing the world from that of procedural languages. In designing an application using a procedural language, we ask questions such as: What input do I have? What do I do to it to get the output I want? When using an o-o language, the questions become: What things are there in this problem? How do they behave?

This shift in viewpoint facilitates the transition from a conceptual model of a problem to a running application. If our model consists of things that interact in some fashion, an object-oriented application can have the same structure.

In the case of cadastral
FIGURE 1.
Hierarchy of locational dependency for the cadastral layer. The arrows may be read, "(entities at head) depend on (entities at tail) for location." Physical entities whose position has been located in the field are held steady; legal (non-physical) entities are plotted with relation to them. Among themselves, the locational hierarchy of legal objects follows a different, though still formalizable, set of rules than those for physical objects.

- control
- physical entities
- legal entities

(location defined by fiat—e.g., USGS monuments, points tied in by high-order survey)

(location measured in field—e.g., monuments from prop. survey, stream edges from photogrammetry)

(location described in deeds—e.g., easement lines, property points)

maps, we are concerned with a set of entities in a hierarchy of locational dependence (Figure 1).

Except for control entities, everything knows where it is by applying a specific locational procedure (from surveying or legal description), with relation to a specific set of reference entities, and using specific measurement values.

In producing a map from a cadastral, we can take advantage of a number of simplifying assumptions since such a map is not a legally binding document in the sense that deeds are. We can assume, for instance, that an object will not occupy more than one location at a time, and that a single chain of location dependency can be determined for any object. (This does not mean that any object depends only on one other object as a reference object. In the case of closed traverses between fixed points, for instance, both ends of the traverse are reference points; objects in the traverse are located using a transformation procedure allowing the relative coordinates [and relative locations] to remain invariant, while the global position may change. Obviously if the relative positions of the endpoints change, the traverse needs to be readjusted.)

Present status

Our previous work may briefly be described as involving the definition of object classes using a Forth- and Smalltalk-descended language called Neon.

The present work has been carried out on an Apple Macintosh II in ParcPlace's Smalltalk-80 development environment for three reasons: 1) Smalltalk is a more powerful language; (2) it is used more widely within the community of o-o researchers and developers; (3) and it is easily portable to different applications and platforms.

A standard Smalltalk application consists of three parts (Figure 2):

- A Model, which can be any kind of object;
- One or more Views, each of which displays itself on the screen, making use of information contained in messages sent by the Model;
- And a Controller, corresponding to each View, that accepts input from the user (via keyboard and cursor movement).

All parts of the application are linked to some degree, but the Model is relatively independent of the other two. It doesn't really know, or care, how many Views are looking at it; all it does is respond to messages. The View, on the other hand, is tightly linked to a particular Model, and often performs some action automatically (such as redisplaying itself) if the Model changes. Similarly, the Controller and View are linked to each other so that the View (often) knows that it should perform some action when the cursor is within its window and a particular mouse button is down.
In the following discussion, we first describe the Model (and the objects it contains), the View, and then the Controller for this particular application.

**Model (Cadastre)** The Model in the prototype is a Cadastre (Figure 3), a kind of object that contains other objects in a list accessible by names, or keys (it is a subclass of a standard Smalltalk class called Dictionary.) As a subclass of Dictionary, it knows (among other things) how to add a new object to itself, how to tell how many objects it contains, and how to return a particular object when given the object’s name. As a Cadastre, it knows, in addition, how to find

**FIGURE 2.** The Smalltalk Model-View Controller paradigm. Within the application, the Controller receives input from the user and typically sends a message to the View. The View in turn usually sends a message to the Model, which performs some action and replies to the View, which probably uses it for output. The View also sends messages to the Controller now and then. Less often, the Controller may have something to say directly to the Model. Meanwhile, out in the real world is the entity being modeled. ("The map is not the territory" [Korzybski 1941])

**FIGURE 3.** The internal variables of the objects that make up the Model for the prototype cadastral mapping application. A Cadastre contains a dictionary-like list of Cadastroids, each of which is referenced by name. Each Cadastroid, in turn, contains a Locoid, which stores names of reference objects and values, and uses them to recalculate current location.

<table>
<thead>
<tr>
<th>Cadastre</th>
<th>Cadastroid</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td></td>
</tr>
<tr>
<td>George</td>
<td>a ControlPoint</td>
</tr>
<tr>
<td>Fred</td>
<td>a MonumentPoint</td>
</tr>
<tr>
<td>Mary</td>
<td>a MonumentPoint</td>
</tr>
<tr>
<td>Alice</td>
<td>a PropertyLine</td>
</tr>
</tbody>
</table>

Fred, a MonumentPoint

- material: 2" brass disk in conc.
- surveyor: Jones (26558)
- location: an AngleDistancePoint

an AngleDistancePoint

- referencePoint: Mary
- referenceLine: Alice
- angle: 45-15-30
- distance: 145.36
- currentLocation: 325.658432.93
the object within itself that is closest to a given point.

The objects in the Cadastre are Cadastroids. More precisely, they are all descended from the abstract class Cadastroid. (An abstract class is one which does not itself have instances, but is used to define behavior common to its subclasses.) The subclasses of Cadastroid are: MonumentPoint, ControlPoint, PropertyPoint, MonumentLine, and PropertyLine. As their names imply, these classes correspond to the kinds of things that appear on cadastral maps (aside from such things as grid ticks, legends, titles, and text).

Any object descended from Cadastroid has an internal variable called "location." An internal variable is part of the private memory of an object, and can itself contain an object. In this case, the "location" internal variable contains a Locoid. (Again, to be precise, Locoid is another abstract class, so the internal variable actually contains an instance of some subclass of Locoid.)

These are the objects that do all the work. Each subclass of Locoid corresponds to a locational procedure (AngleDistancePoint, AzimuthDistancePoint, AtPointPoint, IntersectionPoint, and StraightLine have been defined so far). The procedure is used in one of the methods that the subclass knows how to perform; it typically consists of asking the reference objects for their current location and applying values stored in other internal variables. Thus, for instance, an AngleDistancePoint object stores the name of two reference Cadastroid objects (one linear, from which the angle was measured, and one punctual, from which a distance was measured—usually, but not necessarily, at the origin of the line), and two measurement values (an angle and a distance). Computation of current location is a straightforward application of trigonometry.

In addition to capturing the "why" of where an object is positioned, a Locoid captures where it presently is: the current location is stored as a Point (x-y coordinates) or Line (ordered collection of points) in an internal variable.

Other procedures Locoids can perform include the ability to set up dependency relations with reference objects so that when one of these changes its location, the dependent objects will be notified. Because of the dependency link set up between objects and their reference objects, locational changes propagate through the model. Thus, whenever a Cadastroid receives a message from one of its reference objects that its location has changed, its Locoid performs the locational procedure, the new current location is stored, and dependent Cadastroids are informed that a change has occurred.

View (CadastralView). The CadastralView is really, at this point, not a very exciting variation on the standard Smalltalk View. It is a single-panned window with the capability, when it is started up, of linking itself with a given Cadastre. It can send the Cadastre messages to have its elements display themselves in the CadastralView.

Controller (CadastralController). The CadastralController is also pretty rudimentary at this point. It can do one interesting thing: send a message to the Cadastre, along with the coordinates of a mouse-click, that will cause the Cadastre to return the name for one of its elements so that a window can be opened showing its internal variables.

Planned Near-Term Enhancements

More kinds of objects in Cadastre. More locational kinds of classes are needed before a reasonable property map prototype can be modeled. These include arc, spiral, and curve and more interesting (and robust) line intersection classes. Smalltalk does not have a generous supply of geometric classes; it is necessary to translate code from other languages or algorithmic descriptions. ParcPlace's new version of Smalltalk allows user-defined primitives (Smalltalk 1988). This might be useful for importing code written in other languages to perform basic jobs such as computing intersections of lines, chains, arcs, and so forth.

In addition, it will be
desirable to implement topological knowledge; this will require amendments to the object hierarchy. Topological objects ("Topoids") should be defined to go into a new internal variable slot of Cadastroids. They will require an ability to track dependency relationships similar to Locoids. For instance, the instantiation of a new area object will require methods to notify related line and point objects of the change.

Improvements to Cadastre. The choice of a subclass of Dictionary as the data structure for a Cadastre is still not fixed. It might be better to organize the assessor objects into another kind of Smalltalk Collection that could utilize efficient spatial search methods on object keys. The virtue of the present arrangement is that it is accessible using standard system tools, and it is reasonably close to the structures used in at least one object-oriented database system modeled on Smalltalk (Penney and Stein 1987).

Improvements to CadastralMap. To a surveyor or cartographer, the most serious deficiency at this point is that the map is upside down: y-coordinate values increase toward the bottom of the screen, in line with computer graphic convention. This is (in principle) not difficult to fix. Other possible improvements are cosmetic in nature: the addition of grid ticks, coordinate value text, perhaps a fixed window size and aspect ratio so that a given scale can be presented.

Improvements to Cadastral-Controller. At present, most interaction with the Cadastre is through the text workspace, a standard Smalltalk system feature. It would be nice to be able to add or edit points by selecting them with the cursor and working through a series of templates or dialog boxes. This is a lower priority than other goals, as it may be advantageous to use a commercially available application interface developer.

These improvements will eventually produce a more convincing prototype of a cadastral map; however, since Smalltalk is a single-user, programming language environment, it does not produce objects that persist beyond the existence of the program in which they are created and manipulated. Computer-aided cadastral mapping requires an environment capable of working with persistent objects accessible by multiple users. This leads us to an investigation of present and future directions in database system development.

Mapping and the Next Generation in Database Systems

CAD and Mapping Environments

Practitioners involved in efforts to improve database systems are concerned with modeling structures that are more complex than the typical business applications, and see their challenges in such applications as design engineering (especially mechanical and electrical), document authoring, and hypermedia. They do not see mapping as a high priority, but the problems are similar, especially to mapping of the cadastral variety.

It was particularly fascinating to read a description of the CAD application environment, substituting the words "cadastral cartographer" for "design engineer"; "cadastral map" for "design object"; and "update" for "refine" (Ketabchi and Wiens 1987):

...In these applications large amounts of data are created and shared by design engineers who do not want to concern themselves with the details of storage and data organizations. . . .

Design is the work of a team. Each member of the design team may begin a transaction which involves a large volume of data and persists for a long time. Therefore, conventional locking and time-stamping techniques cannot be used to control concurrent operations.

Design starts with high level descriptions of a design object and continues through its iterative refinements. Since the history of the design operations must be maintained, refining a description should not destroy the original description, but must create a new description of the design object. . . (p. 44).

Each of the points raised—large data volumes, multiple users (with skills in a subject field other than data management), long transactions, neces-
sity to track previous states of the database—is also characteristic of cadastral mapping.

**Object-oriented Database Systems**

We examined various candidate technologies proposed as a basis for advanced database capabilities—extensible toolkits (e.g., EXODUS [Carey and DeWitt 1987]), semantic database systems (e.g., SIM [Tolbert 1988]), enhanced relational systems (e.g., POSTGRES [Stonebraker and Rowe 1986]), object-oriented (e.g., GemStone, Encore [Smith and Zdonik 1987]; VBASE [Andrews and Harris 1987])—with two requirements in mind:

- First, as we have conceptualized the problem domain, we find we are dealing with composite entities: maps contain tracts, tracts or subdivisions contain parcels, parcels contain boundaries, and so forth. And the objects defined in our prototype cadastral location application contain location objects (which in turn contain current coordinate objects) and would presumably contain topological or non-geometric attribute objects.
- Secondly, we wish (with the inclusion of measurement procedures) to include behavior, and hope to be able to update location or topology “inside the database.”

The object-oriented database approach seems more suited to meeting these requirements than any of the other general ones noted above.

Even within the area of research into object-oriented databases, it's still a fluid situation with a number of competing approaches. The main division seems to be between object-oriented database systems (OODBS) and object-oriented database programming languages (OODBPL).

An oodb can manage composite objects and encapsulate behavior with values, but it is separate from the language interface used by the database's developers and users. GemStone, for instance, runs as a “back end” on a minicomputer and responds to “front end” applications written in Smalltalk, C, or Pascal on microcomputers linked by a network (Purdy, Schuchardt and Maier 1987). An object-oriented database programming language would bring these two environments together. This approach avoids “impedance mismatch” between programming language (front end) and data manipulation language (back end) (Maier and Price 1984).

Within both oodb and oodb programming approaches, methods can be added to object classes (or, as database researchers are prone to call them, “types”) to allow the kinds of things we are interested in for cadastral mapping; i.e., dynamic updating within the database by recalculating location, topological connections, and so forth. But it would appear to be advantageous to be able to import code from other languages as user-defined primitives that can be used inside methods. This would lessen the necessity to recast every spatial analysis method into a new language, since there is a large repertoire of functions, procedures, and techniques for spatial manipulation already extant in other languages, such as C.

Because of the inheritance of behavior, it is easy to extend object-oriented languages to have new capabilities. Research in progress has brought out extensions to Smalltalk that allow persistent objects (Kaehler and Krasner 1983) and a distributed Smalltalk (Bennett 1987). To develop an oodbpl from this language, the next step would presumably be a distributed Smalltalk with persistent objects. But there appear to be problems with the class construct of Smalltalk when extended to persistent objects accessible by multiple users. All object-oriented languages don’t implement characteristics peculiar to the o-o paradigm (such as inheritance) in the same way, though. A language that uses another mechanism (e.g., prototyping) may be found to be more appropriate as a basis for an oodbpl (Merrow and Laursen 1987). Regardless of how that avenue of research turns out, it seems fruitful to continue using Smalltalk to develop more kinds of locational methods, since the basic types developed would be useful regardless of the particular inheritance mechanism.
Meanwhile, by keeping an eye on the development of object-oriented database systems, we hope to eventually identify one that can be made to manipulate spatial information.

Finally, we hope to continue exploration of how the object-oriented paradigm will be useful in mapping and geographic analysis generally. The following section presents some thoughts we have already had on the subject.

Extensions to Multi-Layer Systems

While the research reported here has emphasized cadastral objects, the paradigm for locational determination has a broad potential for application. Shared or common boundaries among layers or data types can be addressed by an object-oriented database approach, which lends itself to better handling of the interrelationships among objects of different types.

Currently, the representation of various themes or data types as separate layers in a GIS results in duplicate approximations of common boundaries. Some systems use a "shared primitive" approach to resolve this problem (Charlwood, Moon, and Tulip 1987). In a relational model this requires a single underlying geometric layer, which is difficult to modify as changes may warrant.

For example, in a conventional GIS the cadastral layer may actually consist of sublayers of control, property lines, rights-of-way, etc. Yet, a right-of-way line usually is locationally related to a set of property lines, both of which depend on physical monuments (Figure 4). Depending on the particular situation (platted subdivision v. deed right-of-way, for instance), the controlling entities for location may be the lot monuments or other (centerline) monuments; the right-of-way may determine the location of property lines or vice versa. An object-oriented approach would allow modeling these diverse situations.

These locational dependency relations are not unique to the cadastral layer, however. They exist in a variety of boundary relations, and just as with the right-of-way lines, the procedures and types of reference objects for location of boundary segments of the same kind can vary from instance to instance. For example, much of the northern boundary of the state of Oregon is the center of the main channel of the Columbia River, a natural feature. Segments of the state boundary are also county boundaries (Figure 5). The northern boundaries for these counties would be determined by a method contained within the county boundary object that would reference the state boundary, intersecting it with the east and west county boundaries. (The state boundary would locate itself by a method that referenced the channel of the Columbia River.) Meanwhile, the remaining county boundaries are probably monumented, referencing objects of a different class.

Users of multipurpose systems having a cadastral layer as a base are interested in four:

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**FIGURE 4.**
(a) Property lines coincide with right-of-way and locations for both are determined by parcel property monuments. (b) Location for front lot lines is determined by location of right-of-way line, which is determined by location of centerline monuments.
A case in which a natural feature determines the location of a jurisdictional boundary, with the locations of boundaries of subjurisdictions determined hierarchically. Location of the north-south trending county lines likely follows other procedures.

![Map showing Washington and Oregon](image)

general classes of area entities: jurisdictions, statistical areas, natural resource areas, and property ownership areas. As with cadastral location, the boundaries of these areas depend for location on entities that have been located in the real world—on natural features, such as rivers or ridgelines, and on artificial features, in the form of streets, roads, and railroads. If this real-world structure is reflected in the model used for a mapping system, updating (inputting more accurate) locations of real-world entities will propagate those more accurate locations to dependents. This will result in more accurate responses to queries. Integrity of the database over time requires the capture in the data model of dependencies among entities.

**References**


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Note

"Modeling Cadastral Spatial Relationships Using Smalltalk-80" by Kjerne and Dueker contains three implicit "object-oriented" subjects: object-oriented modeling, object-oriented languages (Smalltalk), and object-oriented database management systems. It is important to recognize that, although these topics share a certain vocabulary, there are many system design choices possible. For example, it is reasonable to design (model) spatial databases using an object-oriented methodology such as entity/relationship models in a relational DBMS and to develop application code with a procedural language. The following comments are organized by these three areas.

The biggest concern in object-oriented modeling is to identify the "correct" objects to model. While I agree with the authors' concept of "locational dependence," I take exception to their choice of the cadastral map as the relevant object as well as the simplifying assumptions accompanying that choice. Cadastral objects such as monument points, property corners and so forth DO have multiple locations. Although cadastral maps appear to resolve these discrepancies, they must be modeled for use in any comprehensive LIS.

I agree with the authors that much more work needs to be done extending the current object-oriented programming languages to include geometric operators such as intersection, contiguity, "containedness" and so on. It should be emphasized that the more complex the objects are, the more difficult it is to implement relevant operators (e.g., line-intersect-line is much simpler than cadastral-intersect-floodplain).

Finally, we come to the issue of object-oriented databases. These seem very similar to network databases, with their parent-child segment relationships maintaining the inheritance dependencies. While this design may be optimal for certain applications, it can impose severe performance penalties when cross-child access is required. My experience is that most cultural applications may lend themselves to some degree of hierarchical breakdown. These include examples from the legal/institutional field (e.g., cadastral) as well as those from engineering (e.g., a constructed facility has assemblies which have sub-assemblies which have parts) and others. It also seems that most applications that have natural features do not. The boundary conditions of shorelines, soil polygons, ecosystem boundaries and so forth have no discernible dependencies on or from other objects.

This would seem to indicate that the general use of object-oriented databases for managing these objects offers little advantage over current georelational schemes.

A more fundamental observation is the author's recognition that much additional functionality for spatial analysis needs to be added to any system built on top of an object-oriented database. Given the relative additional overhead and complexity of these systems, one wonders about the subsequent increase of the algorithmic complexity and the improvements, if any, over more atomic approaches.

In summary, I think that object-oriented paradigms (models, languages and databases) may provide some advantage over current GIS/LIS approaches to the cadastral layer. The authors have correctly identified some of the minimum features to add to their model in order to make a better estimate of its utility. In general though, given the inherent limitations of identifying all possible objects, dependencies and operators prior to implementing a particular...
object schema, simpler data structures on more “primitive” objects offer more flexibility in support of evolutionary changes.

Alan P. Vonderohe
Department of Civil and Environmental Engineering and Institute for Environmental Studies, University of Wisconsin-Madison

Kjerne and Dueker describe the implementation of a cadastral mapping model in an object-oriented environment, characteristics of object-oriented database systems and programming languages, and extensions of the concept to multi-layered systems which currently may contain numerous representations of the same object such as a common boundary. Their approach is particularly suitable for cadastral information due to its inherent hierarchical dependencies and their reasoning concerning more general GIS applications is sound.

From a practical standpoint, the most significant implication of the work concerns response of the system to updates, particularly those concerning geodetic control. Individual cadastral objects are represented along with their appropriate spatial relationships with other objects. Thus, when the coordinates of a control point change, only those objects related to that control point by their descriptions change position. Appropriate spatial relationships are retained independently of the quality of “absolute” control coordinates. Cadastral databases may be constructed at convenience and control upgraded over time without resorting to sporadic and inappropriate transformations of the entire cadastral map. In addition, new information concerning individual cadastral objects, such as that arising from resurveys, can be treated in a similar manner with similar effects. It seems that this aspect of the approach alone compensates for the increase in database overhead.

The authors admit to simplifying assumptions such as individual objects having single chains of location dependency and unique locations at any given time. Their concern is for mapping, not for legally binding representations. On the other hand, von Meyer (1989) has developed a model that accounts for conflicts arising from over-constrained cadastral objects and for multiple representations of the same object. Examples of the latter are multiple monuments intended to represent the same property corner and multiple coordinate pairs for the same monument, situations that occur frequently in practice. Both of these works make substantial contributions to representation of the complex nature of spatial cadastral information.

Reference

Legal Issues in Providing Public Access to an AMS: Case Studies and Variances

Howard Roitman

Howard Roitman, who has a J.D. from Yale Law School, is an associate director of PlanGraphics, Inc. He has worked extensively on public access issues involving automated mapping systems.

Abstract: Last year, approaches were explored which could be used by public agencies to market and sell information products and services for a fee greater than the costs of reproduction traditionally allowed under freedom of information and open records laws. For some entities, this has not been a problem; for others, however, it has been a major stumbling block. This paper examines some of the issues which have been encountered by agencies on their way to marketing information and ways in which they have dealt with them. The questions discussed are:

Legal Authority—Does the agency have the authority to market and sell information?

Open Records Laws—Can the agency recoup costs for information products beyond those allowed by open records laws and implementing regulations?

Equal Treatment—A public entity has different obligations than a private one. To what extent must a public entity supply products and services to everyone who wants them? This is a particular concern if on-line access to the data is one of the services to be offered.

On-line Access—Besides the equal treatment question, on-line access raises a number of issues, including protection of proprietary information and security.

Public access to automated mapping systems (AMS) datafiles has been a hot issue in recent years. Public agencies have invested in expensive systems for their own public purposes, but have also found that the data are of value to many in the private sector—either in the format used by the agency or processed differently by the system. Several agencies have marketed and sold the data and other information products without questioning very carefully whether they had the authority to do so and, if so, whether they could charge more than state open records laws allow. Others have concluded that they have difficulties in undertaking such a project and have created separate entities to conduct the information business. Two agencies in two different jurisdictions have conducted studies recently to determine the answer to some of the issues involved and to consider strategies on whether and how to proceed in marketing AMS products. This paper discusses some of the major issues they have considered and possible implementation strategies.

Legal Authority

A major issue that has emerged in some jurisdictions is whether the agency has the legal authority to market and sell information products. The answer is largely dependent on two factors:

1) The legal characterization of the agency, and
2) State law on powers of that type of entity.

The most typical agencies involved in automated mapping systems are state agencies and municipalities. As a general proposition, the state as a sovereign entity has broad powers to further such goals as public health, safety, and welfare. Many states and courts take an expansive view of state powers and would likely uphold the right of an agency to market AMS products.

Municipalities, on the other hand, usually have only those powers specifically granted by state constitution and the legislation creating them. Judicial construction of those powers will, of course, vary from state to state and from category to category of municipal corporations. As a general proposition, however, municipal corporations possess only those powers which are expressly given by constitutions or statute, or are necessarily implied by those powers. Most municipalities have the express power to conduct the function(s) for which the AMS provides support and it may be argued in some jurisdictions that, implied by that authority, is the authority to recoup its investment or collect funds to maintain the system through the sale of AMS products.

Another way of viewing authority is based on the types of authority exercised by municipal corporations. Municipalities are generally regarded as having two types of powers, governmental and proprietary. Governmental functions are those which are exercised by the municipality as an arm of the state for the general public welfare. Proprietary functions are those exercised for the benefit of the citizens of the municipality as a corporate entity in its private capacity. Sales of products and services from the AMS appear to be a proprietary function.

There is a broad range of case law nationally on what a municipal corporation may do within its proprietary powers. Although there is not, generally, authority for municipalities to engage in a business which is ordinarily carried on by private enterprises, recent law in many areas has broadened the scope of what municipalities may do under their proprietary powers, even to the extent of competing with private business.

There is also a split of opinion among the states on the construction of proprietary powers once allowed. Several states have, for example, dealt with the question of whether a municipally owned electric utility may also sell electric appliances. Some courts state that once a power is determined to be within the municipality’s powers, the municipality may exercise all powers that a private owner might exercise to economically and efficiently furnish the product or service. However, most courts follow the view that all powers of municipal corporations be given the rule of necessary implication, that is, that municipalities may only exercise those powers explicitly granted by constitution, law, and ordinance, and those additional powers implied as necessary to carry out those explicit powers. Thus, while it may be necessary for the general health and welfare to provide electricity, it may not be necessary for the general health and welfare to sell refrigerators.

In one state struggling with the issue, it seems likely that the courts will take an expansive view of municipal proprietary powers. The state constitution favors a liberal construction to the powers of local government and provides that a home rule city may exercise all legislative powers except those prohibited by law or their charter. State law echoes the constitution and allows municipalities to exercise all powers and functions necessarily or fairly implied in or incident to the purpose of all powers and functions conferred by law, including providing a public service. At most, all that would be required would be for the local legislature to make a finding that sale of AMS data serves a public purpose. An ordinance resolves the authority question.

In a second state, however, courts have taken a restrictive view of municipal powers.
and "if there is any reasonable and substantial doubt as to the existence of a particular power, such power will be deemed not to exist" (1). In such a jurisdiction, arguments in favor of marketing AMS products would be based on one or more theories. One is that strict construction of municipal powers should not be used to hamper a reasonable exercise of explicit powers. Use of an AMS is a reasonable means of implementing the municipality’s explicit powers. In order to finance and maintain the system, it is necessary to sell products and services. Denial of this authority would deny the complete exercise of its powers to the municipality.

Another argument would be based on the theory that municipal corporations have powers implied by and incident to their express powers. This theory would support an argument similar to that above. Another argument could be modeled on cases which allow a municipality to sell excess utility capacity as incidental to its main function.

A final theory to be explored is based on the distinction between governmental and proprietary powers. Courts allow municipal corporations much greater latitude concerning proprietary powers than governmental powers. Use of the AMS could be viewed as a proprietary power, which could be construed to encompass the sale of products and services from the AMS.

Open Records

What constraints are imposed on the sale of information under state and local open records laws? In many states there are strong public policies supporting full public disclosure of agency information at nominal cost. These laws pose a substantial potential roadblock to the sale of products and services at prices above those set by law, often the cost of copying, sometimes with a labor retrieval component. In addition, agencies have a substantial investment in their automated mapping systems and datafiles, which are interested in guarding against wholesale copying by private interests and other public agencies that did not share in system development costs. Thus, there are good public policy reasons for charging fees, which may be above nominal costs for at least some of the products and services that may be available from the AMS and options allowed by law should be explored to determine whether greater cost recovery may be available.

Most state and municipal laws and regulations on open records define the term "open record" to include records stored in computer-compatible formats. Thus, tapes and disks come within the definition and could be requested. In jurisdictions which have not explicitly included computer media, it is likely that courts would interpret the law broadly to include tangible media used in the AMS. Thus, reliance on the definition of a "record" is unlikely to resolve this issue.

All open records laws contain certain exclusions. An exhaustive review of all state exclusions and how they have been treated by the courts has not been undertaken. However, among the typical exclusions are some which could support the removal of AMS datafiles from the coverage of open records laws.

Chief among these is the usual exclusion for proprietary information. The language will vary, but this exclusion will generally cover trade secrets and other information of commercial value. Of course, the exclusion is intended to guard private business interests, but an argument can be made that, acting in its proprietary capacity, a public agency is equivalent to a private business and should be able to avail itself of the same protections for its valuable, commercial property.

Other exclusions that may be relevant include ones for preliminary or draft records. An argument can be made that datafiles are always preliminary in the sense that the data are subject to constant updating. While this is far-fetched, this exclusion should at least be applicable during the period of system development and implementation, which may buy time until a more permanent solution is reached.

Finally, if the system contains data, the disclosure of which would constitute an inva-
sion of privacy (billing, adoption, criminal records, as examples), this information is generally not subject to disclosure. Although this could form a basis for exempting the datafiles from open records, more often, in reviewing this situation a court would order that the private data be excluded and the rest of the data be made available.

Although not an exclusion, some statutes and regulations provide that documents need not be reproduced in the exact form or medium in which they are stored. This may serve to lessen outside interest if, for example, the agency can respond to open records requests by giving a paper copy reproduction instead of a tape or a mylar map.

Similar to this, some statutory schemes allow extra charges for copies of records that are not in a standardized size or format. Some also allow a charge for published records, which may allow greater recovery of costs. Published records would seem to refer to records specifically prepared for distribution by the agency to members of the public. These approaches may allow more of a market-driven cost decision so long as the cost does not exceed preparation costs. If preparation costs could include a prorated share of system acquisition, maintenance, and update costs, this should not be a problem, as those costs are likely to exceed any charge established. In addition, many agencies may charge a fee for search and retrieval of records at a specified rate, which also allows a certain level of cost recovery.

Finally, some statutory schemes allow a fee not to exceed actual cost to the agency. Although this phrase could be interpreted to allow only direct reproduction costs, it might also be interpreted to allow additional factors, including labor, overhead, and perhaps a share of system development and maintenance costs.

The above approaches will vary from state to state. Generically, there are four broad approaches that should be explored in most jurisdictions to resolve the question of open records applicability to AMS data products and services:

- First, the possibility of legislative amendment should always be considered. The approach could be taken as an amendment to the state open records law or as a change in the authorizing legislation of the agency incorporating an exclusion which would then take precedence over the open records law.

- Although most people think such an approach unattainable, it is consistent with the purpose behind the enactment of open records laws nationally. Open records laws were enacted to allow members of the public to have access to the information that government officials used in making public decisions. Although some of the open records laws contain scattered references to computerized information, none of them really seriously dealt with the consequences of their applicability to complex computerized information systems. The standard open records procedures do not work very well in that context.

- Further, there is no compelling public policy reason why open records laws should apply to AMS products and services. The data in these systems are not, by and large, the type used by public officials to make public policy or individual permitting decisions. That is not the type of data that should be exempted from the system. Rather, it is the massive compilations and manipulations of geographic data that would be exempted, data which are not used in policy formulation and which have commercial value. In this sense, what an open records exemption would do, in effect, is impose a user fee to be borne by those who presumably are profiting from use of the data as processed by the system.

- The second and third approaches focus on what is and is not covered by open records laws. To start with the simplest of propositions, information as such does not usually come within the scope of open records laws. In other words, it is not "information" that the public has a right to obtain, but "records." Thus, the agency is generally under no obligation to engage in extensive data processing activities to provide data in a particular format pursuant to a request by private citizens. It is only when the information is reduced to some tangible format that it starts to be drawn within the ambit of open records laws.

Using this approach, the agency is only subject to open records requirements regarding actual records it possesses. This will serve to relieve the agency
from any obligation to provide information it does not maintain in a record format, and may thereby allow it to make reasonable charges above the costs of reproduction to create other records upon request. Thus, many cases allow agencies to provide certain information they are not otherwise required to provide under open records laws. Note, however, that perhaps the most crucial information to this analysis, the basic data files, generally do come within the definition of a "record," and are not aided by this approach.

- What does the agency actually provide when it is requested to produce an information product that is not a record which it maintains? Neither state law nor municipal ordinances typically deal directly with information services provided by the agency that usually has an AMS. A logical analysis of the process of producing customized maps and other products leads to the conclusion that this process is, in fact, a service, which has as its end result an associated product. The agency is being asked to serve, in effect, as an information specialist which not only helps the consumer identify what information is needed, but arranges for access, interpretation, and use of the data. The law does not generally address what fees may be charged for such a service and the agency may have a much broader range to collect appropriate fees. Under this analysis, reinforced by the lack of connection of the end product to use in the public's business, a considerable amount of the potential revenue-producing aspects of the AMS might be outside the scope of the open records law.

- The fourth approach involves use of an outside entity to handle marketing and sales of information services. For this analysis, "outside" means an entity not subject to open records laws.

Two typical models of an outside entity are a public, non-profit corporation and a contractual arrangement with a private corporation.

The public, non-profit corporation could be set up to specifically handle information services both for the public and private sector. Benefit-cost analyses would need to be undertaken to determine how the efficiencies involved would be counterbalanced by the expense of setting up an additional entity. It is certainly possible that such an arrangement would not have an economic advantage if the sole benefit would be to get around open records. On the other hand, that might be sufficient benefit in itself. A careful analysis would need to be undertaken to ensure that such an entity would not be covered by the open records law. If there is any question, a specific exemption should be incorporated into the law setting up the entity.

A contractual arrangement with a private concern would avoid some of those problems. The public agency might establish a process under which private concerns would bid for the privilege of producing maps and other information products and services based on the AMS. Such an arrangement would free the agency from the burden of maintaining staff and reproduction facilities to comply with both its own and outside information requests.

The private entity might be required to provide copies of documents at the same price to both the public agency and members of the public in order to meet the intent of the open records law. However, the arrangement could still be used to recoup costs through a variety of mechanisms, including a royalty payment to the agency, quantity discounts, credit for system development costs, etc. Copies of the master data files might be made available at significant costs for development costs.

This discussion outlined approaches to recovery of costs in excess of open records law requirements which are generally applicable. In any given jurisdiction, case law and specific statutory and regulatory language may allow other solutions. For example, state law may permit the agency to deny open records requests that constitute an unreasonable burden or disruption of services. In any specific jurisdiction, all of the relevant authorities need to be examined to determine what may be allowed.

Equal Treatment

Several questions arise for a public agency that would not apply to a private company concerning the consumers of the database. If the agency makes its mapping system available to external organizations through on-line access, can non-participating organizations argue successfully that they are placed at a competitive disadvantage? Must similar facilities/capabilities be made available to all firms? What policies should the agency consider to assure access to the database and equal treatment of consumers of database products? What are the possible alternative policies for access based on the
purposes for which the product will be used or the nature of the purchaser? What about other government agencies as consumers? Many of these questions boil down to the question of the extent to which a government agency is obligated to treat potential consumers of a product or service equally.

Addressing this issue starts, to some extent, at the earlier analysis of governmental vs. proprietary functions. The law in this area that is most relevant to the AMS access issue is that related to the proprietary function of supplying utility services—although it is admitted that the situation is not strictly analogous because of the differences in the necessity of the service being provided.

As a general proposition, an agency acting in its proprietary capacity is governed largely by the same rules that apply to private corporations. Yet, a city owning a general domestic utility system also generally has an obligation to supply the utility service impartially to all applicants in a substantially similar position. It is in defining what constitutes a substantially similar position that the questions posed above are best answered.

The governing principle is equal protection of the laws. Although the principal may be somewhat less applicable to a strictly proprietary function like AMS services, this is the starting point for the analysis.

**Equal protection of the laws is violated by municipal exercise of power which arbitrarily, unreasonably, or invidiously discriminates.** Stated affirmatively, local governments can classify, categorize and even discriminate so long as the municipal differentiation of treatment is reasonable (2).

What this principle comes down to is that it is proper for municipal government to categorize consumers and to treat the different categories differently—in terms of rates, for instance—so long as the categorization rests on some ground that has a real and substantial relationship to relevant considerations of public policy. Among the factors that have been upheld in utility service classification are the:

- Cost of the service and delivery
- Purpose for which the service/product was received
- Quantity/amount received
- Different character of service furnished
- Time of use

Thus, a public agency has a fair amount of flexibility in categorizing its potential consumers and setting different rates among them, and perhaps not even supplying the service. But once the consumers have been categorized, there must be uniformity of treatment within the category (3).

In answering the questions posed then, first examine whether there are reasonable public policy grounds for discriminating among consumers of the system. If on-line access is granted to a consumer with a compatible system, is there a reasonable ground for denying such access under substantially similar terms and conditions to another consumer with the same system, even if such access would strain the agency's resources? Probably not.

What about a consumer with a different type of system? That may depend on how differently the agency will have to act in providing that access. Will it take different formatting of outputs, increased resources, etc.? If so, there is certainly a basis for charging more for the service. Whether this forms a basis for denying the service, even at a cost which reimburses the agency for the extra effort involved in supplying the service, is problematical. It is often difficult to guess how a court will view a particular situation, particularly in the absence of relevant precedent. Where there is not relevant precedent, the court will be guided by broad principles which are the same as those that govern the utility service area: The municipality must generally be fair, reasonable, just, uniform, and nondiscriminatory.

It may be possible for the agency, based on a reasonable assessment of demand and interest, as well as its costs and capabilities, to determine that it will make its system available through translators in one or more standard formats. Particularly if these formats cover all existing interested consumers, this would appear to be a reasonable approach, which would be upheld by the courts. Those sub-
sequently interested in making use of the system would know in advance what formats are available and could make their plans for access accordingly, without imposing any new burden on the agency to make data available in additional formats.

Beyond the legal analysis of this situation are the practical, political, and public policy considerations. What would be the real reason for denying access to the consumer with a different type of system? Presumably the agency and its system could be overloaded by the level of usage, and supplying this different type of service could be a technologically and financial resource drain. Either one of these theoretically could be ameliorated through fees to the user. Although, if the level of usage is beyond the capability of the system, the solution of enlarging the system is clearly a significantly higher level of expense and time. The point is that these responses are somewhat predictable and can be dealt with in plans for providing the service and in the fee structure. If this is so, what public policy is furthered by not providing the expanded service? What could the agency say in response to an argument that an interested party is discriminated against if it were not allowed to participate and it was willing to pay its fair share of the cost? Nothing, really. If some public policy is furthered by providing access in the first place, it is difficult to see how that same policy would not be further promoted by making it more widely available.

What about non-participating firms? Can they argue that they are placed at a disadvantage if these services are made available for purchase by their competitors? Probably not. Certainly this argument is substantially undercut if a workstation is made available by the agency for use by the general public or if access to the entire system rather than just the data is made available. Even if this route is not taken, however, these firms can always put themselves into the same category as users of the system through purchase of the necessary hardware and software. The agency is under no obligation to put potential consumers in an equal position to make use of its services; nor is it required to make a service available only if all potential consumers can make use of the service.

Generally, information is open to the public or not—the purpose for which the information is sought is not relevant in most jurisdictions. It is in some. For example, some jurisdictions formally recognize, and many others informally recognize, that some information services may be used by non-profit organizations that promote the general public good. It is a proper categorization to recognize those entities and to provide services to them at a reduced rate or even for nothing. The authority to do this should be set out clearly in ordinance and/or regulation.

Finally, other government agencies are not treated substantially differently from other consumers of the system and the considerations involved in providing for this access are more political and policy oriented. Certainly, services may be provided at a reduced rate or for nothing. On the other hand, the services may be provided as to any other consumer. Much of this will rest on reciprocity of services and sharing of data. The agency should generally be free to categorize other agencies on these grounds and charge accordingly for services.

Accordingly, agencies should do a fairly careful analysis of potential demands on their services before offering them. If not done prior to a pilot feasibility study of on-line access, it should be done concurrently. At the time that the agency understands what resources will be necessary to provide access, it must also make a determination of what the demand for access will be, whether it will be able to meet that demand, and under what conditions. The agency should assume that it must be in a position to treat substantially similar consumers of its AMS services in a substantially similar manner. If it cannot, then it may need to reevaluate what services and products are to be provided.

On-Line Access

One public-access option under consideration by some agencies is on-line access. This is a valuable commercial service
that some elements in the private sector could use, and thus constitutes a real public service, as well as a potential revenue producer for the agency. One of the issues which must be addressed in considering on-line access is equal treatment, discussed above. Among the others are system security and protection of private information.

Once a system is opened up to use outside of its primary user, security of the system, and the data in it, becomes an issue requiring resolution. System security is a function of hardware/software, database structure, the communication network, and administrative procedures. Access to the system by consumers, even other agency partners, should be defined by contractual arrangement. System access should be subject to control by password and identification codes assigned to parties and/or projects. These identifiers also can be used for billing procedures. All system users outside of defined agency partners would be restricted to “read only” access to the system. Therefore, they would have no ability to modify or delete data in any manner.

A particular concern is the protection of information that is required by law to keep confidential. State law defines this information, which typically includes proprietary information, criminal investigation records, and information the disclosure of which would constitute an invasion of privacy. Often, no confidential information is contained in, or projected to be contained in, the AMS.

However, system managers should review the contents of the database before access is allowed to ensure that there is no information in the system subject to protection. Any questions should be resolved by management and legal counsel. Whenever additional information is added to the database, and particularly should the system be integrated with that of other agencies at some point in the future, a review should be made to determine whether there are data which must be protected. Any integration of the database with a utility, for example, might require protection of information, such as the location of power boxes or credit and billing records.

Of course, whenever it is determined that there are data requiring protection from outside access, such protection must be built into the system so that the data are not accessible. Should the data be subject to such manipulation, it may be possible for such data to be aggregated in such a manner that the desired information is obtained without disclosing specific information about individuals.

Conclusion

This paper identified some of the major legal issues faced by public agencies seeking to recoup system costs through sale of AMS products and services. The issues are real. However, none of these issues should prove to be insurmountable. It is recommended that these issues be identified and addressed in the planning stages of any AMS through a careful analysis of local authorities and cases. By addressing these issues early, there should be sufficient time to satisfactorily resolve the issues before they arise in the context of a public request and a threatened law suit.

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(1) McQuillan Municipal Corporations, sec. 10.19 (3rd Ed).
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FEATURES

Statement of Editorial Intent

Information, lightly or seriously treated, presented in many styles and formats, responding to your diverse interests—that is our intent.

We provide you an opportunity to enjoy information. And an equal opportunity to share information with others. In this section of the Journal you can communicate ideas, impressions, perspectives to colleagues you know and those whom you have not yet met.

Topics mirroring the diversity of our readership, reflecting your (and their) diversity of needs, activities, places and personages. Blending information with the art and science of communication. These are our goals.

Please contribute.

John C. Antenucci
Gilbert H. Castle, III

Note: Jodi Kilcup, a staff writer at Plan- Graphics, Inc., is a contributing editor to this section.
And Now, the Envelope Please...

Rosemary Horwood

The Horwood Award is presented annually at the national URISA Conference to the author of the most distinguished paper included in the conference proceedings of the previous year. The award was established in 1975 in honor of Dr. Edgar M. Horwood, the first president of URISA and an early innovator in the field of electronic mapping and graphing techniques. On August 10, 1989, Mrs. Edgar Horwood presented the 1989 Horwood Prize to Dr. W. T. Watterson for his paper on urban models. Her remarks clearly carry on the Horwood tongue-in-cheek tradition.

Ms. President, Mr. Past President, Honored Guests, URISA members, and URISA friends:

As I log in and you finish your megabytes, I believe I owe you all a progress report, because for the past three years I've been assuring you that my fondest ambition is to become the ultimate computer nerd. Well, I have a confession: my progress to date is zilch.

After the URISA Conference last year, I tried hard to get started but the first thing that happened was that awful computer virus. Somehow I got it and it laid me low until I was able to get an Antidote and a Magic Bullet. Later, there was the matter of an RM-resident program, but I just couldn't see having a billy goat in my apartment on the eleventh floor. And especially not if it had Productivity software, or was on my laptop, and not if it was a Supersport or Multimate, not to mention having to debug it.

At Christmastime I was hoping for a power surge or some Online Help, because I wanted to get a Professional Gem, like a Diamond Scan or a Token Ring or Gold-Disc Software, but the great Event Manager in the sky would only let me have Relay Silver or a Battery Watch.

After I got over that disappointment, I decided to get a new car at the Trading Post. My First Choice was a Turbo XI or a

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*The 1989 Horwood Paper will be published in the Fall 1990 issue of the URISA Journal.*
Lotus Express, either of which could send me to Paradise with Orchid Technology.

But then, the family seemed to be getting into it, what with a DAD-is, a Motherboard, a Brother Printer, B-Tree Sons, and other Children. Also, I started getting Micro-Illusions about my Raw Copy VI, when what I really needed was New Image Technology. About then, I got into Hypertext and started to write my Data Life Verbatim, but I got stuck in a While Loop and blew a fuse on my Electric Desk, which set me cursoring.

Finally, the laser rays burned me out and I decided to get back to BASIC before you all could boot me up. So that’s my NeWs-Unix.

Seriously, it is an honor to present the 1989 Horwood Prize, and to congratulate the winner on the quality of the paper. Incidentally, now that we finally have a female president, I hope we may soon see a URISA woman as a Horwood Prize winner. Let’s see you women take a RISC (processor) and be Tigers (I mean tigresses), and not Mouse Drivers. And now, the envelope please.

The 1989 Horwood Prize winner is a person who has written on the use of urban activity simulation models for metropolitan planning in the Seattle region. His paper, entitled “Adapting and Applying Existing Urban Models: DRAM and EMPAL in the Seattle Region,” outlines the models and their modifications and enhancements for Seattle, summarizes the calibration of the latest version, and briefly describes some of the forecasting and analysis projects to which the models have been applied.

He is the director of technical services for the Puget Sound Council of Governments, located in Seattle, and his name is Dr. Tim Watterson. Let’s give him a big hand.

Rosemary (Mrs. Edgar) Horwood was a Seattle city planner for 25 years until her retirement five years ago.
Human Potential in the Age of the Smart Machine

An Interview with Shoshana Zuboff

S

hoshana Zuboff is associate professor of organizational behavior and human resource management at the Harvard University Graduate School of Business Administration. She has consulted and written extensively on information technology in the workplace. Her latest book, In the Age of the Smart Machine: The Future of Work and Power, explores ways in which the widespread deployment of computer-based technologies is transforming the nature of work in America.

The book is based on extensive field research and in-depth interviews with workers and managers in eight manufacturing and service organizations. In it, Prof. Zuboff addresses the organizational and human resource strategies and innovations necessary to fully exploit the economic and competitive advantages inherent in information technologies. She sets forth the qualities of knowledge that will determine the competence of the work force of tomorrow. And she clearly identifies emerging patterns of power and influence in the computerized organization.

In the Age of the Smart Machine frames the managerial choices that will determine the future consequences of information technology in the workplace. Managers interested in employing the unique attributes of computer-based technologies to promote organizational learning and innovation will find the book absorbing, provocative and useful.

Prof. Zuboff is a member of the editorial board of the Harvard Business Review. She serves on the Visiting Committee to the College of the University of Chicago, where she earned her baccalaureate degree. She holds a Ph.D. in social psychology from Harvard.

TCF In your book, you describe two basic outcomes of computer technology: the traditional one—automating—and a new phenomenon you call "informating." Will you describe and relate these two approaches?

SZ Historically, technology has been used largely as a substitute for human activity. Technology can out-perform people on certain tasks, offering advantages in speed, reliability and cost. Implicit in this view of automation are two key management assumptions. One is that the more technology you have, the fewer employees you need. The other is that the "smarter" the technology is, the less intelligent the people who run it have to be.

Many executives apply these same assumptions to information technology as well. Typically, information technology is designed, sold, justified and installed according to the classic model: to lower costs, achieve greater reliability and standardization, simplify work in order to control it better, and coordinate it from higher levels in the organization. In short, information technology meets all the goals that have been familiar to industry since Henry Ford created the first mass-production factory.

But unlike other automating technologies, when information technology is used to automate a work process, it simultaneously accomplishes something else altogether. It translates those automated processes into data—information—which is then displayed.

TCF In other words, the process itself generates new information that didn't exist before?

SZ Exactly. Consider the prototypical example of the industrial robot, which is designed not only to mimic the actions of a human being, but often to resemble the human body as well. In automating a particular part of a production process, that robot also codifies and registers new data about the process. It measures many variables in real time that did not exist before except, perhaps, in the mind of the person who previously did that job. Finally, the robot enables the systematic display and storage of

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those data in a control room frequently monitored by the very person who had previously worked on the line.

Consider what has happened here: In addition to automating a process, information technology has made that process transparent in a way that it never was before. This is what I call informing.

This development is not merely evolutionary, however. It represents a radical discontinuity in industrial history. Now, instead of making tasks simpler and more mindless, information technology actually raises the intellectual content of work. This, in turn, creates the opportunity for the job to become a richer and more challenging experience. Still, while we have learned a great deal about how to design and run organizations that do a good job of automating, we know little about how to create and manage organizations to exploit the informing capability.

TCF Why is this important?

SZ More and more, top managers are asking why their companies don't always achieve the expected strategic benefits and competitive advantage promised by huge investments in new information technology. Why? Because they simply haven't been told they must first change the direction and structure—even the outlook—of their new informed organizations.

TCF What does an informed organization look like?

SZ A truly informed organization exhibits several characteristics. First, it is an organization dedicated to linking comprehensive information technologies to its strategic goals. This means that the leadership must achieve some clarity regarding its strategy and mission and the role information technology can play. Where in the business can information make a difference in creating new sources of competitive advantage? What technological infrastructure is necessary to support this?

Typically, this framework will involve some combination of text, graphics and video processing, internal and external databases, and the availability of sophisticated market and competitor information.

In the informed corporation, these elements help move the organization toward the goal of having the right information closest to the people who can use it to make a difference. But that's just the beginning.
As more of the core organizational processes (production, service, etc.) become informed, previously hidden dynamics of the business become visible, knowable, shareable and discussible in ways they never were before. This new transparency becomes the basis for an unprecedented amount of learning and insight into the actual functioning of the business both internally and in its interactions with the marketplace.

Informating generates endless new sources of added value by using information as a basis for improving products and services, innovating, customizing, and being first to respond to changes in the marketplace.

TCF How are employees affected by informing?

SZ Leaders of informed organizations recognize that new forms of skill and knowledge are needed to fully exploit the potential of an intelligent information technology. In general, this means a much broader distribution of analytical, conceptual and interpretive skills, as understanding information becomes the key task in a wide variety of jobs.

This development engenders a new approach to organizational behavior, one in which relationships are more intricate, collaborative and bound by the mutual responsibilities of colleagues. It contrasts markedly with the traditional relationships of command and obedience characteristic of hierarchical organizations.

As the new technology integrates information across time and space, managers and workers each overcome their narrow functional perspectives and create new roles that are better suited to enhancing value-adding activities in a data-rich environment. The milieu of this new informing technology becomes a resource for innovative methods of information sharing and social change. These methods in turn produce a deepened sense of collective responsibility and joint ownership, as access to ever-broader domains of information lend new objectivity to data and pre-empt the dictates of hierarchical authority.

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**Information makes previously hidden dynamics of the business visible, knowable, shareable and discussible in ways they never were before.**

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Finally, informing technology lays bare every aspect of every process and action throughout the company—in excruciating, moment-by-moment detail. If it is used to enable everyone to learn from mistakes rather than to fix blame when something goes wrong, then information technology creates opportunities to instruct the people involved, upgrading their skills and their understanding. Thus technology gives employees ever more freedom to act intelligently, responsibly and innovatively in the organization.

In this scenario, managers, too, use the computerized infrastructure to free themselves from their routine work, concentrating instead on managing people and developing the intellectual skills of those engaged in using information to create added value.

TCF Informing, then, depends more on people than it does on smart machines?

SZ Definitely! The real benefits of information technology won’t emerge just because you plug a piece of technology into the wall. The technology can only provide information. So the question is: Are your people able to convert information into value? Furthermore, have you created an organization in which knowledge can be not only developed, but also expressed?

TCF In other words, do your people have permission to use the new information in value-adding ways?

SZ That’s right. And in that little word “permission” resides a world of new roles and relationships, new approaches to organization, and new patterns of authority and knowledge. But more than simply making new relationships possible, information technology encourages workers to do things they couldn’t accomplish before.

Still, it requires boldness of spirit on the part of executives to recognize that if they want these strategic benefits, they’ll have to experiment. They will want to learn what it means to organize activities and people in ways that will exploit the revolutionary potential of new information technologies.

There is always a lag, however, between the potential
of new technologies and our ability to create the institutional forms that best take advantage of the possibilities. Fortunately, because managers are pragmatic, I believe they will eventually learn how to organize around the informing process.

TCF And this process is much more than just another technological development?

SZ It certainly is! I believe we are facing a decades-long period of discontinuity, requiring organizational pioneering, discipline and adaptation. A new vision of the technological infrastructure has emerged. We are pulling more and more information out of people's heads, off paper and electronic documents, off pieces of equipment—all codified and rationalized in information systems. More and more our information systems are coming to reflect the organization in all its complex, living dynamics. We haven't reached this vision completely yet, but computer communications and networking are pointing us toward it.

The closer we come to fulfilling that vision, the more acute our organizational and human resource challenges become. The center of gravity of our economy is moving toward organizations that achieve this new infrastructure. Eventually the phenomenon of informing will become just as second nature to us as automating is today.

TCF Specifically what kinds of things can an informed company achieve that a merely automated organization cannot?

SZ There seems to be wide-spread confusion about where the true benefits lie. Senior managers need to understand that competitive advantage does not emerge from simply offering a new product or service, or from getting it to market first. Sustainable advantage is achieved when the organization embraces the skills and operating style that enable it to continuously exploit new information. Then the organization can create new products and services and consistently get them to the marketplace ahead of anyone else.

New forms of skill and knowledge are needed to fully exploit the potential of intelligent information technology.

TCF So you believe that managers must give workers the information they need and then create the psychological environment in which they can use it.

SZ Yes, I do. In my book I describe a fairly elaborate set of ideas which the informed organization needs to address in terms of skills, roles and relationships.

Essentially, we need to change the way we think about organizations. What does it mean today, for example, to be centralized or decentralized? These terms no longer have anything to do with physical place. Technology now makes it possible for all information to be at the center and at the periphery simultaneously. In an informed organization, division of labor has less to do with who's at the top, middle or bottom. It is more closely aligned with who gets access to what information in what time frame, and who has the skills to deal effectively with that information.

Or consider span of control. Once upon a time, it was determined that one manager could competently manage seven people. But this was based on the need to be in face-to-face communication with those who had the relevant information in their heads. Today we think of communication in terms of networks, electronic conferencing and messaging, and other techniques. Collectively, these systems take advantage of the fact that information is housed and used throughout the enterprise, not just in people's heads.

TCF Isn't it simply good management to make sure employees have the information they need to make optimal decisions?

SZ Of course it is. But now we're talking about a process that is driven by technology itself, rather than by some concept of effective management practice. Information is being created before any plans for its management are in place. Consequently, we often tend to think we're being presented too much information. We don't think we know how to deal with all of it. But if we were organizing ourselves around this new information potential, we'd see new sources of competitive advantage, instead of just information overload.
Hence we have an opportunity to exploit information by helping people develop their intellectual skills for resourcing, interpreting, problem-solving, recognizing trends, procedural reasoning, and innovative thinking. In short, we need to focus on the organizational structures, management practices, and skills development that will turn data into useful information with specific value for reaching the organization's goals.

TCF How will the role of management, particularly middle management, change in order to better realize the potential of the informing process?

SZ Historically, the middle manager's role has been to receive and then preside over the organization's explicit knowledge base. But now information technology is changing that role, and some people think we no longer need middle management. But if we stop and reflect for a moment, we recognize this phenomenon as simply another version of the labor substitution logic of automation we talked about earlier, but at a higher level in the organization.

In information-rich learning environments, it falls upon middle managers to create the conditions that nurture employees' intellectual skills. Managers become facilitators of data integration, identifying new interdependencies and linkages, developing new ways for the various parts of the organization to generate new synergies. This is very different from the traditional role of middle management.

TCF Middle management's role, then, must be redefined if the informed organization is to flourish?

SZ Yes, but there's not a prayer of that happening unless CEOs begin to understand what's implied by the shift from an automating to an informing paradigm. The promise from technology which they so fervently desire can't be realized unless they change the web of reward systems, policies and practices in which middle managers are caught. The CEOs who do this will be leaders, visionaries, pioneers.

TCF Are managers and employees intimidated by all this new information and education?

SZ Some are. But I've noticed that many more are excited about making this transition, and they're much more capable of it—both intellectually and motivationally—than we frequently assume. Empowerment inspires people. Anyone who conducts research or consults in an organization and penetrates below the layers of top management knows that most people in the so-called "lower echelons" have far more to offer than what is asked of them.

Too often, the work force is stymied, frustrated and unfulfilled because its members can't develop their skills, and because they have difficulty being heard.

The CEOs I know who are best at recognizing the potential of this new informing model are people who truly believe in human potential. Typically, their management style demands that they wander around, ask questions, rub shoulders with the work force. They see informing technologies as one more force to enable organizational innovation and change.

TCF And learning is the key?

SZ Absolutely! Learning is neither an activity separate from productivity, nor one preserved for management alone. Behaviors that define learning are the same as behaviors that define productivity. Learning is not something that requires time out from being engaged in productive activity. Rather, learning is the heart of productive activity. In organizations that are truly geared for both automating and informing, learning is the new form of labor.
The Wisconsin Land Information Association: A Professional Organization for State-Wide GIS Coordination

Allen H. Miller

Computer-based geographic information systems are valuable tools for storing, accessing and processing information related to our land resource. Applications ranging from the routing of emergency vehicles to planning and zoning offer users rapid access to information not previously available through paper records. Technology has provided exciting new tools to increase our capability to use the information and communicate with decision-makers. What technology cannot solve is the rudimentary problem of information-sharing.

As efficiency and effectiveness in land-related data processing are sought by government and private companies, each organization addresses its own well-defined, specific needs. For example, a state agency may collect and computer-store topographic data at a resolution suitable for its own specific purposes. Because budget constraints generally prevent managers from obtaining data that are more accurate than necessary for the agency, other users—local governments for example—then re-acquire the data at the scale they need. The end result is that the public often pays for the same data two, three, or four times, whether through taxes, utility bills, or costs of services. This is an all-too-common scenario. It doesn’t mean that people are unwilling to coordinate, but with limited budgets, government agencies and private companies each tend to meet their own specific needs in a scale, format, and accuracy suited only to their purposes. Without coordination, GISs will proliferate with little capacity for data-sharing and unnecessary data collection and handling.

The Wisconsin Land Information Association (WLIA) offers one approach to addressing this issue. The association’s 300 members are professionals from various disciplines in the public and private sectors, each with a common interest in the modernization of Wisconsin’s land records. Membership represents the diverse disciplines needed to develop multipurpose GISs: registers of deeds, resource managers, surveyors, title insurers, cartographers, transportation engineers, tax listers, attorneys, university researchers, planners, property listers, assessors, and others working in land-related fields.

The idea of a professional land information organization follows concepts in other professions that are well recognized for self-direction. The American Association of State Highway Transportation Officials (AASHTO), known for its highway design standards, is the professional association of highway engineers. The American Medical Association and the American Bar Association are other examples. People working in a given field generally are the most knowledgeable on the subject and, through collective efforts, are best able to advise public officials, develop technical standards, and educate the public on the need for changes in that field. In Wisconsin, the absence of any state-level coordinating body on GIS ripened the idea for a professional organization.
The Seeds of Change

Wisconsin is a state with two million land parcels, governed by 2,592 local and special-purpose units of government and a multitude of state agencies, and appraised by 1,334 property tax assessors. These governments, together with the state’s utilities, spend more than $135 million a year (1987 dollars) to maintain land information. The big spenders are local governments, whose budgets account for 53 percent of the total. Efforts to develop more efficient and effective computerized, geographically based information systems are found within the private sector and at all levels of government, especially at the local level.

Wisconsin’s involvement with geographically based systems, dating from the late 1960s, provides a unique research, educational, and application history. The state government’s interest has been sporadic over the years, ranging from attempts to coordinate the development of a statewide information system in 1972, to a detailed analysis of the costs of land information in 1978. The 1978 report documented land information costs and the need for state level coordination of land information. It took another seven years to convince state leaders to look at the issue in a comprehensive manner. In 1985, then Governor Anthony Earl appointed the Wisconsin Land Records Committee (WLRC) to examine the immediate needs of state and local agencies, and to recommend how Wisconsin should approach the long-term issue of land records modernization.

The 32-member Land Records Committee eventually grew to about 100 people involved in 12 subcommittees addressing various aspects of land records modernization. The WLRC recommended future state policy and provided excellent technical reports on benefits and costs, geographic reference standards, and institutional arrangements to mention but a few. Equally important, it brought together people from many disciplines throughout the state and germinated the desire to improve the state’s land records.

What technology cannot solve is the rudimentary problem of information-sharing.

When the seed for a professional association was planted during the course of the WLRC inquiry, many participants were anxious to begin. They recognized the need to coordinate GIS efforts, they were frustrated by the vacillating interest of state government, and they were motivated by the excellent collective efforts accomplished under the WLRC.

An Association is Born

The initial step was to create a state chapter of URISA, whose broad mission encompasses all aspects of automated information, geographic or tabular, that is oriented to urban and other land information issues. A handful of practitioners and university faculty saw the opportunity to build on URISA’s long-established organization and professional reputation. The breadth of the URISA charter provided an open door to a large number of practicing professionals. Within months, the new chapter leadership put out a general call for other professionals interested in establishing a state organization to address land information issues in both urban and rural environments. In less than a year, by-laws were drafted and adopted, and the new Wisconsin Land Information Association was formally established with more than 100 enthusiastic members. It was quite clear that the professional community was ready and willing to take the leadership and move the state forward.

The WLIA is designed to encourage membership of both individuals and interested groups. Four categories of membership—institutions, corporations, associations and individuals—are provided, with an additional category for nonvoting student membership at reduced rates. The majority of members are registered as individuals, with good representation in the three group categories as well. Forty-seven percent of the WLIA members are employed by county governments.

The overall goal of the WLIA is to modernize the state's
land records by fostering the development of a statewide land information systems network—not a single system, but a series of compatible, interactive, multipurpose systems. WLIA governance is provided by a president, president-elect, past-president, and a 12-member board of directors. The board is structured to provide seats for three members from each of the four membership categories. The treasurer and secretary are appointed by the president.

Committees, each chaired by a board member, carry out the activities of the organization as defined under four broad objectives. The by-laws identify these major objectives as:

1) Policy development/political action: to actively promote land information systems development;

2) Networking: to facilitate interaction among local governments, state agencies, utilities and the private sector, and foster a climate of information sharing;

3) Technical evolution: to recommend GIS standards and provide a forum for examining new ideas; and

4) Education: to promote public understanding of land information systems and of the WLIA, its members, and activities. In addition, a committee plans and conducts an annual conference in concert with other professional associations, institutions and corporations.

Does It Work?

Time will tell whether the WLIA model is successful. In two years, however, the membership has jumped to more than 300 professionals. Two annual conferences have been conducted before standing-room-only crowds, and state GIS legislation has been drafted, introduced, and passed. The fact that the WLIA has addressed relevant issues, been active in the legislative effort, and conducted an excellent conference has spurred broader involvement by its members.

The overall goal of the WLIA is to modernize the state’s land records by fostering the development of a statewide land information systems network—not a single system, but a series of compatible, interactive, multipurpose systems.

As the ink was drying on the by-laws, the WLIA undertook the task of drafting legislation that would stimulate GIS development within the state. Building on the work of the Wisconsin Land Records Committee, and rather than wait for someone in the state administration or Legislature to take the initiative, WLIA went ahead and drafted a bill. The draft bill became a target for discussions within the organization and a means to interest legislators and administrators in the issue.

Introduced early in the 1989 session, the bill gained legislative support as it progressed through the system. There is no doubt that the support came because the bill represented a consensus of the professional community. WLIA efforts to move the legislation were well organized. Letters to the governor and legislators, coupled with the appearance at the bill’s hearing of 35 members—all with bright green name tags—notified legislative committee members that WLIA was serious. The presentations at the hearing by an array of professionals from various levels of government and private industry demonstrated the breadth of support.

WLIA members already are realizing the advantages of being part of a professional GIS organization:

- As professionals working in land information systems and related fields, they are able to interact without agency or company bias. The WLIA is supported by its membership and is open to everyone. Individual members represent only themselves. A common turf is established around the shared goal of modernizing the state’s land records. Such neutrality allows participants to address common concerns, such as GIS standards, and to prepare bipartisan legislation.

- They are experiencing the breadth of professional viewpoints associated with multipurpose GIS development. Each member brings a wealth of working knowledge to the table, and interactions often provide WLIA members with a view of GIS not seen before. Discussions between state and local officials, public and private managers, and surveyors and registers of deeds, have been extremely productive.
• Unconstrained by company or agency budgets and pragmatic goals, members can look at the entire system of land information and evaluate the mesh between organizations and government agencies. The freedom to step back and look at the efficiency and effectiveness of the whole system is a luxury generally not available to operating agencies or private businesses. Long-term questions, like the major restructuring of the land records systems, are all too often low-priority issues that give way to more pragmatic concerns, such as the next budget cycle.

• Free of bureaucratic constraints, the association can move quickly. State land records legislation has been discussed for years, but none was introduced. The WLIA drafted legislation, helped identify legislative sponsors, made other legislators aware of the issue, wrote letters and generally shepherded the bill until it became a law—all within nine months. Within six months of its creation, WLIA organized and conducted the first state conference on land information system implementation. Held in the spring of 1988, the conference drew 263 people, nearly double the number expected.

• Because members comprise a diverse professional group, they have the power to influence decision-makers in the private and public sectors. The WLIA has been effective because it speaks with a unified voice. The consensus among the practicing professionals convinced the committee hearing the proposed legislation of the need for land records modernization. Similarly, it was the professional community that was seeking to develop land records standards from the bottom up, making the standards workable and palatable—as opposed to a top-down mandate from state government.

Professional organizations also have some disadvantages. Perhaps the biggest disadvantage is that, because participation is voluntary, only a part of the GIS community takes part. Those who are interested and willing to share knowledge and information join the WLIA and become strong, active members. But some organizations or individuals that should be part of the discussions are not. The absence of members from upper management of government or industry, or the lack of formal links between organizations, may make implementation of recommendations more difficult. As WLIA becomes increasingly involved in state-level GIS activities, those who hesitated to join the organization will eventually become members—or will be left behind.

While time will provide the final test, we anticipate that the professional community in Wisconsin, through the Wisconsin Land Information Association, will continue to provide leadership in GIS coordination and development, and can serve as a model for professionals in other states who recognize that the time has come to speak with a unified voice.

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IN A DISPLAY OF PERVERSE BRILLIANCE, CARL THE REPAIRMAN MISTAKES A ROOM HUMIDIFIER FOR A MID-RANGE COMPUTER BUT MANAGES TO TIE IT INTO THE NETWORK ANYWAY.
Integrating Photolog Data into a Geographic Information System

David Fletcher

Since early 1987, the Wisconsin Department of Transportation (WisDOT) has investigated exciting new concepts in integrating state trunk highway systems (STHS) data with other non-traditional electronic information. Combining elements of 35 mm photolog photography, optical laser disc storage, automated geometric data collection and processing, digital mapping and geographic information system (GIS) concepts, has resulted in a prototype environment with far-reaching implications for the future. Planners and engineers at WisDOT soon will have rapid, simultaneous access to STHS inventory and operational databases displayed thematically with image support. This powerful tool will greatly assist in the difficult tasks of data interpretation and analysis.

Photologging in Wisconsin

WisDOT’s eight transportation districts and the central office have used photolog data to assist in the planning, design and operation of the STHS since 1975. Photolog data are used for several purposes by WisDOT, particularly for such traffic engineering applications as signing and pavement marking reviews, and site-specific analysis of high-incident accident locations, congested intersections, and other problem areas on the STHS. The data also help identify right-of-way considerations related to access, visibility, and development.

The original photologger was a vehicle-mounted 35 mm camera. Driver’s-eye-view photographs were taken every 0.01 mile (52.8 feet), in both directions, along Wisconsin’s 12,000-mile state trunk highway system. The positive prints were edited and spliced onto reels containing approximately 16 miles of highway coverage. These reels were then viewed on 35 mm motion-analyzers.

WisDOT acquired a new generation of photolog devices in 1984. In addition to the 35 mm images, the new system included an instrumentation package that simultaneously collected geometric displacement and other measurements. These included vector displacements of the vehicle’s bearing and slope, which were measured by on-board horizontal and vertical gyroscopes and calibrated to the photographs.

A research project was initiated that same year with the University of Wisconsin’s Department of Civil and Environmental Engineering (CEE) to develop software that could produce meaningful geometries from the displacement measurements. The software produces summary horizontal and vertical curve information. These statistics identify the location, curve radius, and estimated design speed of horizontal curves and vertical deficiencies, such as passing and stopping sight restrictions.

In 1986, the department studied the feasibility of transferring the photographs to video discs, due to the limitations of then-current motion analyzers. The devices were expensive to maintain and replace, and were noisy and difficult to operate.

The study recommended functional specifications and a contract was awarded to develop the prototype hardware and software. The objective of the new system was to retain the advantages of high-quality 35 mm photography in a more convenient environment. The Roadview II™ system was delivered in late 1986 and quickly demon-
FIGURE 1.
Each video disc can hold up to 24,000 photo images, or 240 miles of highway.

RS232 serial communications port and a 19-inch, high-resolution video monitor. The controller allows interactive, random access by either frame number or highway and log-mile. Search and scan capabilities are available, including the ability to advance the frames at simulated driving speeds. Any frame on the disc can be randomly accessed in less than one second. Image quality is only slightly less than on the original 35 mm system. Photolog data are distributed to the public by making a videotape copy of one or more frames. This is faster and less expensive than reproducing film.

The Photolog/GIS Connection

The integration of video disc photolog images and data with a GIS was demonstrated in WisDOT's GIS feasibility study in 1987, and encompassed hardware connections, software enhancements to both systems, and data calibration and registration. The process originates in the GIS, when the operator selects a location on the GIS map display. A GIS command developed by WisDOT, called "WHEREIS," calculates the accumulated distance along a prespecified highway to that point, forms a log-mile keystring, and sends it to the photolog device via the RS232 port. The photolog controller transforms the key into a frame number and activates the video player, which displays the appropriate image on the video monitor. Result codes are returned to the GIS software for error handling. At this writing we are not able to initiate a GIS event from the photolog (call up a location map from the photolog image), although it would be technically feasible to do so.

The entire STHS in both directions can be stored on approximately 120 discs.

Once the photolog images are registered and calibrated with the GIS map, pointing accuracy is consistently within ± 3 frames (160 feet). This is acceptable to the application's sponsor. The 1987 demonstration underscored the feasibility of three departmental goals for the GIS.

First, the GIS must interface with the department's existing spatial data resources. This example shows how three types of spatial data (vector, image and attribute) on two different storage media (magnetic and optical disc) in two spatial reference systems (logmiles and state plane coordinates) can be combined seamlessly and made available to the systems operator.

Second, the GIS should provide a consistent, intuitive method of accessing and presenting spatial data. Using the new integrated system, an operator need only point to a map location and the system retrieves the
The display unit allows the user to search, scan, and randomly access any photo image in less than one second.

Prospects and Potential

The addition of both photolog images and derived geometry to the GIS database presents promising implications for a number of programs at WisDOT. The photolog is now easier to use for its traditional applications. In addition, the integration of accident and traffic data will assist in the areas of preliminary design and program planning. The highway designer will be able to easily identify problems in highway sections based on a number of deficiency models (congestion, accident rate, geometric deficiency, etc.), review the features and operating characteristics of those sections and, at the same time, review the photos.

The system can be used to verify and audit data in a number of inventory databases. This validation now can be performed in the office instead of the field, saving both time and money. New inventory databases also can be derived from the information implicitly stored in the photos.

The current instrumentation platform can be expanded to include measuring devices for pavement condition and serviceability. The combination of this electronically collected, integrated data will allow a more systematic approach to pavement management and other programs.

The 19-inch, high-resolution monitor can show a series of frames at simulated driving speeds.
One significant result of this effort was the realization that video disc technology is not limited to the storage of photolog images. Potential data items that could be stored on this new medium include aerial photography, "as-built" construction drawings, documents such as accident forms (including large-scale location sketches), accident scene photography, bridge inspection photographs, and other items that are traditionally difficult to digitize. WisDOT currently is working with the Federal Highway Administration (FHWA) on a demonstration project designed to show the feasibility of transferring one or more of these items onto the new storage medium. Other potential applications under investigation include real estate snapshots, utility inventories, underwater photography, and fire zone scenes.

New Directions

Both the photolog and the GIS projects have opened several new doors. A new generation of photolog display has been released by the vendor - Roadview III™. This system provides a map interface as a built-in capability and also includes limited GIS spreadsheet functions.

With recent advances in digital photography, images can be transferred directly onto the laser discs in the van, eliminating the film-to-disc transfer step. This process has been successfully demonstrated by the Iowa DOT as part of an FHWA demonstration project.

Much work is required to transfer this new technology to the engineers and planners whom it will most benefit. The integration of photolog with GIS (more importantly, the integration of image, graphics, and attribute data in a common environment) represents a major milestone in WisDOT's continuing commitment to use better tools to manage the transportation network.

Acknowledgements

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Note

WisDOT developed this application using ARC/INFO Ver.3.2 operating on a VAX 8650 cluster running VMS 4.2. All programming modifications were coded in FORTRAN 77. This application has since been ported to ARC/INFO 4.0.2 on the Apollo 3500 running SR9.7.

David Fletcher is the GIS project leader for the Wisconsin Department of Transportation. He is responsible for implementing and coordinating all GIS-related activities at WisDOT.
Lane County, Oregon, located in the beautiful, forested northwest corner of the country, has been at the forefront of geographic information systems (GIS) development for the last 20 years. The county's local government agencies have relied heavily, and successfully, on the regional GIS to help perform their daily tasks. Policy makers are quick to point out that the true benefits of GIS lie within the regional database. To protect their long-term investment in an integrated data system, decision-makers have embraced the latest technological tools. Within Lane County, this commitment has resulted in multi-agency approaches to project funding, data development, and information sharing.

The history of the Lane County GIS nearly parallels the development of the GIS industry. Many current trends are reflected there as well, including multi-participant projects, multi-vendor hardware and software environments, the value of the database as a corporate resource, use of site addresses as a key to the data, and the merger of automated mapping and GIS functionality.

Lane County is a large, diverse area encompassing 4,600 square miles at the southern end of Oregon's Willamette River Valley. From the Cascade mountains in the east to the Pacific Ocean in the west, the county extends 120 miles. The Eugene-Springfield urban area includes only two percent of the land area and has a population of approximately 190,000. The total county population is 275,000, with the non-urban remainder in small cities and rural areas. Lumber and wood products manufacturing is a prime industry since much of the county overlaps the Willamette and Siuslaw National Forests. The University of Oregon is located in Eugene.

Geographic data processing has been used in the region since 1968; a parcel level mapping and information system has operated since 1974. The existing system was developed by the Regional Information System (RIS), a data processing consortium of government agencies in the southern Willamette Valley. In operation since 1965, the consortium has used ever-larger IBM mainframe systems. RIS currently includes five partner agencies: the cities of Eugene and Springfield, Lane County, the Eugene Water and Electric Board (EWEB), and Lane Council of Governments (L-COG).

Some Prehistory

The Lane GIS's roots can be traced to a 1968 study conducted by the Bureau of Governmental Research and Service at the University of Oregon. The study was a comparative evaluation of Map Model (computer mapping) and parcel file (point data only) geographic information systems. The final recommendation was to develop a basic system for the storage and retrieval of geographically related data, using Map Model.

Map Model was developed in the mid-1960s by Bob Keith at the University of Oregon and Sam Arms at the Metropolitan Planning Comission of Portland. The system was a set of procedures and computer programs for the storage, manipulation, and retrieval of mapped data. While the system could handle point and line data, it
was primarily designed as a planning and analysis tool to handle polygon data. As such, it was one of the first systems to employ geoprocessing techniques that are now standard, such as point-in-polygon and polygon overlay. Map Model was recognized as one of the earliest polygon analysis systems, in a paper presented by Jack Dangermond at the 1972 URISA Conference.

The next step was to develop a polygon-based system using existing assessment and taxation maps as the base. Land use and address information were field inventoried and coded to sub-tax lot levels. This parcel-level data provided maximum flexibility and best served all potential users. The Oregon State Plane Coordinate System was used to provide a one-foot grid.

As with all successful GIS projects, several early project champions got the ball rolling. One of them was John Porter, former Eugene planning director, who recalls the massive effort undertaken twice in the 1960s to obtain land-use data for major long-range plans, first for the transportation plan and again a few years later for the area’s comprehensive land-use plan. The effort required up to one-quarter of the planning budget and, because a variety of survey crews was involved, the collected data lacked consistency and was out of date by the time it could be tabulated. There had to be a better way.
Blind Leading the Blind

The people who developed the initial parcel map for the Eugene-Springfield area proceeded much the same way one would begin to assemble a child's bicycle. If the instructions are correct, if all the pieces are there, and if the pieces fit together, then everything should work out. The difficulty was that no one in Lane County had built such a bicycle, and few people in the nation had completed one. From 1968 to 1970, several pilot projects were completed to test the feasibility of creating a GIS. In 1970, a crew of four people began collecting data for a computerized geographic information system.

The initial work involved gathering a set of 750 assessment and taxation maps to use as source material for collecting land use and address information from the field. The task was to drive to a preassigned part of town, travel up and down each city street and back alley, while writing down the land use and address, avoiding traffic, and hoping the car did not overheat.

Once the maps were brought back from the field, care was taken to eliminate any gaps or overlaps between adjoining maps. In 1968, a set of 1" = 1000' planimetric maps had been digitized to obtain state plane coordinate values for each section corner. Four state plane coordinates were placed at the corners of each map to be digitized.

The Eugene-Springfield area was digitized over a four-year period, from 1970 to 1974. About 120,000 parcels were digitized with equipment, which by today's standards was rather crude. The CALMA digitizer was an upright device containing a large tablet connected to a magnetic tape drive. A series of gears and pulleys held the tracking device, which the operator directed across the surface of the tablet with one hand. With the other hand the operator worked a keypad to initialize points. The operator's right foot depressed a "clutch" pedal to unlock the tracking device so it could move across the tablet. If the operator forgot to take his foot off the clutch before releasing the tracking device, the device fell quickly to the bottom of the tablet, an alarm sounded, and the digitizer locked up. Pavlov would have been proud of this system. For alpha-numeric entry, an electric typewriter was connected to the same magnetic tape drive. Of course, the operator could not see the results of his work during the digitizing session, so the process was called "blind digitizing."

A typical assessor's map took about two hours to digitize. The CALMA digitizer's accuracy was one hundred tablet units or "counts" for every inch. For a 1" = 100' assessor map, each count represented one foot. The digitizing software contained no point-matching features or curve line entry. Operators typically would be off two counts when trying to hit a previously defined point.

On a 1" = 400' scale map, this would result in an eight-foot gap or overlap.

Card Party

The magnetic tape was processed to produce a set of punch cards. When the initial digitizing project was complete, over 500 boxes of cards had been produced, with each box containing 2,000 cards. Because the cards were made from high-grade paper, recycling companies were willing to pay extra for them. By selling the cards, L-COG financed a low-budget celebration to commemorate completion of the digitizing.

ADLIB—The Site Address Library

One of the most important products of the geographic system was the countywide site address library, ADLIB. RIS agency staff came up with the brilliant idea for this on-line index, which was developed by city of Eugene programmers and Paul White of the Lane County Elections Department. White, now technical support manager for RIS, recalls that the idea of a separate file containing site address, tax lot number, and a state plane coordinate seemed like a natural progression of the GIS. In 1974, address data were already available for the Eugene-Springfield area from the initial database capture. On-line programming was increasingly available on the IBM mainframe, and there was growing need for a
standard set of addresses and the geocoding capabilities offered by the GIS.

A rural readdressing program initiated in 1975 also helped the project by transforming a route- and box-numbering scheme to a standard street number based on the state plane coordinate of the driveway location. By 1976, the address file was complete countywide; access was provided by a specially written on-line program. The ADLIB system was highlighted in a series of papers at the 1982 URISA Conference in Minneapolis. The system is the key that unlocks access to all of the other land records systems on the IBM system (Figure 1).

The Dawn of Interactive Graphics

In 1975, a year after the initial parcel file digitizing, the first of many annual updates to the parcel base was completed. Subdivision and minor lot changes were still digitized on the CALMA. However, in early 1976, procedures were devised to update a tape file containing the parcel data. By 1977, the parcel data coordinates and alpha data could be displayed on IBM 3200-series alpha-numeric terminals. This allowed some automatic update of certain fields, such as number of units, land use, or tax lot number. Simple-to-moderately complex tax-lot boundary changes were made by manually calculating or "building" the new state plane coordinates and typing in the new points. Typos were still a problem, with points sometimes appearing in such far-away places as Idaho or Hawaii.

In 1976, the CALMA digitizer finally gave up the ghost. Fortunately for the region, in 1975, RIS and city of Eugene programmers had already started work on interactive graphic capabilities. Tektronix, with headquarters located in Beaverton, Oregon, was anxious to fieldtest a model 4081 graphic workstation using real data. Further assistance from IBM helped provide the necessary hardware connections between the IBM mainframe and the 4081. The Tektronix workstation configuration consisted of the first 4081 produced (Model #B00), a 36" x 42" digitizing tablet with a one-button mouse (or optional pen mouse), and a high-resolution monochrome monitor. The workstation was the size of a regular office desk and came equipped with a large-cartridge tape drive used to load the operating system. The workstation was of all-metal construction, built like a tank, and equally hard to move. A hard copy device was used to make prints of the screen. The region's com-
mitment to pursue the latest technology was once again demonstrated.

**Oregon Grown**

Two very significant graphic applications were developed once the 4081 was operating. The first was a program called GRDIG. This interactive digitizing package offered many of the features used by today’s graphic software packages, such as point deletion and moving routines. It automatically snapped digitized points together using “gravity” features. It windowed, zoomed in and out, and flashed elements for verification. And it interactively displayed a map while it was digitized or edited. For the formerly “blind” digitizer, this system was truly a marvel.

The second application, known as the GRAPH program, allowed display-only capabilities across map boundaries. The graphic data was organized in separate geographic areas so that information outside user-defined windows could be ignored for display. Selective display by polygon attributes (such as vacant parcels over five acres) was also available. In short time, police agencies began using GRAPH to display, report, and plot crime data. The system was also used extensively by the city of Eugene Planning Department.

In 1977, a second 4081 purchased by Lane County Land Management extended the parcel base to cover the rest of Lane County. Over 2,500 assessment and taxation maps were digitized over the course of the project.

**Early GIS Tools**

While the ability to plot geographic data was a very important characteristic of the GIS, it was not primarily a mapping system. Map Model did not provide many cartographic features found in modern GIS packages, including color, line types, symbology, fonts, and control of annotation. However, the system did offer powerful GIS functions such as area calculation, centroid calculation, and point-in-polygon processing. The latter function is still the most widely used GIS function in the region. Many point data files, including site address, tax lot centroid, road intersections, and administrative records systems contain one of these indexes. L-COG now maintains over 200 boundary files (polygon coverages). Examples include city limits and annexation history, zoning, land-use plan designations, census geography, special district boundaries, soils, and flood-hazard zones. The point-in-polygon technique allows data from the boundary files to be coded on the point records. Reports summarizing the results can be easily tabulated from these records.

**Evolution, Not Revolution**

In 1982, the RIS partners considered broadening the scope and purpose of the GIS to provide an engineering-quality common base map for the region. They wanted to take advantage of new hardware and software on the market, while maintaining the broad functionality of the existing GIS. The Common Mapping Steering committee was formed to develop requirements for the upgraded system. The project was coordinated by L-COG and RIS staff. Following the initial steering committee work, subcommittees were formed to assist in other phases of the project (Figure 2).

**Project Implementation**

Hardware installation began in April 1985 with the installation of a DEC VAX 11/750 CPU minicomputer (with all the hardware in place by August 1985), and Synercom mapping and information management system software. Project costs were allocated according to agency responsibility for six different data utility layers that were developed as part of the project (Figure 3).

Today, the region uses a variety of graphics workstations, including four VaxStations, five Tektronix terminals, and five IBM-type PC workstations. The VAX 750 has been upgraded to a DEC VAX 6310, and the single 456 megabyte disk drive used to store the initial graphic data in 1985 has grown to six in 1989. Three pen plotters and an electrostatic plotter produce hard copies. The lesson learned is that any added resource will be used.
Eugene surveyors anticipated that the survey work would take over four years. However, it was completed in two and a half years (by September 1987) and covered over 400 miles of road network within Eugene.

Survey data was offloaded to Eugene’s engineering system; appropriate points and lines were then automatically sent to the mapping system. An assessor map registered to the digitizing tablet and coordinate geometry was used to create the base layer. This work was completed for Eugene in June 1989.

In the Meantime

Fourteen years of graphic data collection, update, and maintenance still resided on the IBM once the new system was operating. Until the new base map was created, we realized this data would still be needed. Methodologies to transfer the “old” data began in September 1985. Six layers of information were transferred. These were tax lot lines and centroids; land use

GRE 3 field-data collectors to capture the base-layer data in Eugene. A common-field coding scheme was defined by the region’s surveyors, and the actual surveying began in fall 1985.

Base Map Creation

One of the questions asked initially by the steering committee was, “How accurate is accurate enough?” Planners’ accuracy requirements differ from those of surveyors. The committee decided the base data should be gathered at the most accurate level required by any of the users.

The steering committee defined the base map components as monument points, road centerlines, road intersections, water features, railroads, government corners, road rights-of-way, and street names. After several field studies, they decided to use state-of-the-art WILD T2000 electronic theodolites and

FIGURE 3. Common Mapping Project Funding

EWWEB

WATER

STORM SEWERS

SANITARY SEWERS

EUGENE

ELECTRICITY

LANE COUNTY

COUNTY ROADS

CITY ROADS
lines and centroids; right-of-way lines; and street name. By December 1985, L-COG and RIS personnel had developed a process to preserve the region's data collection effort. As a bonus, the old data files were cleaned up during the transfer by electronically eliminating gaps and overlaps. Data were segregated by layer and displayed in color, monochrome data were colorized, and a process was developed to transfer boundary files to and from the IBM and DEC environments.

**EWEB Conversion**

As a primary participant in the Common Mapping Project, EWEB recognized that quality maps could be produced and maintained more efficiently using the new mapping system. A study conducted in 1985 showed the utility would save $800,000 over a ten-year period in drafting costs alone with automated map set maintenance.

EWEB chose to hire a conversion vendor to enter the 630 electrical distribution maps to the common mapping systems. Both graphic and non-graphic elements were entered. The conversion work began in 1988 and was completed in June 1989.

**Other Applications**

A challenge for the Common Mapping Project has been to focus on the goal of an accurate countywide base. The other challenge has been knowing when to take the blinders off and allow other application development.

The police-crime analysis application was one of the first to convert to common mapping. Today, a monthly set of 67 maps...
is created that details a variety of crimes by region and eight-hour period.

Other applications include mapping Eugene's storm and sanitary sewer system; creating maps of zoning, address, and developed areas for Lane County Land Management; and digitizing right-of-way acquisition for the Land County Surveyor (Figure 4).

The Beat Goes On

Multi-user environments are becoming more common throughout the nation as a way to combine resources to meet mapping, GIS, and land-record needs. Part of the solution explored by these projects includes multi-vendor environments. Lane County agencies have successfully integrated DEC and IBM systems through the use of a DEC SNA Gateway. The Gateway's file transfer feature, combined with application and graphic software, has simplified the job of transferring IBM GIS files and the day-to-day operation of the common mapping project.

In addition, data on the IBM have been transferred to the Synercom system, AutoCAD, and to Eugene's VANGO computer-aided drafting system. The creation of a new Lane County Atlas required L-COG to share their Synercom data with the geography department's Intergraph data at the University of Oregon.

Two final projects illustrate the region's commitment to use the GIS to help solve problems, provide improved products, and better serve the citizens of Lane County. In 1989, L-COG successfully integrated a transportation modeling package, which runs on the IBM mainframe with a graphic display of the model, using Synercom mapping software on the VAX system.

During the summer of 1989, a project for Lane County Public Works was initiated to inventory the roadside vegetation along 1,500 miles of road in Lane County. This information will be matched to digital files of county road centerlines and milepoints. Milepoints are a geographic index that can be used where addresses do not exist to manage many features, such as pavement management, guard rail locations, bridges, fences, traffic signs, and vegetation.

Information in the Lane County GIS has accumulated over the last 20 years. It first was collected on equipment that has long since been sent to the scrap heap, and was manipulated by software that is now antiquated. The data collection and maintenance effort is by far the most costly component of any GIS, but an investment in the data will stand the test of time. Choosing the right tools to collect, manipulate, and output information should be done with a primary emphasis on how the process will save time and money. Today's software and hardware technologies, while meeting this challenge, offer a further benefit—they are limited only by the imagination and creativity of the people who use and push the potential offered by their information systems.

Cress Bates is program manager of the geographic data system at Lane Council of Governments. He began working for L-COG 17 years ago as a member of the original data collection and digitizing team and has since managed the update, maintenance, and extension of the regional geographic data system. He is currently chairperson of the International Association of Synercom Users and has been a member of URISA since 1982.

As assistant director of Lane Council of Governments, Jim Carlson manages local government projects in the areas of transportation and energy planning, land use administration and planning, natural resources, economic development, public safety, data processing and the geographic data system. He has been at L-COG for 16 years and a member of URISA since 1981.

Bob Swank is the associate director of Lane Council of Governments, and is responsible for financial management, administration and special projects. He was hired 17 years ago as the first programmer for the Lane GIS, but now focuses on long-term and strategic planning for the system. He is currently on the Oregon Land Records Committee and has been a URISA member since 1975.
The Digitizer Blues*

Clint Brown and Dale Honeycutt

When I got here this morning I was feeling fine,
Then the digitizing crew, we all start to whine,
The bossman says, "Put on your digitizing shoes
And get to work on them digitizing blues."

Chorus:
I got the digitizer blues
I got the digitizer blues
I'm so damned low
I got the digitizer blues

Now, there's a lot of arcs and labels and a whole lot of nodes,
I just wish I could get this polygon to close.
My nodes won't snap and my arcs got crunched,
and I'm already three hours late for lunch.

I've been tracing polygons and arcs all day
Now I need to do a clip and an overlay,
But the digitizer's smoking and the program just bombed
Me and this digitizing, we just don't get along.

I'm gonna lay my head down on top of the digitizer line,
Said I'm gonna lay my head down right on that digitizer line,
When that big thing comes rolling,
It's gonna pacify this poor boy's mind.

Now come next payday when the eagle flies
I'm gonna see my boss and look him right in the eyes,
I'll point my puck and say, "This is what you're gonna do,
It's your turn, son, to have them digitizer blues."

Chorus:
You've got the digitizer blues
You've got the digitizer blues
You're so damned low
You deserve the digitizer blues

*With apologies to genuine blues artists.

Clint Brown manages Environmental Systems Research Institute's (ESRI) software products group, which includes all ARC/INFO releases across all platforms. The team writes all user documentation, conducts software tests, and publishes accompanying workbooks. He has been a member of URISA for five years.

Dale Honeycutt is a member of the applications programming group, an advanced systems modeler using GIS, and a pretty decent guitar player.
FEATURE MAP

Statement of Editorial Intent

A good picture is worth several thousand words, and so is a good map. Pages of data can be summarized in a single map, and spatial patterns become apparent that are impossible to discern among pages of numbers or words.

Computer mapping and geographic information systems play a key role in URISA's mission to help local, regional and state/provincial governments make the best use of information system technologies. And now that computer-generated maps have become an important part of URISA's domain, the URISA Journal intends to showcase the efforts of mapmakers by featuring an exceptional map product in each issue. Our intent is to share a wide variety of maps, hoping to inspire others to learn and copy good ideas and techniques.

We are looking for maps that are easy to read and that allow the reader to readily see what the mapmaker intended. Perhaps new symbols were designed or special colors chosen to meet a particular purpose. New ways of presenting data or of understanding phenomena through mapping techniques are also desirable. And, of course, we will also consider publishing a map that is exceptionally pleasing or beautiful.

William J. Craig

GUIDELINES FOR FEATURE MAP SUBMISSION

1. The focus of the map section is on the image itself. We will consider both color and black-and-white submissions. You may submit a complete map, an enlarged portion of a map, or both. The following criteria will be taken into account: visual quality of the map; amount and quality of information transmitted; and reproducibility of the map within the journal context.

2. We will accept printed maps or maps available in hard copy, provided they are clean and that you indicate the portion you wish to be published. Alternatively, we require glossy 8 X 10 color or black and white prints. Slides are acceptable but must be accompanied by a print. All submissions should be of high quality. This is especially important for computer-generated images, which can be difficult to reproduce.

3. Two to six double-spaced pages of text should discuss the map and its construction.

4. Include a separate page with the title, and author's name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author's professional positions, current affiliation, and research interests.

5. Any acknowledgement must be included at the end of the text under the heading: Acknowledgements. If your submission is a copyrighted image, please contact the map section editor to make special arrangements.

6. Submit map materials and text to the section editor:

William J. Craig
Center for Urban and Regional Affairs
330 Humphrey Center
University of Minnesota
Minneapolis, MN 55455
Authors' Note: Will Craig called last August and asked if Geographic Data Technology, Inc. would produce the first feature map for the new URISA Journal. He specified that, in order to tie it to the 1990 census, it be a TIGER map. We protested that TIGER was too big (all streets and hydrology for USA) to plot on one map: that TIGER is a digital map with infinite zoom levels; that TIGER contains lots of annotation related to census and postal geography, which couldn't be expressed in one map. . . . But Will wouldn't take no for an answer. "TIGER/3193" is the result.

TIGER stands for Topologically Integrated Geographic Encoding and Referencing. TIGER files are the embodiment of a fully computerized geographic support system conceived by the U.S. Census Bureau's Geography Division in the early 1980s. TIGER integrates all of the spatial information needed to administer and publish a census. For example, all statistical and reference maps for the 1990 Census will be computer plotted from the TIGER database.

Integrating all geographic resources into one computer file promises to make future census statistics more accurate and consistent and to streamline ongoing maintenance and processing.

TIGER files are best thought of as computerized street maps, overlaid with complete 1990 Census geography (tracts, blocks, MCDs, etc.) and "postal" information (street names, address ranges and zipcodes) sufficient for geocoding.

TIGER is in the public domain and is available on computer tape and CD-ROM. The biggest obstacle in using TIGER is file size: 16 billion bytes, eight times the data volume of the GBF/DIME files. Initial 1990 editions of TIGER will contain definitive 1990 Census geography, but will not have current or complete postal fields. The Census Bureau has not committed to update TIGER information between censuses.

TIGER/3193

The title of this map expresses the fact that we're displaying only 1/3193 of TIGER: less than one-tenth of a percent of the TIGER database. TIGER is partitioned (roughly) by county and we chose Prince Georges County, Maryland out of the 3193 partitions available.

Each row displays a different zoom level. TIGER is a digital map database, and can be plotted at any scale and in any projection. We've chosen scales of approximately 1:350,000; 1:200,000; 1:85,000; 1:40,000; and 1:27,500 for the five zoom levels.

Each column expresses a different theme encoded in the TIGER database. Each line segment in TIGER has 500 to 600 bytes of geographic data attached to it, on the average. We chose Map Source, MCD Code, Zip Code and Feature Classification for the four views of TIGER.

Map Source

Displays in the first column are color-coded to indicate the origin of the digital map information.

The bulk of Prince Georges County is colored green, denoting GBF/DIME (the TIGER precursor) as the source. Actually, the Census Bureau contracted with GDT and three other firms to extend DIME coverage out to a "MAW" (Metropolitan Area Window) and to add new streets within the old DIME coverage. Consequently, the green area may extend well beyond the DIME coding limit; it usually ends on a 7.5 minute "quad" boundary.

Reading down column 1, TIGER coverage outside MAWs comes from U.S. Geological Survey Digital Line Graphs (DLG). These features are coded in blue. The Census Bureau did extensive work updating the DLGs, indicated in red.

The astute reader will conclude that information in
TIGER has a broad and complicated pedigree. Line features in TIGER are located to varying degrees of both accuracy and precision depending on their sources.

The Map Source display zooms in to a rural portion of the county. We’ve used TIGER’s “shape” features (intermediate coordinate measurements) in this display to demonstrate TIGER feature representation at its best. “Shape” representation is contained in an auxiliary optional record type, an important improvement over GFB/DIME achieved at the expense of added complexity to the user.

MCD Coding

In column 2 we employ MCD (Minor Civil Division), a Census Bureau statistical zone that equates roughly to town. All we’ve done in this display is to color all TIGER lines for a given MCD the same color. (It’s a tossup as to what color the actual MCD boundary receives.)

What you see in the small-scale view in the top view is a pseudo-choropleth representation of the towns in the country. What isn’t shown is evidence that it is relatively simple to extract a reliable boundary file of any Census Bureau geographic unit from TIGER. Simple, of course, is one matter, easy is another—processing over 100 reels of computer tape is never easy!

Other maps we’ve plotted (not used here) show similar patterns—finer-grained—for smaller Census Bureau geographic units like tracts and block-groups.

Zip Codes

The third column uses a technique similar to the MCD display process to show zip codes in TIGER.

A major difference, however, is the use of black to indicate lines with no zip codes. Note the total lack of zip coverage in southeastern portions of the county, and spotty zip coverage in other places.

Postal information is the most costly and time-consuming portion of TIGER content to compile. The Census Bureau did not have the time or money to complete this portion of TIGER in time for the 1990 enumeration.

The bad news lurking beneath the zip code display is that the black streets not only do not contain zip code; they also are missing low and high address ranges. Geocoding is impossible in these areas.

The lack of geocoding capability is the most serious flaw in the initial TIGER publications; private firms will have to improve this portion of TIGER to make it broadly useful.

Incidentally, this map series zooms toward 5001 Silver Hill Road, home of the bureau’s geography division. Census Bureau headquarters in Federal Office Building 3 is about one-half mile southwest.

Feature Classes

The final theme draws from a much-improved feature classification scheme in TIGER, replacing the “NS” (Non-Street) code in the GFB/DIME files.

We’ve used this code to plot roads in black, water features blue, railways green, and artificial statistical boundaries magenta.

Streets are further subdivided according to USGS classes which distinguish limited-access highways and major thoroughfares from residential streets.

The Future of TIGER

TIGER arrives at a time when the geographic and cartographic communities are evaluating the initial 25 years of experience with maps and computers.

Maps are almost the last body of recorded information to be computerized. Fields like accounting and engineering embraced computing like ducks to water; automated word-processing is practically universal. This is not the case with maps.

There are several reasons for this:

1) It’s harder to computerize geographic information than a payroll. Payrolls are linear; maps are two-dimensional. The Von Neuman architecture in today’s computers is linear. Only in the past decade have techniques for dealing with spatial searching and retrieval become well-known.

2) Geography as a discipline has been in decline for half a century. Our cultural perception of Earth as a global village with limited resources amplifies the point that geography is pervasive; everything is connected to everything else. Geographers are overloaded and the normal reaction is to put on blinders and concentrate on some relatively minute phenomenon.

3) Cartography as a discipline is pulled in two directions. The vast majority of the use of computers
in this field has been to automate the cartographic production process. For example, most AM/FM and GIS systems are ultimately used for map-making.

Conventionally trained cartographers continue to perceive that their job is to communicate spatial information and to concentrate on issues of cartographic representation. They pass over the other traditional function of maps (not counting decoration), which is storage of geographic information. Map encoding, digitizing and storage techniques have been developed for the most part by computer technicians rather than trained cartographers.

This schism is exacerbated by growing commercial demand for computerized operational systems in logistics applications like vehicle dispatching and fleet management. Traditional cartographic practice is irrelevant; most such systems never generate a graphic depiction—a map. Yet practically all such systems in the United States will use digital map databases derived from TIGER.

Real problems like acid rain, global warming and resource depletion can be lessened by improving logistical efficiency. Commercial motivation to operate fleets of trucks efficiently will result in consumption of TIGER-based products.

TIGER will also be used by traditional cartographers to further the practice of representational maps. The same TIGER information will be used by a new breed of cartographers who concentrate on the map’s other function of information storage and jump straight to the use of spatial information without getting sidetracked on issues of representation. These new cartographers won’t care that the map is invisible in their applications; it will still be a map to them.

Donald F. Cooke is president of GDT. He has been a member of URISA since 1967.

Stuart Levasseur has an A.S. degree in graphic arts and photography. He has worked at GDT for four years.
TIGER/3193: Prince Georges County, Maryland

Each column expresses a different theme encoded in the TIGER database. From left: Map Source, MCD Code, Zip Code, Feature Classification. Each row displays a different zoom level. From top (approximate scale): 1:350,000; 1:200,000; 1:85,000; 1:40,000; 1:27,500.
Statement of Editorial Intent

The reviews section of the URISA Journal provides critical reviews and information concerning publications, information sources, and software in the field of urban and regional information systems. Professionals in this field must draw from a variety of sources and materials to support their activities. Accordingly, this section will include reviews of a variety of information sources that, in general, fall into one of four broad categories:

1. **Book reviews** will focus on books relating to the development, implementation, application, evaluation and management of information systems in urban and regional environments. Books written for use in academic settings, as well as those aimed at the practitioner, will be included. This issue of the Journal includes a review of a book on the use of microcomputers in planning activities.

2. **Publication reviews** will examine a variety of publications that offer significant contributions to URISA’s area of interest. These will include conference and symposium proceedings, reports, resource papers, monographs, technical publications, development guides and manuals related to urban and regional information systems issues. A review of an American Public Works Association report on public works practices is included in this issue.

3. **Video reviews** will provide another review category, because videotapes are becoming a popular tool for education and information dissemination, particularly in the area of geographic information systems. The URISA Journal will include reviews of new videos that could be useful information sources or tools for Journal readers. This issue includes reviews of a sampling of recent videos related to geographic information systems.

4. **Software reviews** also will be a feature of the reviews section. They are intended to help readers become aware of software that could aid them in their work, and to help them choose the right software by reviewing it from a URISA professional’s viewpoint. The software reviews are categorized as follows:

   - **In-Depth:** Detailed reviews of substantial programs. An In-Depth Review covers areas including ease of use, performance, and support. A program summary and overall rating complete the review.
   - **Head-to-Head:** Program comparisons that take a class of programs such as thematic mapping software, introduce each package, compare their strengths and weaknesses, and discuss their use.
   - **From the Inside:** Explanations of non-commercial programs by their creators, to inform readers about program capabilities and encourage use of the programs.

As with all reviews, software expresses the opinions of the authors. The publishers of commercial software will be given the opportunity to check review drafts for factual errors, but cannot change opinions expressed in the reviews. URISA Journal does not encourage complimentary submissions of software for review. We prefer that software publishers identify expert users of their software and then encourage them to write a review. Potential reviewers are encouraged to evaluate programs they use frequently, decide whether those programs would be of interest to Journal readers, and find out if the programs have been adequately reviewed elsewhere. Many programs useful for our professions are not reviewed, or are reviewed by journalists, rather than by members of our professions.

In addition to submissions of book, publication, video and software reviews, we welcome suggestions and insights pertaining to the identification, critical review, and recommendations of all information sources in the field of urban and regional information systems. (See p. 104 for guidelines for submission of review materials.)

Rebecca Somers
Peter Van Demark
Advances in the use of information systems are made through research. The papers presented at the 1989 annual conference represented a significant move forward both in articulating that agenda and in presenting solutions to problems listed in earlier agendas. Significant presentations were made in the areas of the planning information systems and GIS implementation issues. Four other papers expanded on the research agenda. In addition, eight high-quality papers and one panel offered findings significant to solving past problems.

URISA’s research agenda has a strong user orientation. It is developed from two perspectives, one formal, the other less formal. The formal statement was prepared by a special Research Agenda Group and published in this journal (Craig 1989). That statement listed several dozen research topics, sorted into the two major categories of social concerns and technical concerns. The less formal agenda appears annually in the conference call-for-papers as each special interest group (SIG) lists the topics it wishes to cover. The 1989 call-for-papers listed over four dozen topics. The result was a number of high-quality papers and presentations that spoke directly to URISA’s formal agenda and expanded on the scope and nature of that agenda.

What Do We Know About GIS?

Wellar (1989) set the tone for research papers with his question, “In truth, what do we know about GIS?” He argues that too much of our “knowledge” is based on insight and unique installations. Very little synthesis has been done on GIS literature, a problem compounded by its eclectic and fugitive nature. The general point is one that Wellar made at the 1988 conference (Wellar 1988), but now he goes into more detail. He would like to see systematic analyses of how and why GIS technology has affected better solutions, impacted its host organization, or changed the various organizations or sectors related to each other. Most importantly, he challenges his readers to document the sources of their research and conclusions.

Planning Support Systems and GIS Technology

The shortcomings of current GIS as a useful tool for urban planning were well articulated by Britton Harris (1989). He works from a matrix comparing planners’ needs on one axis and GIS capabilities on the other. The need to integrate land use planning and transportation planning is one key need; they are inseparable in reality, but almost always separated in practice.

This requires both conceptual and operational changes based on research—including for example, simple means whereby streets may be treated simultaneously as elements in transport and utilities networks and bounding links for areas (p. 14).

The treatment of space in a GIS is different from the way planners use space. GIS technology usually treats space as simple contiguity or as bounded proximity, (e.g., place A being within a two-mile ring around place B). Planners use space as a game board on which social and institutional processes occur, often among all places simultaneously. Harris lists eight research agenda items that need to be pursued if GIS technology is to be transformed into a planning support system.

The transportation/land use planning issue was also ad-
addressed by Ferguson and Drummond (1989). They look for ways to improve planning through GIS technology and find impediments similar to those listed by Harris. Geographic space, appropriate scale, flexibility, and the usefulness of data from an “integrated” database are topics where they see particularly promising research opportunities.

Questions about using parcel level data for planning purposes were raised by Prosperi (1989). Specifically, he raised the issues of scale and space. Most models use a different level of generalization that would need to be modified or replaced. Having worked with parcel level data in Florida, Prosperi also sees a need for research on intragovernmental cooperation, especially the combination of operational interests with the needs of spatial analysis.

GIS Implementation

Identification of key factors in GIS implementation is a GIS topic we do know something about, thanks to a structured analytical approach used by Peter Crosswell (1989). He read and analyzed an extensive list of publications. His finding is that organizational and institutional issues are the principle problems encountered in GIS implementation; technical problems are secondary. Based on his readings and on his experience as a GIS consultant, Crosswell lists 13 institutional, societal and industrial maxims that he feels will improve the chances of successful GIS implementation.

Somers (1989) used the literature of administration and organizational management to make recommendations about GIS implementation. The biggest problem, she argues, is the horizontal structure required for GIS data sharing and communication. Organizational change is required and she lists a number of strategies, including acquiring of a mandate from upper management and designating a group or individual as the specific change agent.

A different approach to developing an implementation strategy was heard at a panel presentation organized by Public Technology, Inc. (Gilman 1989). PTI is working with a number of local jurisdictions that are in the process of implementing a GIS. The result will probably be a guidebook, based on their experiences.

New or Expanded Research Issues

Other authors presented papers that articulated important new or expanded research topics:

- Williamson and Hunter (1989) called for the development of better conceptual (graphic) models to “illustrate system principles and concepts to government agencies, other potential users, and politicians” (p. 14).
- Bedard (1989) discussed software engineering and the need to expand this important technique to cover GIS, giving some examples of his work in Quebec.
- Beard (1989) presented some general ideas on how to reduce the misuse of maps in a GIS environment, for example expanding the scale of generalized small-scale maps. Research is required to expand the scope and detail of these recommendations.
- Robinson (1989) articulated the concept of “domain sensitivity,” as a problem of misinterpretation of data in a shared-data or distributed workstation environment. This issue was raised, in one way or another, by each of the authors writing on planning support systems. This problem will be most significant for planners, because they are always using someone else’s data, but the issue is pervasive in all system work. Robinson said we need a variety of new techniques to standardize data and pass semantic information among users.

Other Solutions

While the vast majority of URISA Conference presentations contained useful information, several papers and one panel have been identified as particularly germane to the URISA research agenda and of sufficiently high quality to deserve special mention.

The special panel presentation on “Optical Disc Technology—Current and Future Trends” was organized by URISA past president, Charles Kindleberger. This technology promises to bring more power to the desktops of individual users. The panel included the following:
• Crane (1989) described a system used by the Wyandotte County (Kansas) assessor, which allows a user to point at a parcel map on the screen and see a video image of the property on a second monitor. This information is used to verify property characteristic data and verify comparability of sold properties.

• Mandli (1989) used a similar map/image approach for improving the usability of the Minnesota Department of Transportation’s highway photo logs. Road condition and engineering information can be displayed on the screen.

• Moosic (1989) spoke about data from the Census Bureau of CD-ROM. One disk can hold the information formerly contained on six tapes. Much of the 1990 Census will be available on CD-ROM and many test disks are already available.

The papers that deserve special mention include the following:

• MacIntosh (1989) addressed the economic issue of land record automation, an important aspect of everyone’s research agenda. His paper contains much useful data on the costs and cost recovery, based on his land information work in the Maritimes. His recommendations are that the name of the current property owner is the most important piece of information to be computerized, but that all other initiatives should be weighed carefully against potential paid uses of the data.

• An “Exemplary Systems in Government” award was presented to the city of Santa Monica for its innovative system providing citizens with electronic access to city information and services (Barrette 1989). Much information is available for reading, but citizens also can request responses to inquiries of city departments and communicate with each other. One of the items on URISA’s research agenda is to determine how to improve public participation in the utilization of information systems technology.

• Joffe and Wright (1989) presented a computer game, SimCity, which can be used as a teaching tool for those needing to learn how a city manager can mold and develop the growth of a city.

• Ehlers and Haggerty (1989) revived hope in the use of satellite data to monitor and update land use information, at least at scales of 1:240,000 or smaller. Their work integrates GIS into the interpretation and verification.

• Schaefer and Ashauer (1989) addressed the problem of unknown spatial accuracy on parcel maps by maintaining an audit trail of all digitizing and boundary modification decisions.

• Cowen and Shinar (1989) described their work in developing and integrating economic development models into a GIS. The issue of integrating models into GIS is one of the URISA Research Agenda items.

• Han and Kim (1989) explored the issue of conflicts among knowledge sources when building an expert system, then presented useful approaches for resolution.

• Kindleberger (1989) gave a concise description of the history and utility of hypermedia, then an interesting example of using this technology for accessing a wide variety of source material about the St. Louis riverfront.

Conclusions and Next Steps

The 1989 URISA conference made significant advances in articulating URISA’s research agenda. Particularly strong papers were presented in defining the shortcomings of current GIS technology for the planning function. With the shortcomings so defined, researchers can begin to work on solutions. The strong set of papers on overcoming problems of GIS implementation proves that URISA members can respond to well-articulated issues with excellent research. The 1989 conference provided a rich array of other problem definitions and solutions.

With luck, the 1990 conference will be every bit as fruitful for advancing URISA’s research agenda. Results again will be summarized and published in this journal.

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References


Reviewed here are four grid-based geographic information systems that are classified “quasi-commercial.” The primary criterion for inclusion in this class is that the systems be developed within academia or a non-profit organization. All four GISs are intended to be used as teaching tools and for small research projects. They are each priced under $200 and run on microcomputers (two on IBM-PC and compatibles; two on Apple’s Macintosh).

This class of GIS is still the most widely utilized around the world, despite recent emergence of low-priced, vector-based alternatives. Grid-based GISs are especially well-suited to addressing natural resource, land management, and other environmental projects, due to the grid data structure’s inherent encoding of space rather than objects in that space (such as points, arcs, and polygons). Grid-based systems have been unjustly characterized as being somehow less precise than vector (object-based) systems due to their stereotypical blocky or ‘jaggy’ appearance. This blockiness is only due to low resolution data collection and to memory constraints that do not allow microcomputers to handle large matrices. This is changing as data are being sampled via remote sensing at extremely high resolution and ‘micro-GISs’ now can use expanded random access memory (RAM) to handle larger grid files and can display the files using higher resolution graphic devices.

While spatial resolution is becoming less of a problem within this class of GIS, attribute data management is not. Typically, grid cells are allowed one z-value per “layer” or “theme.” Mathematical overlay of multiple themes can provide meaningful visualization of attribute relations, but there exists little tabular data management and output in any grid-based, quasi-commercial GIS. This problem perhaps should be addressed by the next generation of these GISs.

This comparative review discusses the merits and faults of each of four systems, relative only to others in this class. Comparisons between IBM-only and Macintosh-only systems are difficult, so head-to-head rankings will concentrate on functionality and usefulness to the classroom and small research problems, rather than on absolute benchmarks such as speed. Each GIS is rated in the following categories: performance, documentation, ease of learning, ease of use, support, and value. Ratings are based upon the following scale: Poor, Satisfactory, Good, Very Good, Excellent. A summary of the major findings of this review is presented in the final section.

IDRISI (version 3.1 tested)
Graduate School of Geography,
Clark University, 950 Main Street,
Worcester, Massachusetts 01610.
Contact: Lee Thomson.

Introduction
Described in its documentation as a “grid-based geographic analysis system,” IDRISI is a full-featured system suitable for introductory and intermediate classroom exercises and research. IDRISI is designed to run on IBM PC/XT/AT or full compatibles, under DOS 2.1 or higher. System memory of at least 256K is required and a hard disk, dot matrix printer, and Microsoft-compatible mouse are recommended. IDRISI is not a deriva-
tive of Dana Tomlin’s MAP, but consists similarly of an open collection of Pascal modules which allow grid-based files to be entered, stored, displayed, and analyzed. Modules are nicely divided into three groups: “Core” modules; “Ring” or analytical modules; and “Peripheral” or conversion and auxiliary modules.

Features

A primary feature of IDRISI is its open architecture. Users may write modules in one of several languages, using the Pascal and BASIC source code templates provided, and then add them to IDRISI. The exchange of new modules by users is encouraged by IDRISI’s developers, and a public bulletin board has been established to allow users to upload or download files.

Another nice feature is support of a wide variety of both vector and raster import/export data formats, such as Landsat, DLG-E, Arc/Info, ERDAS, and AutoCAD. In addition, I successfully imported rasterized map data into IDRISI from the Roots (Harvard Laboratory for Computer Graphics and Spatial Analysis) digitizing package. Attribute data may be exported from IDRISI to Lotus 1-2-3 and Borland Quattro (spreadsheet), or Professional File 2 (flat file DBMS) formats.

Support for Microsoft-compatible mice, several input devices, and high-resolution (VGA) graphic output are other additions to a GIS that was already very functional. IDRISI offers more functionality than the other GISs tested here. Several spatial statistics routines, supervised image classification routines, and the ability to overlay vector map data are included. Additionally, whereas some systems simply list available routines alphabetically, IDRISI organizes routines by function, which facilitates command execution.

Performance

I tested IDRISI on a Dell System 220 (80286-20 Mhz CPU, 640K RAM, math coprocessor, VGA display, Microsoft mouse) under DOS 3.3 without problem. IDRISI’s speed at both number-crunching and graphic display of a 350 row by 579 column map is quite respectable. Given that my test machine runs at 20 Mhz it should be noted that even at a third of this speed (8 Mhz PC-AT), IDRISI will be acceptable for classroom use of large map files. It should also be noted that a few calculation-intensive procedures, such as that which constructs Thiessen polygons, can take 15 minutes or more to complete, but this is to be expected. From the standpoint of usability, command execution using the mouse menus is very easy compared to command-line driven execution. Mouseless users of IDRISI’s “Access System” may find command execution awkward at times (discussed below). IDRISI’s overall performance, especially on 80286/386 machines, is rated Excellent.

Documentation

The printed documentation consists of a three-ring binder containing about 200 pages and is divided into 15 logical sections including “Installation,” “Getting started,” “Creating new modules,” and “Interfacing.” This is a very easily navigated user’s manual, though torn pages due to an overstuffed binder were a problem after a few readings. On-line help is sparse, consisting of only one screen of command information, which is available only to Access System (non-mouse) users. IDRISI’s overall documentation rates Good.

Ease of Learning

Thanks to the grouping of commands by function, support of mouse menus, and structured documentation, IDRISI is very simply learned. It is not so simple, however, that a novice can immediately begin exploring the system without having read the documentation (see next section). The 15 student exercises included, with topics such as “polygon analysis” and “distance analysis,” help to make the learning process interesting and relevant. Nontrivial questions, that students must investigate or else feel they have missed something important, appear throughout the exercises. IDRISI’s ease of learning rates Very Good.
Ease of Use

Mouse menu support is termed "experimental" in the documentation but is very useful nonetheless. The lack of a complete explanation of mouse menu installation may be problematic, but the process can be figured out in about five minutes. Another small problem is that the menu mouse offers a few traps, such as the inability to cancel a command sequence other than by hitting a "CNTL-C" or "CNTL-Break."

The command "Access System," for non-mouse users, simplifies command choice (relative to typing commands at the DOS prompt) by displaying commands grouped by function. Unfortunately, it does not simplify the user interface enough to make command execution an intuitive process. The Access System user must rely on the printed documentation for command modifier details to properly execute many commands.

IDRISI does not organize map files (images) within a "project" subdirectory system. Therefore, the IDRISI "exercise" subdirectory can easily become one long list of both useful and intermediate (scratch) files. Users must remember to give their map image files clever names and to properly utilize documentation files so as to recognize maps as part of specific databases.

These few minor problems flattened the learning curve a bit but did not affect my obtaining the expected results while running the system. IDRISI should be relatively maintenance-free in a public laboratory, given that proper file management is instituted. IDRISI receives a rating of Very Good for ease of use.

Support

Developer Ron Eastman has always offered limited IDRISI support via telephone and bitnet. Beginning with version 3.1, IDRISI users may now purchase full software support, with future versions of IDRISI to include 90 days of free support. Still highly recommended is communication via bitnet (idrisci@clarku) with the newly hired project manager. Responses by bitnet can be slow during early and late semester, when the university is busiest, but upon arrival they are usually detailed and very helpful. IDRISI is not copyright protected. Software support for IDRISI is rated Excellent.

Value

IDRISI is priced at $50 for students, $100 for academic/research institutions, and $300 for others (plus shipping). Given its low cost to the research community, relative maturity, full functionality, and strong support policy, IDRISI rates an Excellent value.

OSU Map-for-the-PC (version 3.0 tested).

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Introduction

OSU Map-for-the-PC (here abbreviated "OSU MAP") is a reworked version of Dana Tomlin's IBM-PC Map Analysis Package. The FORTRAN routines (a trace of C now exists) have been cleaned up, augmented, documented, and linked to flexible color graphics routines. The system is similar to that described in the AutoCarto 8 paper by Marble and others (1987). OSU MAP is available in two versions: one designed for 512K RAM, which handles small databases; the other for 640K, which handles larger databases. Therefore, an IBM-PC/XT/AT or 100 percent compatible (or PS/2) with 512K RAM is required to run OSU MAP. A 20 MB hard disk and a math co-processor are recommended. OSU MAP is appropriate for introductory and intermediate GIS instruction and research projects.

Features

An important feature of OSU MAP is its management of database map layers using DOS subdirectories. This is nice when the hard disk is loaded with several class projects and every student wants to have a layer named "land use." Another feature, due to OSU MAP's use of the MetaWINDOW graphics library, is its ability to read and adjust to most any hardware configuration, from monochrome to super-VGA. In addition, support for postscript-compatible laser printers has been added.
The menu-based user interface offers sufficient on-line assistance to allow the user to experiment with the system without needing to rely on the written documentation. OSU MAP represents a substantial improvement in functionality relative to the original MAP.

Performance

I tested the large (640K) version of OSU MAP on a Dell System 220 (80286-20 Mhz CPU, 640K RAM, math coprocessor, VGA display) under DOS 3.3 without problems. Number-crunching and display of even large maps (over 50,000 cells) is quite rapid; OSU MAP is not noticeably faster nor slower than IDRISI. As is true of all the GISs tested here, there are numerically intensive operations that require 15 or more minutes to execute; these operations are executed infrequently. Once learned, the menu-based user interface allows
the user to operate rather quickly. OSU MAP's performance, especially on 80286/386 machines, is rated Excellent.

Documentation

OSU MAP documentation is in 8.5-by-11 inch, three-ring binder format and consists of a "User's Guide" of about 180 pages and a "Database Guide" of 60 pages. It is neatly organized by command function, and is single-side printed to "facilitate local reproduction" by academic owners. OSU MAP offers more on-line help than the other three GISs combined. This is partly due to the need to remember command syntax, as mouse support is not available. Given this on-line assistance and well-written printed documentation, OSU MAP rates Excellent in this category.

Ease of Learning

Unlike the other three GISs, OSU MAP does not include example problems in its documentation. The user may, of course, read the documentation and experiment with commands using one of the databases included in the OSU MAP package. Abundant on-line assistance further aids the learning process. For ease of learning, OSU MAP rates Good.

Ease of Use

Due to the arrangement of map databases into separate DOS subdirectories, OSU MAP allows users to easily identify, utilize, and store map layers for particular study areas. Whereas the "list" command in IDRISI provides the user with a long scrolling list of all available "image files," OSU MAP's list command provides a list of the map layers available within a single database, and some map attributes as well. The user can then execute a command referring to this list for specific file names and their spelling. This is a functionally adequate alternative to supporting mouse-driven selection. After learning OSU MAP's command options and user interface, the system is quite easy to use, and thus rates Very Good.

Support

A statement of "limited support" is made in the OSU MAP shipment cover letter, and an on-screen invitation to write or call if questions arise appears upon exiting the system. In addition, registered users receive periodic software updates (I received an update only three days after taking shipment of version 3.0). Academic institutions may arrange to obtain OSU MAP source code by contacting Dr. Marble. OSU MAP is not copy protected. Software support for OSU MAP is rated Good.

Value

At prices ranging from $70 for academic institutions to $160 for outside individuals, OSU MAP is a bargain. The inclusion of several useful map databases is an added bonus. However, lack of well-defined user support and limitations to import/export capability may make OSU MAP a bit more burdensome than others in this review. OSU MAP is rated a Very Good value.

MAP II (version 1.0 tested)

John Wiley and Sons, Inc., Eastern Distribution Center, #1 Wiley Drive, Somerset, New York 08875. Telephone: (212) 469-4400.

Introduction

MAP II's documentation defines it as both "Map Processor" and "Geographic Information System for the Macintosh." This same documentation then defines Dana Tomlin's MAP as a GIS, yet MAP II as a "map processor, an offshoot of GIS" offering user friendliness, ease of map input and output, and the "ability to perform spatial processing using screen tools and menu choices as well as text-based operations." These definitions are questionable, but it is clear that MAP II is a unique product unlike more traditional GIS.

MAP II is designed to run under System 6.0 or higher on the MacPlus, Mac SE, and Macintosh II. The software requires at least 1MB of memory, and 2MB is recommended. A hard disk is also recommended, as is a color monitor and 8-bit video upgrade (if using a Macintosh II). Although now being distributed by John Wiley, MAP II has roots firmly in academia, specifically
in the Department of Geography at the University of Manitoba.

Features

MAP II is the first successful marriage of map analysis package "map algebraic" functionality with Macintosh user interface technology. This interface allows the user to explore and experiment with various "projects" (collections of map overlays) by simply double-clicking here and there. This exploration gives the user a comfortable feeling, one which is difficult to attain with a command-line user interface. Nearly every command issued in MAP II may be "undone" if a problem should result from its execution. Additionally, direct manipulation of icons and windows offers flexibility not found in most GIS. MAP II is the only one of these four GISs that allows several maps to be displayed on the screen simultaneously, each in its own window. The map layers can be scrolled, colored, or manipulated, and their attribute (legend) windows may be displayed as well. This provides superior data visualization, since two maps and the result of overlaying them may be displayed on a single Macintosh II screen. MAP II offers a fine collection of both
user interface and map manipulation features.

Performance

I tested MAP II on a Macintosh II (8MB, no math coprocessor, 8-bit color) without problems. System operations proceed quite rapidly, with the exception of those related to image filtering, which could utilize a math coprocessor. Another minor, time-consuming problem is that map (bitmap) redraw occurs whenever an overlaid window or dialog box is removed, and this redraw is disappointingly slow. Lack of the math coprocessor is not, unfortunately, a factor in map redraw or other integer-based window management operations. Given the flexible multi-window user interface and the acceptable processing/display speed, MAP II's performance rates Very Good.

Documentation

MAP II includes two 6-by-9 inch, spiral-bound, professionally printed manuals. The first, "Reference," contains about 200 pages including a table of contents, 10 chapters, three appendices, and a comprehensive index. The second volume, "Tutorial," contains about 160 pages of pedagogic information and practical examples. The examples are relevant and their solutions are kept in a separate appendix. Some of the material in the two volumes is redundant, but this is necessary since users might buy one but not both. Surprisingly, no on-line help, other than standard dialog boxes, is available. For this reason, MAP II's documentation is rated Very Good rather than excellent.

Ease of Learning

As mentioned earlier, the user interface is a marvelous support while learning MAP II. The two volumes of documentation may require a bit of time to sort through, but the user can learn the system within an hour or so after parts of the documentation have been digested. For ease of learning, MAP II is rated Very Good.

Ease of Use

MAP II is very straightforward and offers few unpleasant surprises. Some icons may take a while to catch on to, such as the vertical slide bar to control zooming in and out: this is a questionable graphic metaphor. Also, users must remember to "lock" maps to avoid editing the original data. After learning the system's few idiosyncrasies, however, analyzing map layers becomes a real pleasure. The ability to open multiple windows displaying several map layers (in color!) and to watch the result of an overlay routine evolve in still another window is something I am accustomed to seeing in the microcomputer world. This implementation of MAP commands transcends simple number-crunching. Students and other users may be able to conduct better-organized research within this GIS environment. MAP II rates Excellent in ease of use.

Support

Registered users of MAP II may receive technical support by calling either the publisher (John Wiley) or the developer (University of Manitoba). It is comforting to have two parties to call on if trouble arises. The publisher restricts phone support to educators only, asking that students not call directly. MAP II is not copy protected. MAP II's support policy is as good as can be expected for an inexpensive software product, and therefore rates Excellent: best in this class.

Value

MAP II is priced at $125 for a laboratory site license, which includes the two volumes of documentation. Extra (student) copies of the Reference Manual are priced at $39.95 each, a figure that violates somewhat the inexpensive nature of the software. MAP II is a gift to any laboratory utilizing the Macintosh. Its low price, full functionality, professional documentation, and doubly covered technical support make this GIS an extremely safe purchase, and MAP II is therefore rated an Excellent value, in the same range as IDRISI.

macGIS (beta version 0.89 tested)

Department of Landscape Architecture, University of Oregon, Eugene, Oregon 97403. Contact: David Hulse.
Introduction

macGIS is defined as a "raster based geographic information system that streamlines the process of database construction and manipulation by capitalizing on the Macintosh graphic interface." macGIS is appropriate for introductory GIS instruction and for small research projects. macGIS includes a healthy subset of original MAP commands, allows command sequences to be stored as "models" for later execution, but does not directly support color on the Macintosh II.

The 800K distribution disk includes GIS View, an interesting wireframe surface modeling program, and a database including 18 map layers. Both macGIS and GIS View run on the MacPlus, Mac SE, and Macintosh II, require 384K of memory (though I recommend 1MB for most Macintosh applications), and were designed to run under System 6.0.3. Not as full-featured as MAP II, macGIS does supply the tools necessary to import, analyze, and display grid-based map data.

Features

macGIS is a simple Macintosh implementation of MAP and this simplicity aids in the use of the software. Directly related to simplicity is the software's economy: both macGIS and GIS View fit comfortably on a 400K disk, which eases startup
using even low-density external disk drives. The beta version of macGIS performed quite well, with only minor glitches, and a polished version 1.0 will have been released before this review is published. Another strong feature is what macGIS calls “model building”; the ability to record a session of commands as a macro to be recalled and executed at a later time. Special attention to individual commands, through the implementation of specific dialog boxes, further aids in the use of macGIS.

Performance

I tested macGIS and GIS View on both a MacPlus (1MB) and Macintosh II (8MB), no math coprocessor, color under Systems 6.0 and 6.0.3 without problems. Map (bitmap) display is relatively fast on both the Macintosh II and MacPlus, partly due to the fact that the software is not burdened by color. As far as number-crunching, some commands require several minutes to execute, with a pie-chart icon slowly filling and refilling throughout. The user may be surprised, when the pie first completes filling, to discover that this is arbitrary animation and that number-crunching is not complete. The wireframe model drawing speed of GIS View is noticeably slow even on the Macintosh II, with so called “high resolution” models requiring several minutes to complete. On the positive side, these displays are often interesting enough to warrant waiting, and a direct manipulation cube which contains 3-D viewing parameters is an interesting addition. Overall, the performance of macGIS rates Good.

Documentation

Included with macGIS is an 8.5-by-11 inch format, spiral-bound, indexed user’s manual. It contains about 200 pages including lengthy introduction, command description, and database creation sections. An equally lengthy appendix includes information on operational shortcuts and the use of the “command language” used to execute model sequences. This documentation is the most prosaic yet succinctly written of the four examined here; a pleasure to read. No on-line help, other than the standard dialog boxes, is available; because of this the documentation rates Very Good rather than excellent.

Ease of Learning

macGIS is as easily explored as is MAP II. Some of the powerful and unique functions of macGIS, however, lie hidden as the content of some menus changes depending upon previous choices. For example, the “Pict” menu appeared to contain only one “Open Pict” command. This primary menu belies the many Pict georeferencing functions available in submenus had I chosen to open a Pict file. Often, Macintosh menus display all commands, highlighting only those currently active, which offers the user greater power of recognition.

Beyond the few minor idiosyncrasies encountered, macGIS is quite stable, straightforward, and easy to follow. In fact, relying on the structure of the documentation, in a tutorial mode, allows for easy learning within an hour or so. macGIS rates Very Good in ease of learning.

Ease of Use

Once learned, macGIS is perhaps the easiest to use of the four GISs tested. This is due, again, to its simplicity. A large contribution is also made by the implementation of command-specific ‘dialog boxes,’ which prompt the user for command specifications and parameters. Most commands may be executed by merely checking off a few boxes, analogous to answering a few questions, and then clicking on a “do it” button. macGIS rates Very Good for overall ease of use.

Support

Software support consists of an undefined “limited amount of free telephone support.” Addresses and telephone numbers of the two authors are included in the User’s Guide. The authors did return my telephone calls promptly and were very helpful. macGIS is not copy protected.
Because of the available-but-undefined nature of software support, macGIS rates Good.

Value

macGIS is reasonably priced at $100 for a "university version" designed for instructors and $27 for a "student version," a work-alike copy of the university version that limits data file size. Because of its sheer simplicity, macGIS will find its way into many GIS classrooms as an introductory tool for map overlay and data visualization. Cartography instructors utilizing MapMaker or other drawing software may find exporting PICT files to macGIS useful. On the other hand, lack of additional import/export capabilities and of color support are considerable shortcomings given the strong competition elsewhere in this GIS class. macGIS is, therefore, rated a Good value.

Summary

The four GISs reviewed here are all valid candidates for use in introductory GIS coursework or for small research projects. IDRISI, OSU MAP, and MAP II are judged as being appropriate for more advanced teaching and research projects as well. IDRISI and MAP II were especially impressive, both in the quantity and quality of features offered. A summary of the ratings given in this review (Figure 5) shows them slightly ahead of OSU MAP. A GIS/cartographic laboratory may be most dutifully...
FIGURE 5.
Summary of Software Ratings

Rating Categories:
P: Poor, S: Satisfactory, G: Good,
V: Very Good, E: Excellent

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and inexpensively served by the use of both IDRISI and MAP II, due to their firm software support and their ability to transfer data from and to many common formats. macGIS should not be slighted, though it received a lesser rating; macGIS is in only its first full version and it already matches many functional aspects of the other three GISs.

Other Grid-Based GISs Available

*Map Analysis Package (MAP)*

Distributed through the URISA software exchange. Single 5.25” diskette (compressed). This is Dana Tomlin’s original PC version which has inspired, in some manner or another, the four grid-based GISs tested here.

*PANACEA*

Earth Imaging Systems, Inc., P.O. Box 3000, Cambridge, MA 02238. PANACEA runs on IBM-PC/compatibles and is sold as separate modules. It is a very functional system, handles very large grid files, but is in a higher price range than those reviewed here. A full review of PANACEA can be found in Fisher (1988).

*MACGRASS*

Distributed by The Space Remote Sensing Center (SRSC), Building 1103, Suite 118, Stennis Space Center, MS. 39529. In a nutshell, GRASS version 3.0 has now been ported to run under A/UX, Apple Computer’s version of UNIX, on the Macintosh II series of computers.

*EPPL7*

Minnesota State Planning Agency, 658 Cedar Street, St. Paul, MN 55155-1600. Version 2.0 of EPPL7 handles tabular attribute data and performs
standard 2-D topographic functions. A bit more costly than those reviewed here.

References


Michael D. Gould is a Ph.D. student in geography and a research assistant at the National Center for Geographic Information and Analysis, State University of New York at Buffalo. His current research interests include spatial cognition, human-computer interaction in GIS, and the mating of GIS and geographical analysis.
Editor's Note: The following article is an extract from a monograph produced in 1989 by AURISA—The Australasian Urban and Regional Information Systems Association. AURISA is a sister organization to URISA, is approximately 17 years old, and is a major player in GIS/LIS development in Australia. Australians have produced a number of notable GIS/LIS including several exemplary systems, education programs, and significant research. The findings and recommendations presented in this monograph reveal some of the innovative activities in GIS/LIS in Australasia, and indicate directions and solutions that would be applicable for GIS professionals in a variety of settings. The appendices and details, including a GIS/LIS research agenda at the University of Melbourne, international trends in GIS/LIS research and development, research activity in educational institutions, contacts, and institutions teaching GIS/LIS are contained in the full document.

As the major interdisciplinary body associated with the development of Land and Geographic Information Systems (LIS/GIS) in Australasia, AURISA has an obligation to contribute towards a strategy for implementing more effective, responsive and coordinated education and research programs in LIS/GIS in the region.

Consequently, AURISA established a National Working Party in 1987 to examine education and research programs in LIS/GIS, with the following objectives in mind:

To provide a national strategy for integrating and promoting research and development applications and education in LIS/GIS, and to address the current needs and potential growth of the Australian industry, user community, and educational institutions involved in spatial information technology.

AURISA believes that it will provide an effective contribution towards fulfilling these objectives by satisfying the following goals:

- Determine the research issues and the research facilities and programs relating to LIS/GIS in Australia;
- Determine the educational requirements and document the educational facilities relating to LIS/GIS in Australia; and
- Develop methods towards implementing a national strategy on education and research in LIS/GIS.

In this way, AURISA expects to be in a position to participate in both curriculum
development and the directions taken within industry research and development programs.

At the same time, it is noted that AURISA is just one of several parties seeking a voice in this area and that it must present a united front with other interested groups—for example, allied industry representatives and bodies, the Australian Land Information Council (ALIC) and the Australasian Advisory Committee on Land Information (AACLI).

Therefore, the intention of this document is to state AURISA’s policy and opinions, and to stimulate discussion concerning the implementation of better education and research programs in LIS/GIS.

The Australian LIS/GIS Industry

LIS/GIS is now established as one of the major market sectors in information technology with a rapid growth rate. A recent survey (by Dataquest, USA) indicated that the international market for LIS/GIS will be $400 million in 1991. At present, there are about 30 companies

Executive Summary

The major activities of the working party were (1) to determine the research issues and the research facilities and programs relating to LIS/GIS in Australia, (2) to determine the educational requirements and document the educational facilities relating to LIS/GIS in Australia, and (3) to develop methods towards implementing a national strategy on education and research in LIS/GIS.

AURISA recognizes that the development of such a strategy is only the first step in raising the awareness of the need for LIS/GIS education and research in Australasia; however AURISA believes that it is an essential task which is vital to the nation’s economic future. Therefore, with regard to education and research in LIS/GIS, AURISA’s policy will be to:

1. Respond to national forums, reviews, and surveys relevant to research and education in LIS/GIS;
2. Maintain a working party tasked with deriving methods for addressing the education and research issues highlighted in this report;
3. Encourage both public and private sector agencies to support industry-related research and the provision of scholarships at the tertiary level;
4. Encourage both public and private sector agencies to become more actively involved and aware of the need for LIS/GIS education, which includes staff retraining;
5. Support programs of general/specialist short courses dealing with relevant matters in education and training in land and geographic information systems—either by AURISA in its own right, or through its regional affiliates, or in association with other professional societies;
6. Coordinate the provision of materials to assist with education and awareness of the importance of land and geographic information systems (e.g., annotated bibliographies, digital data sets, classroom exercises);
7. Reward innovative research by annually awarding a ‘best research paper’ at the URPIS conference;
8. Include, as a matter of course and in conjunction with future national URPIS conferences, specialist education and training workshops in land and geographic information systems;
9. Include, as a formal part of the URPIS program, sessions devoted to discussion of education and research issues;
10. Include information on education and research developments in AURISA News on a regular basis;
11. Facilitate the maintenance and use of LIS/GIS research and development databases among its membership;
12. And assist with the establishment of a ‘register of experts’ who can be approached for advice not only in education and research in LIS/GIS, but also in other aspects of the industry.
offering LIS/GIS products in Australia, although only a few of these provide Australian-developed products. There is considerable activity in implementing these systems in Australia, and already there are departments in federal and state governments, and many local governments, which have installed extensive LIS/GIS.

The future development of LIS/GIS clearly depends upon the advances made in information technology and the growth in the information industries. Strong growth in these industries is essential in order to reduce the expanding national trade deficit, expected to be around $10 billion in the early 1990s.

In September 1987, the Australian government, through the Department of Industry, Trade and Commerce (DITAC), released an "Information Industries Strategy" aimed at expanding Australian capacity to develop new information industries products and services, which to a significant degree incorporates LIS/GIS developments.

The Information Industries Strategy contains a number of initiatives, including the "Partnership for Development Program"; the "National Procurement and Development Program"; and an expanded "Industrial Research and Development Scheme" (IR & D) in information and communication technology. Clearly, the opportunities exist for LIS/GIS companies to participate in these initiatives.

In addition, issues relating to research and development in the information industries were discussed at a DITAC IR & D Board Workshop earlier this year, where information systems, and LIS/GIS in particular, were seen as an area in which Australian research and development could profitably contribute to the nation's export activities.

However, regardless of the incentives offered by governments, the lack of trained technical and professional personnel is still seen as the most pressing problem facing the growth of the information industries—a situation which applies equally to the development and application of LIS/GIS.

It is obvious that the Australian industry, in both government and private sectors, must display greater commitment and recognition of the urgent need for better educated and trained people in the broad cross-section of technical and professional areas affecting LIS/GIS. Industry must support education and retraining through scholarships, research grants and other funded activities that help produce more people qualified to fulfill the necessary roles in this emerging industry.

Without appropriately trained personnel, neither governments nor the information industries can expect to fully achieve their future objectives in Australia.

Education and Research in LIS/GIS

The Australian government's recent "White Paper on Higher Education" has prompted academic institutions to more closely consider their profiles in education and research. This review has also provided a timely opportunity for institutions to promote the disciplines underlying LIS/GIS—such as geography, surveying, statistics, computing and planning—and to focus on the research necessary to develop and apply LIS/GIS.

The government's increased emphasis on research is expected to result in considerable increases in Australian Research Council funding over the next few years, and both federal and state governments have introduced measures to encourage and promote research and development in high technology areas such as information technology, which underpin LIS/GIS.

AURISA believes that the time is now appropriate for these new opportunities to be promoted to the LIS/GIS community, in order for it to take full advantage of them.

Determining the Research Issues

To date there have been few attempts to identify the research issues facing LIS/GIS, and clearly they will not be solely determined by AURISA. Indeed, industry-wide problems must be recognized and solved by the industry as a whole, and in this
respect the URPIS Conferences represent perhaps the best forum for voicing LIS/GIS concerns and issues, which in turn can be reported via AURISA News.

Recently the U.S. National Science Foundation determined five basic research priorities in LIS/GIS:

- Improved methods of spatial analysis and advances in spatial statistics
- A general theory of spatial relationships and database structures
- Artificial intelligence and expert systems relevant to the development of GIS
- Visualization research pertaining to the display and use of spatial information
- Social, economic and institutional issues arising from the use of GIS technology

However, this type of list is only a starting point towards implementing a national strategy and must become part of a more formal and systematic program of basic and applied research. Furthermore, in carrying out such a program, long-term strategic research objectives have to be defined and clearly distinguished from short-term 'brush fire' type issues confronting systems on a day-to-day basis.

Obviously, industry-wide discussions are needed on this matter and it is expected that the major contributors will include:

- Members of the Australian Land Information Council (ALIC) and the Australian Advisory Council on Land Information (AACLI);
- Federal, state, regional and local government agencies developing LIS/GIS;
- Major educational institutions;
- The Commonwealth Scientific and Industrial Research Organization (CSIRO);
- The LIS/GIS private sector; and
- Other practicing professionals involved in the development of LIS/GIS.

Given Australia's relatively advanced stages of LIS/GIS development, it could be argued that there are perhaps a number of 'system-saving' issues that need to be given high priority and investigated immediately, in order not to encumber operational systems with liabilities such as corrupt data and poor performance levels.

Specifically, a number of systems in Australia need to have operational answers to problems such as: the updating of graphical data, particularly across networks; quality assurance mechanisms to detect low quality rather than non-conforming data; efficient methods of quality identification on individual data items; and methods of maintaining performance levels and curtailing data volumes as systems grow beyond the capabilities of existing data models and database management systems.

Nevertheless, if research in LIS/GIS is to achieve the impact and reap the benefits that it deserves, it will have to be performed and directed in accordance with some overall research methodology and plan as determined by the LIS/GIS community. AURISA contends that it should take the lead in developing and promoting such a research and development strategy.

Naturally, research priorities will vary with time. However, unless AURISA assists in defining the framework within which this research should be organized and directed, then it is likely that much of the research effort will be expended in undertaking needy short-term problems to the detriment of investigating perhaps the more fundamental difficulties that are confronting LIS/GIS technology and practice.

Research Facilities and Programs in LIS/GIS

A good starting point for determining the level of LIS/GIS research activity within Australia is to consult past proceedings of the AURISA national conferences which, to a large extent, contain the body of knowledge underpinning the LIS/GIS industry in the region. AURISA also maintains past proceedings on microfiche and keeps an index of all papers presented at its conferences.

In general, the LIS/GIS research effort in Australia is shared among four main sectors of the industry:

- Tertiary institutions
- Government departments and instrumentalities at federal, state and local government levels involved in LIS/GIS initiatives
- CSIRO
- Private companies and particularly LIS/GIS software vendors.

First, as a means of determining the level of research and development activity in the tertiary institutions, AURISA sent a questionnaire to each university and college of advanced education with Australia and New Zealand—receiving replies from 52 departments and schools at 38 institutions.

The results of this survey show that while there is considerable work being done in the areas of natural resource, land use and planning, and parcel-based systems development, few institutions are researching the application of artificial intelligence to LIS/GIS, or the study of utility, transportation, and local government systems.

While it was relatively easy to gauge the research and development activity in the education sector, a more difficult task was to quantify the level of research taking place within government and semi-government agencies. The reasons for this are complex, although the lack of publicity possibly is due to the need to keep a low profile until developments are proven, and because as a general rule, these organizations have difficulty justifying this type of expenditure.

AURISA suggests that the best way to determine the level of research and development within public agencies in each state is to make initial contact through the secretariat of the Australian Land Information Council (ALIC), or to contact the state representative of AACL.

With regard to the CSIRO, considerable research and development in LIS/GIS is being undertaken by the Divisions of Information Technology, Soils, Wildlife and Ecology, Water Resources, and Construction and Technology, and it is fairly easy to identify since the CSIRO has a strong need to publish the results of its work.

Finally, the activity by software and hardware vendors is, for obvious reasons, hard to assess until new products are released, although most vendors keep their customers well informed of proposed developments.

Determining LIS/GIS Educational Requirements

Already, the Department of Employment, Education and Training (DEET) has initiated a study of the skill and training needs of Australia's computing professionals and para-professionals. This study will assist academic institutions in developing curricula which relate to the needs of industry over the next 10-20 years. Academic institutions should react positively to these results and use them as a foundation for determining the added requirements of LIS/GIS education.

An essential step in determining these requirements is to identify those market areas that need personnel with LIS/GIS skills. These are tentatively nominated as being:

- Land Administration and Management
- Local Government
- Spatial Data Processing and Handling
- Environmental and Natural Resource Studies
- Defense Systems
- Social and Economic Research
- Education
- Urban and Regional Planning
- Utilities/Facilities Management
- Surveying and Mapping
- Health Services
- Market Research
- Retailing/Finance/Banking

From these market areas, subjects can be derived which should form the core of any education program designed to provide students with a background in LIS/GIS skills, regardless of their major disciplinary interest.

It is AURISA's view that the aims of such programs should:

1. Provide an understanding and awareness of the real world and existing structures.
2. Develop a knowledge of methods of representing the real world.
3. Understand the characteristics of technology.

4. Provide students with the skills necessary to use technology.

While educational institutions are already capable of addressing the first two aims, the latter two present difficulties because of the rapidly changing technological environment. Therefore, education strategies will also be needed to maintain our educators' knowledge base, and to maintain the standard of software and hardware required for training.

One possible solution to this last point is to place the emphasis upon cooperative education and training through the help of industry support schemes. This would be more economical for the country as a whole, since the latest technology will be placed in industry rather than residing in institutions and being continually updated at public cost.

Currently, there are several programs that are bringing the academic and industrial worlds closer together, thereby satisfying the needs and aims of both governments and the parties concerned. These programs include Teaching Companies, the federal government's Civil Offset and Partnerships program, and the 150 percent R & D tax incentive scheme.

In other disciplines, computer science for example, state governments are already providing funding for industry-supported courses that require students to spend part of their time working with major companies. In addition, schemes such as the Victorian Education Foundation (VEF) offer support in high-technology areas through "seed funding" for new courses.

The need for education and training in LIS/GIS was recently highlighted in an excellent study by the Western Australian Land Information System Executive Policy Committee, and undertaken by Arthur Young Management Consultants ("WALIS Training Needs — Final Report" published by the WALIS secretariat, Perth, 1988).

Even though the study was primarily directed towards government needs, the findings have a general application. The study confirmed that a large number of people require education and training in LIS/GIS.

Training needs were categorized into fourteen skill subject areas ranging from an understanding of the Western Australian land data environment, to skills training on specific software packages. Proposed courses were identified from this needs analysis.

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**Membership of the AURISA National Working Party on Education and Research in LIS/GIS**

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<tr>
<th>Chairman:</th>
<th>Ian Williamson</th>
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<td>Secretary:</td>
<td>Gary Hunter</td>
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<td>John O'Callaghan</td>
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Some of the major recommendations of the report are:

- Establishing a real-life multi-disciplinary project ("pilot project") to apply modern techniques in LIS/GIS to give staff realistic project experience;
- Establishing a Research Chair in GIS applications;
- Involving the WALIS secretariat in the curriculum activities in tertiary institutions;
- Instigating public service scholarships for study in LIS/GIS; and
- Appointing a training coordinator for LIS/GIS.

**Educational Facilities in LIS/GIS**

In order to determine the extent to which educational institutions are already responding to the needs of LIS/GIS, it was necessary to identify which major institutions have relevant education programs in place. In addition to formal courses in LIS/GIS related areas, it is noted that other forms of industry education may cover a much broader range of activities.
including seminars, conferences, workshops and short courses—services which are already provided by many institutions.

It is also noted that AURISA and other professional societies often run continuing education courses, and some state government departments are also taking an active role in the sponsorship of short courses, workshops, and the funding of international speakers at LIS/GIS seminars.

Methods Towards Implementing A National Strategy in Education and Research in LIS/GIS

AURISA intends to formally engage in the promotion of its policies in education and research in land and geographic information systems, at all levels consistent with the aims and objectives embodied in its charter of incorporation, and in conjunction with other interested parties.

The areas of LIS/GIS with which AURISA is concerned are:

- Research and development
- Education and training
- Information exchange
- Advisory services

Research and Development Policy

With regard to research and development in LIS/GIS, AURISA will:

- Maintain a working party tasked with deriving methods for addressing the research and development issues highlighted in this report (this working party will also deal with education and training);
- Encourage both public and private sector agencies to support industry-related research and the provision of scholarships at the tertiary level; and
- Reward innovative research by annually awarding a 'best research paper' at the URPIIS conference.

Education and Training Policy

As a means of encouraging increased education and training, AURISA will:

- Support programs of general/specialist short courses dealing with relevant matters in education and training in land and geographic information systems—either in its own right, or through its regional affiliates, or in association with other professional societies and bodies;
- Include, as a matter of course and in conjunction with future national URPIIS conferences, specialist education and training workshops in land and geographic information systems; and
- Encourage both public and private sector agencies to become more actively involved in and aware of the need for LIS/GIS education, which includes staff retraining.

Information Exchange Policy

In adopting the role of an information exchange agency, AURISA will:

- Include information on education and research developments in AURISA News on a regular basis;
- Facilitate the maintenance and use of LIS/GIS research and development databases among its membership;
- Include, as a formal part of the URPIIS program, sessions devoted to discussion of education and research issues; and
- Coordinate the provision of materials to assist with education and awareness of the importance of land and geographic information systems (e.g., annotated bibliographies, digital data sets, classroom exercises).

Advisory Services Policy

As a professional association, AURISA has an inherent body of expertise in LIS/GIS within its membership that is unmatched in the region. Therefore, as a service to both its membership and to the community, AURISA will:

- Assist with the establishment of a 'register of experts' who can be approached for advice not only in education and research in LIS/GIS, but also in other aspects of the industry.

Promotion of AURISA's Policies

As a means of promoting AURISA's policies in LIS/GIS education and research, the following organizations should be advised:

1. Government (Industry, Trade and Education)
   - Federal ministers
   - Funding agencies
   - AIDAB/IDIP
   - AVCC/ACDP
   - State education departments

AURISA Monograph/URISA Journal 101
• Australian Research Council (ARC)
• Department of Education, Employment and Training (DEET)
• DITAC
• ASTEC

2. Information Industry
• Information Industries Council (export ties)
• Australian Information Industry Association

3. Others
• Other professional bodies associated with LIS/GIS
• Allied industry councils, e.g., survey and mapping
• Corporate members of AURISA
• Academic institutions
• Local government associations
• The media

Clearly, the initial thrust should be aimed at governments, emphasizing that LIS/GIS are important new areas of the national economy; Australia is up with the world leaders in the field; and LIS/GIS have excellent export market potential, especially in the Pacific region.

With these particular areas in mind, it is recommended that the style of document to be distributed to each group be tailored accordingly for maximum impact. For example, one document would be intended for ministers and AVCC/ACDP members (there may be several versions). A summary document/policy statement would be tailored for industry, outlining AURISA's position. An advisory document would be designed to assist institutions in starting their courses. (This could be a 'getting-started kit' and might only concentrate on establishing low-cost course packages.)

Summary

While AURISA is just one of several groups having an interest in research and education programs in LIS/GIS in Australia, it is recognized that coordination and cooperation are the essential keys (as they are with the establishment of LIS/GIS) in ensuring that a single voice on this matter is presented to those parties that have the greatest effect on changing this aspect of the industry.

AURISA views its role as that of a facilitator and coordinator, which implies close working relationships with other parties in working towards the implementation of a national strategy.

The challenge rests with all people and parties involved with the industry, and AURISA believes that it can make a valuable contribution to the debate and hopefully act as a catalyst for promoting a strong education and research base in LIS/GIS in Australasia, for the benefit of the whole community.
GUIDELINES FOR MANUSCRIPT SUBMISSION

REFEREED ARTICLES

1. *URISA Journal* welcomes manuscripts and accompanying graphics and illustrations on all topics that are germane to information systems, their evaluation and implementation. Articles must be based upon sound scholarship and provide information that is relevant to information systems and associated disciplines.

2. Since the review process requires that voluntary evaluators spend a significant amount of time selecting papers for publication, the submission of a manuscript marks the author's intention to publish in *URISA Journal*. Therefore, the simultaneous submission of a manuscript to other journals is considered unacceptable. Also, manuscripts previously published, either in a literal or approximate form, ordinarily cannot be accepted. Consult the editors if in doubt.

3. Submit three (3) copies of the manuscript to:

   Kenneth J. Dueker, Portland State University, Center for Urban Studies, P.O. Box 751, Portland, OR 97207.

   Be certain to retain a fourth copy for your own files. All submissions must be typewritten and double spaced on 8-1/2" × 11" paper. Leave a margin of at least 1" on all sides. Double space all material, including lengthy quotations, the abstract, notes, and references.

4. The cover page should include the title of the paper and the author's name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author's education, professional positions, current affiliation, and research interests.

5. Submit a one-paragraph abstract of approximately 100 words. Include the title of your paper with your abstract, but do not place your name on this page. Similarly, do not indicate your name on the first page of the manuscript.

6. To ensure anonymity in the blind review process, authors should be careful that the text not refer directly to their previously published works. In other words, avoid sentences such as: "The author's (Doe 1975, 1977) previous work revealed that..." If the paper is accepted, sentences can later be reviewed to reflect the above.

7. Within the text, references should be cited by using the author's name and year of publication. When using direct quotations, also include the page number(s). For example:

   Many employers and corporations have chosen to pursue a hands-off policy (Taylor 1915). "City planning and unified architectural design," according to Tunnard and Reed (1953, p. 131), "were lost to these new communities."

8. Multiple references in the text should be listed chronologically rather than alphabetically (Zube 1973; Jackson 1978; Tuan 1980).

9. References should be listed on separate pages at the end of the text. These should be alphabetized by using the authors' last names. When an author has more than one publication, arrange the references by placing the most recent one first. For books, be certain to include place of publication and publisher; for a journal include volume, month, and pages. Do not abbreviate titles or citations:


10. If necessary, explanatory notes may be used. These should be numbered consecutively and must be included on separate pages at the end of the text.

11. First-order subheadings should be placed to the left-hand margin on a separate line. Capitalize the first letter of major words. Text should follow on the line below the subhead.

12. Second-order subheadings should be placed to the left margin and followed by a period. The first letters of major words should be capitalized. The text should begin on the same line.

13. Third-order subheadings should be placed to the left margin and underlined. Capitalize the first letter only.

   EXAMPLE:
   • First-Order Subhead
     The text should start on the line below.
   • Second-Order Subhead. The text should begin on the same line.
• **Third-order subhead** The text should begin on the same line.

14. Long quotations (five or more lines of typescript) must be indented five spaces and double spaced.

15. All tables should be typed on separate pages. Indicate where a table or figure should be placed in the text by including notations such as (Table 1) or (Figure 1). Wherever possible, place these notations at the end of a sentence. Try to avoid sentences such as "Table 1 shows that..." Instead, use constructions that place the table or figure number at the end of the sentence:

   "The data indicate that all species were susceptible (Table 1)."

16. Any acknowledgement must be included at the end of the text. The heading for this page should be: Acknowledgements.

17. Authors will receive two copies of the URISA Journal issue in which their article appears. Reprints of articles can be ordered, at cost, by the author.

**FEATURES AND REVIEWS**

1. Submit two (2) copies of the manuscript and accompanying photos, graphics or illustrations to the appropriate section editor listed below. Be certain to retain a copy for your own files. All submissions must be typewritten and double spaced on 8-1/2" × 11" paper. Leave a margin of at least 1" on all sides. Double space all material, including lengthy quotations, notes, and references.

2. The cover page should include the title of the paper and the author's name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author's professional position, current affiliation, and interests.

3. Follow refereed article guidelines listed above for proper presentation of subheadings, quotations, tables and acknowledgements.

4. Contact the following section editors for details regarding specific manuscript formats for categories such as software reviews:

   **Features editor:**
   John Antenucci, PlanGraphics, Inc., 202 West Main Street, Frankfort, KY 40601.

   **Reviews editor:**
   Rebecca Somers, County of Fairfax, Division of Communications, 4103 Chain Bridge Road, Fairfax, VA 22030.

5. Authors will receive two copies of the URISA Journal issue in which their article appears. Reprints of articles can be ordered, at cost, by the author.

**GUIDELINES FOR ILLUSTRATIONS**

Photocopies of proposed illustrations, photos, or other graphic materials should be submitted with the text at the time of submission (three (3) copies for refereed section; two (2) copies for other sections). Include, on a separate page, a brief title and explanation for each figure.

**Line Copy**

1. Line copy (e.g., sketches, graphs, computer graphics) should be submitted on high-quality paper or as original drawings on illustration board or drafting paper in black ink.

2. Graphic material should not normally exceed 8-1/2 × 11 inches (21.5 × 28 cm), in order to prevent damage during mailing.

3. Line copy will often be reduced to meet space limits. Therefore, avoid extremely small print or complicated graphics (such as fine cross-hatching or dot patterns), which would not "read" at a reduced size.

4. Lettering on all copy should be clean and open. Use capital letters whenever possible.

5. All line copy should be identified with: (1) author's name, (2) the figure number, (3) where applicable, artist credits.

**Photographs**

1. Submit only original glossy black-and-white photographs. (Color is acceptable only for map section.) 5 × 7 inch or 8 × 10 inch sizes are acceptable.

2. Avoid fingerprints, heavy pen or pencil marks, or damage from paper clips on the photographs.

3. Identify all photographs with: (1) author's name, (2) the figure number, (3) credits (e.g., Photograph courtesy of Arizona State Museum, Jack Smith, photographer).
GUIDELINES FOR FEATURE MAP SUBMISSION

1. The focus of the map section is on the image itself. We will consider both color and black-and-white submissions. You may submit a complete map, an enlarged portion of a map, or both. The following criteria will be taken into account: visual quality of the map; amount and quality of information transmitted; and reproducibility of the map within the journal context.

2. We will accept printed maps or maps available in hard copy, provided they are clean and that you indicate the portion you wish to be published. Alternatively, we require glossy 8 × 10 color or black and white prints. Slides are acceptable but must be accompanied by a print. All submissions should be of high quality. This is especially important for computer-generated images, which can be difficult to reproduce.

3. Two to six double-spaced pages of text should discuss the map and its construction.

4. Include a separate page with the title, and author's name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author's professional positions, current affiliation, and research interests.

5. Any acknowledgement must be included at the end of the text under the heading: Acknowledgements. If your submission is a copyrighted image, please contact the map section editor to make special arrangements.

6. Submit map materials and text to the section editor:

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