MONTANA
Policy Review

THE POWER OF GIS APPLIED TO LOCAL GOVERNMENT

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A Geographic Information System (GIS) is a computerized data base management system for the storage, retrieval, analysis and display of spatial data.[1] These systems can be distinguished from other computer mapping and computer-aided design (CAD) tools in that they: (1) fully integrate map and attribute data; (2) use modern coordinate systems to define the positions of features on the earth's surface so that they can be accurately represented in the database; and (3) provide spatial analysis tools unavailable in most other software packages. This paper will describe these features and use the location of a new park to illustrate how they can be applied to assist local government planning efforts.

> ***Geographic Information Systems combine map and attribute data and afford local governments new opportunities for integration in that these data can be processed together as a single product with little manual intervention. This integration is possible because geography is a common reference used by virtually every activity in local government, whether it to be to find a water main valve, set property tax assessments, or begin a new solid waste recycling program.[2]***

Database Integration

Maps and data associated with locations have been used throughout history by local governments for delivering public services, managing public resources, and setting public policy.[2] Most of these information resources are still stored in file cabinets and map drawers and used as paper records and products in city and county government offices. In addition, those property tax and other financial data that have been computerized during the past twenty years only acquire meaning when they are used with a map as a reference, and these data will often have to be manually transferred to maps for further review, display, and analysis. Huxhold[2] opened his recent book on Urban GIS with the following quotation:

> We have for the first time an economy based on a key resource that is not only renewable, but self-generating. Running out of it is not a problem, but drowning in it is.
>
> (Naisbitt, p. 24)[3]

This last statement indicates how information can (and should) be viewed as a resource by an organization (similar to people, money, and equipment) and why careful management will be required if it is to improve the effectiveness and efficiency of local government operations.

Geographic Information Systems combine map and attribute data (Figure 1) and afford local governments new opportunities for integration in that these data can be processed together as a single product with little manual intervention. Hence, these systems can be used to integrate information from many different sources (e.g., the engineering, finance, and planning departments) and at many different levels of responsibility (i.e., the operations, management, and policy levels) in an organization. This integration is possible because ***geography*** is a common reference used by virtually every activity in local government, whether it to be to find a water main valve, set property tax assessments, or begin a new solid waste recycling program.[2]

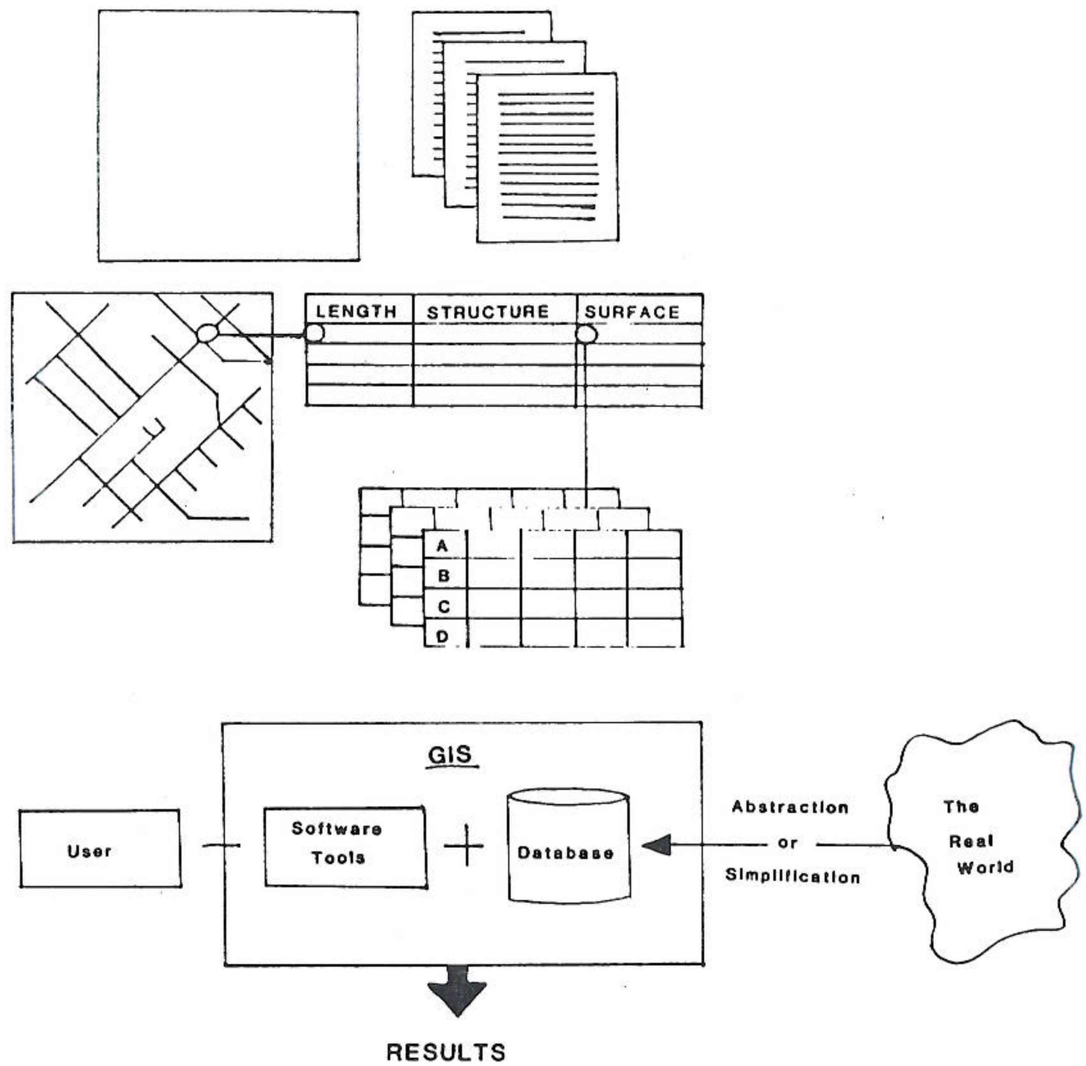


Figure 1: Components of a modern GIS. [4]

Most GISs store attribute data in a series of relational database tables. The records can be combined so long as a common item exists in two or more tables. A property tax identification code is often used for this purpose in local government GIS applications (Figure 2). The spatial or map data are usually stored in some proprietary format, although these data can be linked with the tabular data based on a common item as well. There are two choices: (1) adding an item to the spatial data, or (2) adding one of the items from the spatial data to one of the tables with your attribute data. The first option is illustrated in Figure 2 where an item representing a property tax identification code has been added to the four default items generated by PC ARC/INFO[5] when topology is constructed.

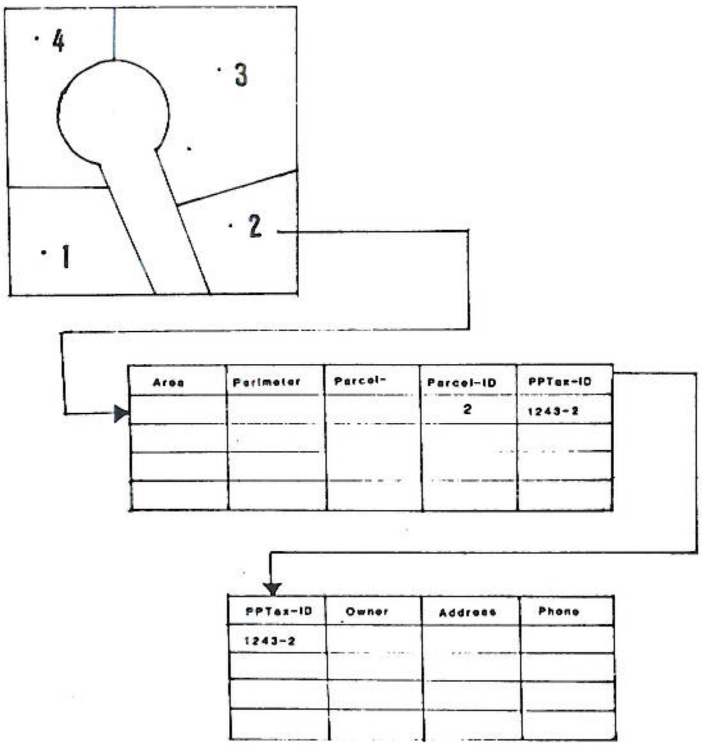


Figure 2. Relational database structure used by PC ARC/INFO[5].

The presence of these common items means that the records in two or more tables can be permanently or temporarily joined based on the values of the common item. This capability means that database queries can be implemented via the spatial features or the tabular database items. Hence, we can query the attribute data to identify all of the land parcels with delinquent property taxes and color a map of land parcels accordingly. Alternatively, we could point to one or more features (i.e., land parcels) in the spatial database and obtain key information such as the name, address, and telephone number of the landowner(s).

Modern Coordinate Systems

The locations of the features stored in the database must be accurately recorded in terms of their real-world positions to perform the spatial operations described in the next section. Their locations can be recorded in global coordinates (latitude, longitude) or planar coordinates (e.g., State Plane feet or Universal Transverse Mercator (UTM) meters) although both types of system imply the existence of a survey control network and the ability to convert measurements (e.g., distances and directions) to locations measured in at least one of these coordinate systems.

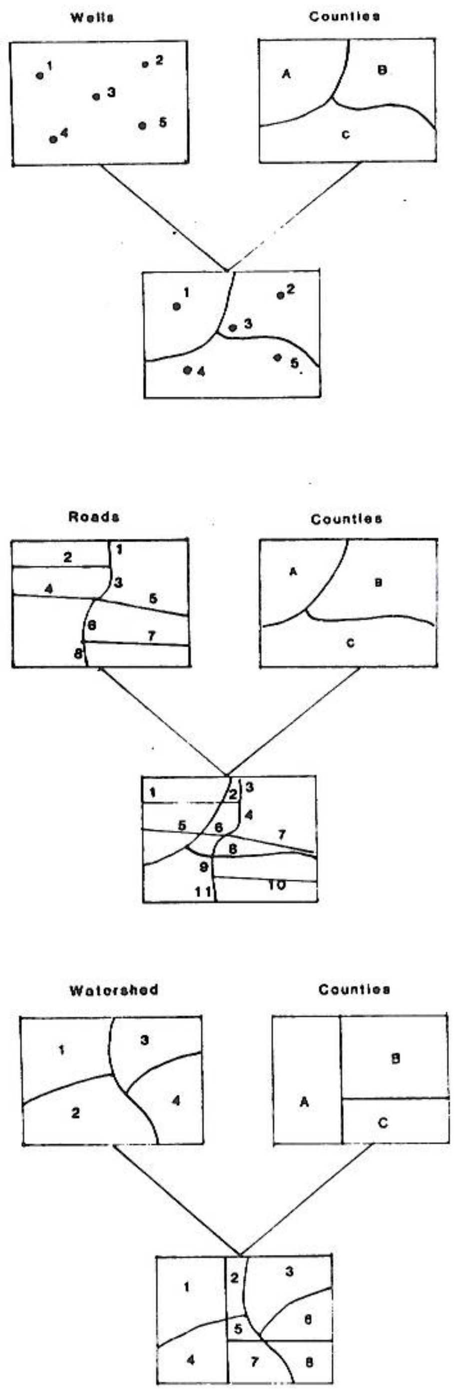
This requirement is often a problem for small cities and rural counties because they: (1) lack a survey control network, and (2) use a local coordinate system. A considerable effort is required to establish a control network and record the locations of important features in some modern coordinate system prior to GIS implementation in these instances. The two papers by Magnant et al. and Breckenridge which appear later in this special issue discuss some of the options as well as the importance of this task in greater detail.

Spatial Analysis Tools

Most successful GIS applications utilize geographically-referenced data as well as non-spatial data and include operations which support ***spatial analysis.*** Two database models are commonly employed: (1) the raster GIS divides the world into a series of pixels or cells, and (2) the vector GIS represents the world as a series of points (nodes), lines (arcs), and areas (polygons). The latter database model will usually be required for GISs that are constructed from land records and applied to city and county government. However, it is the ability of GIS to perform ***spatial operations*** (overlays, buffers, etc.) rather than the choice of database model that distinguishes GIS from the other computer programs (spreadsheets - Lotus 123, Quatro, etc.; statistical packages - Minitab, SAS, SPSS-X, etc.; and drafting packages - MacPaint, AutoCAD, etc.) which also utilize spatial data.[4] Overlay and buffering capabilities are found in most GIS software packages and they are used here to illustrate some of the spatial operations that can be implemented to assist local government.

Topological overlay is the general name given to the procedure in which two or more data layers are combined and then planar enforced. The rules of planar enforcement are required in most vector GISs and mean that new intersections are computed and created wherever two lines cross and that lines crossing area objects create at least two new area objects when overlays are performed. These rules ensure that the relationships between the different geographic features and their non-spatial attributes will be updated for the new, combined maps that are created when one map is overlaid or superimposed over another map.

Figure 3 illustrates the point-in-polygon, line-on-polygon, and polygon-on-polygon overlays that can be performed in a vector GIS. A point coverage showing water wells was overlaid with a polygon



ID	Owner
1	Dickinson
2	Murray
3	Smith
4	McBron
5	Harris

ID	County
A	Park
B	Gallatin
C	Madison

ID	County	Owner
1	Park	Dickinson
2	Gallatin	Murray
3	Gallatin	Smith
4	Madison	McBron
5	Madison	Harris

ID	Highway
1	35
2	22
3	35
4	60
5	60
6	35
7	82
8	35

ID	County
A	Park
B	Gallatin
C	Madison

ID	Original	Highway	County
1	2	22	Park
2	2	22	Gallatin
3	1	35	Gallatin
4	3	35	Gallatin
5	4	60	Park
6	4	60	Gallatin
7	5	60	Gallatin
8	6	35	Gallatin
9	6	35	Madison
10	7	82	Madison
11	8	35	Madison

ID	Status
1	Natural
2	Natural
3	Controlled
4	Controlled

ID	County
A	Park
B	Gallatin
C	Madison

ID	H2o ID	County ID	H2o Status
1	1	A	Natural
2	1	B	Natural
3	3	B	Controlled
4	2	A	Natural
5	2	B	Natural
6	4	B	Controlled
7	2	C	Natural
8	4	C	Controlled

Figure 3: Point-in polygon (a), line-on-polygon (b), and polygon-on-polygon (c) topological overlays.[7]

coverage showing county boundaries to produce a new composite map and attribute table showing both sets of features (wells and counties) in Figure 3A. A line coverage representing a road network was overlaid on a polygon coverage showing the same county boundaries to produce a new composite map and attribute table showing both sets of features (road segments and counties) in Figure 3B. Notice in this example how the lines (roads) were broken at each area object (county) boundary and that the number of output lines (road segments) is greater than the number of input lines (roads). The final example in Figure 3C shows what happens when one area object layer (watershed boundaries) is overlaid on another area object layer (county boundaries). Notice again how the boundaries are broken at each intersection and how the number of output areas (watershed/county combinations) is greater than the total number of input areas (watersheds and counties).

Buffers can also be constructed around points, lines or areas in a vector GIS to create new areas that enclose the buffered objects (Figure 4). Some GISs give the user the option of using one of the attributes of the object to determine the width of the buffer. Hence, the type of street (major, secondary, tertiary) might be used to buffer residential buildings away from a street network (using setbacks of 600 feet for a major street, 200 feet from a secondary street and 100 feet from a tertiary street, etc.). Buffers can help with numerous local government tasks; for example, they can be used to find the names and addresses of all of the property owners who own property that is located within a certain distance of one or more land parcels. The owner of these parcels may have applied for a zoning variance and the city may have a legal obligation to notify surrounding landowners of a public meeting and/or comment period in these circumstances. GIS can speed up and reduce the likelihood of errors in this example so long as the buffer and subsequent queries are properly formulated and the appropriate databases are regularly updated.

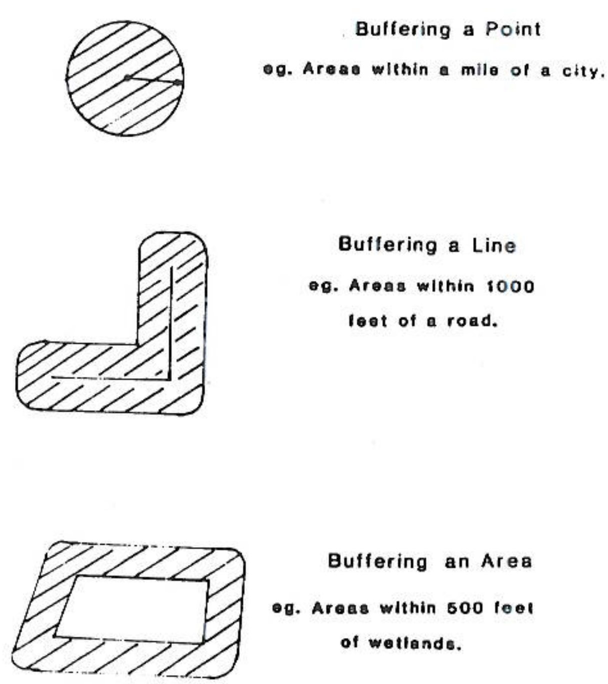


Figure 4: Buffering examples.[7]

Finding the Best Site for a New Park: An Exemplary Application

The number and variety of local government GIS applications can be increased as more and more data are brought into a GIS format and the analytical tools described above are applied to those data. Table 1 covers several pages and shows how street and stream data layers can be used in conjunction with the overlay and buffering tools in PC ARC/INFO[5] to choose the location for a new city park.

1. **Establish the objectives and criteria for analysis**

State clearly what you want as follows:

> "Site must be easily accessible from major highways, yet must not be located too close to highways in order to minimize noise levels and other disturbances"

> "Site should be designed around small, natural streams"

2. **Prepare the data for spatial operations**

Identify and prepare data for analysis; this may necessitate adding items to a coverage as follows:

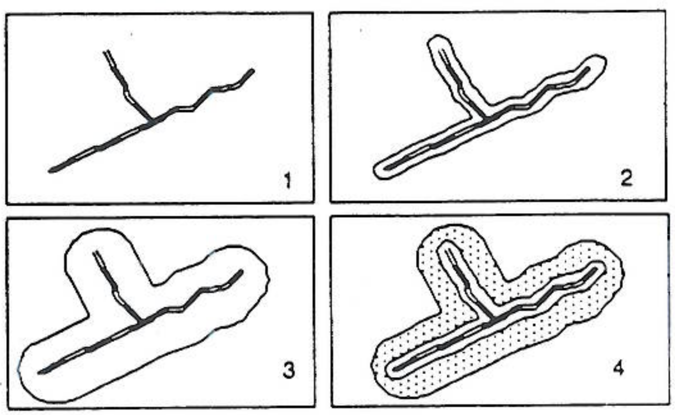
> Identify major highways in roads coverage
> Add item to streams coverage to identify class value

3. **Perform spatial operations**

This is the crux for using a GIS and in this instance it involves translating the problem statement into a series of ARC/INFO commands as follows:

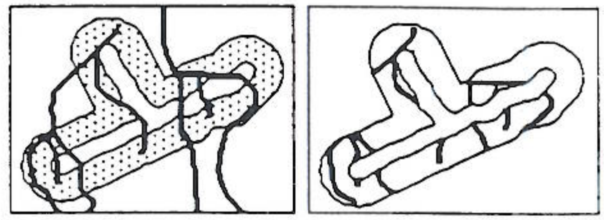
> "Site must be easily accessible from major highways, yet must not be located too close to highways in order to minimize noise levels and other disturbances" can be translated into the following series of spatial operations:

> 1) define major highways in study area
> 2) generate a half-mile buffer (2,640 feet) around major highways
> 3) generate a two-mile buffer (10,560 feet) around major highways
> 4) erase the inside of the wide buffer using the narrow buffer



> "Site should be designed around small, natural streams" can be translated as:

> intersect (a type of overlay) a line coverage of streams onto the results of the buffer coverage generated above to identify only those stream segments which are within the desired distance of the highways.



4. **Perform tabular analysis**

May need to add items that combine information for previously separate coverages

> Add an item SUITABILITY to the overlay output coverage

Determine logical expressions that segregate your results into necessary categories as follows:

> "Site must be easily accessible from major highways, yet must not be located too close to highways in order to minimize noise levels and other disturbances" can be translated from the results of the two buffer zones around major highways so that:

> Only sites within the areas defined by the buffers will be considered for further analysis

> "Site should be designed around small, natural streams" can be translated as follows:

> Select all streams which fall within the buffer zones whose CLASS value is 2. The value 2 for CLASS might represent small first- and second-order streams which have characteristics desirable for a new park site. Calculate suitability to be 1.

5. **Evaluate and interpret the results**

Are the results meaningful? Are the results what you expected? Do you need to prepare your data differently? For the park example described above the conclusion might be:

> "The results of the analysis match the expectations of resource specialists. The selected sites contain areas that they think are suitable for new park sites."

6. **Refine the analysis as necessary**

GIS makes this step <u>much</u> easier; the planner could rework the process beginning anywhere from Steps 1 through 5

7. **Produce final maps and tabular reports summarizing the results**

Use PC ARCPLOT to create maps; TABLES or dBASE for reports

Table 1: Geographic Analysis Steps Required to Choose a New Park Site.[6]

This example is useful because it illustrates several important features of GIS. First and foremost, the first three steps in Table 1 show how the GIS Specialist must translate the objectives specified by the City or County Commissioners into a series of criteria that are used in the GIS analysis. This portion of the analysis demonstrates how the elected officials specify what kind of park is needed and the GIS is used to accelerate or improve the chances of finding one or more sites that satisfy these criteria. The GIS staff can only do their job if they find or generate the appropriate data and perform the spatial and tabular database operations that will be required to identify one or more sites. Notice as well in this example how new items are added to several attribute tables (i.e., in Steps 2 and 4) and how topological overlays and buffers were used to identify those land areas which satisfied the criteria laid down by the City Commissioners. The fifth and sixth steps demonstrate two additional advantages of GIS for decision-making in that the implementation of GIS makes it much easier to: (1) track the rationale and method that was used to make a particular decision, and (2) vary the criteria and perform the analysis again in those instances in which no "suitable" sites were identified the first time. The final step highlights another important benefit of database automation given that a good GIS can also be used to produce multi-colored maps and tables for final reports once the analysis is completed.

Final Remarks

A Geographic Information System is a particular type of information system that can be applied to geographical (spatial) data. It is not surprising, therefore, to find that GIS is commonly applied to help with the management of land and other resources, transportation, retailing and other spatially-distributed entities, and that the connection between the elements in the system is geography (i.e., location, proximity, spatial distributions, etc.). The observations by Huxhold and others that geography is important to 80% or more of the information managed and utilized by local governments indicates how and why this technology is suited to local government applications[2]. The three papers which follow describe the initial attempts of three Montana cities and counties to turn this potential into reality.

Notes

[1] J.C. Antenucci, K. Brown, P.L. Croswell, and M.J. Kevany, "Geographic Information Systems: A Guide to the Technology", (New York: Van Nostrand Reinhold, 1991).

[2] W.E. Huxhold, "An Introduction to Urban Geographic Information Systems", (New York: Oxford University Press, 1991).

[3] J. Naisbitt, "Megatrends", (New York: Warner Books, 1982).

[4] D.W. Rhind, "Why GIS?", ArcNews, 1989, Vol. 11(3): 28-29.

[5] Registered trademark of Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373.

[6] Extracted from the Introduction to PC ARC/INFO course materials with the permission of Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373.

[7] Adapted from diagrams, in Goodchild, M.F. and K.K. Kemp (ed.), "GIS Core Curriculum", (Santa Barbara: University of California, National Center for Geographic Information and Analysis, 1990).