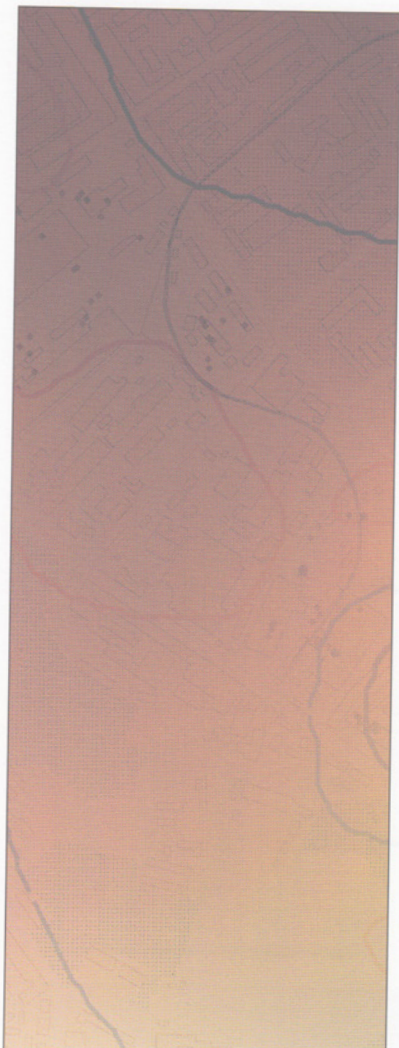
O'Looney, John (2000) *Beyond maps : GIS and decision making in local government*. Redlands, CA : ESRI Press. ISBN 187910279X.

CHAPTER FOUR



Design Principles to Guide GIS Use

This chapter outlines principles for displaying geographic data, provides some guidelines on when GIS applications can be used effectively in decision making, and explains some techniques local governments can use to employ GIS displays effectively. It also discusses some of the pitfalls in GIS displays for decision making.[1]

Principles of Map Design

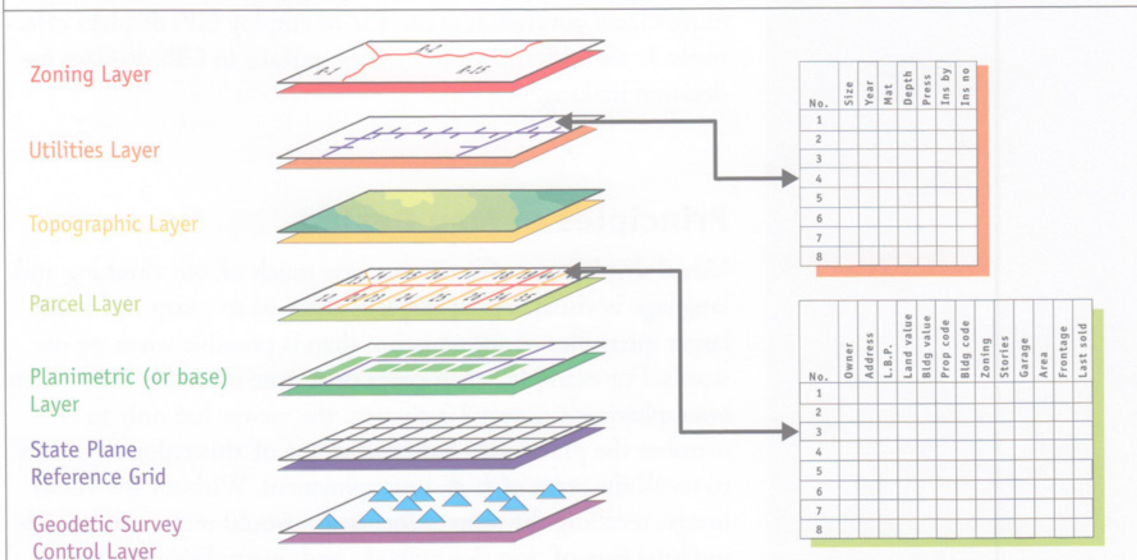
Visual displays are effective because much of our thinking and language is visual. Visual displays allow us to grasp and retain larger quantities of information than is possible when we use words. For example, when color or texture identifies areas where unemployment is over 10 percent, the viewer has only to remember the placement and basic shape of this color or texture to recall the areas of high unemployment. Without the visual image, recalling the same information would require memorizing long lists of area descriptions and unemployment rates.

As GIS applications move from simple inventory uses to more complex analysis, design methods and tools change. As a tool for displaying information, a GIS allows designers nearly unlimited options. Within a single display (or map or display layer), it is possible to combine and customize map features (e.g., lines, points, and polygons that represent roads, rivers, houses, lakes, and so forth), symbols that represent these map features or other user-defined features, labels and text, charts, graphs, images, hyperlinks, figures, and drawings. Moreover, within one display or layer, the basic data can be transformed into map or display features of nearly any scale, size, color, or shape.

However, what makes GIS software particularly useful for displaying spatial data is its ability to organize and display data in overlapping layers. Often, decision makers need information from several sources. Before the introduction of GIS technology, they might have gotten such information in the form of raw data from other departments and sources but they could

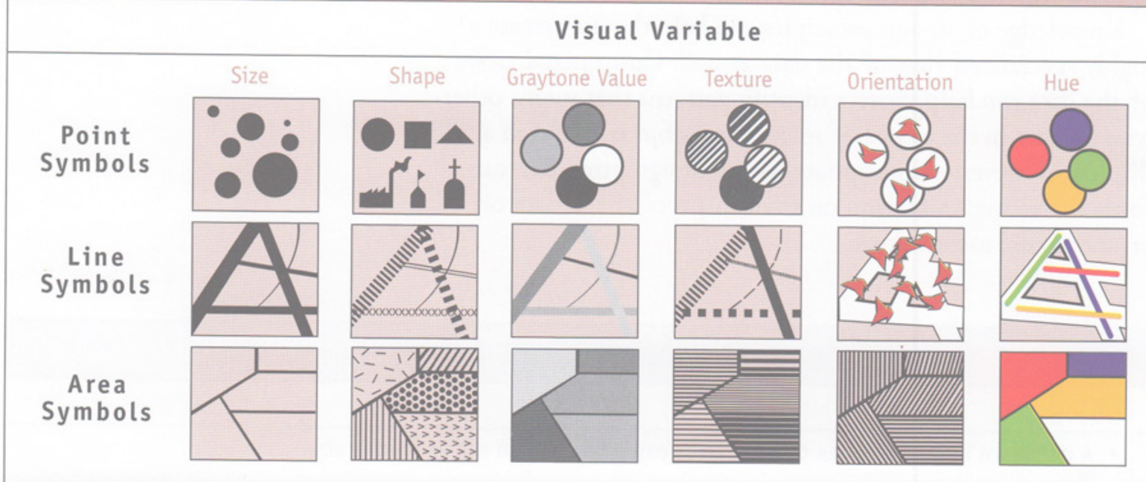
Map Layers in a GIS

Map Layers	Associated Data



Source: William Bell and Mary Maureen Brown, "Geographic Information Systems," in *Handbook for Georgia County Commissioners*, J. Devereux Weeks and Paul Hardy, eds. (Athens, GA: Carl Vinson Institute of Government, 1993), p. 247.

Graphic Variables



Source: Mark Monmonier, *How to Lie with Maps*, 2d ed. (Chicago: University of Chicago Press, 1996), p. 20.

not easily combine it with their own department's data or visualize all the data collected in one format and scale. Essentially, while they could perhaps gather data, they could rarely combine and display meaningful information from multiple sources. The layering ability of GIS technology has made this possible. As long as different local government departments include standard geographic coordinates as part of each data record, a local government executive, department manager, or ordinary citizen can use a GIS to view disparate data within the same display.

While the layering capability is what makes GIS unique, for many applications GIS design tools and principles will differ little from those used in traditional cartography. The checklist shown in the chart on page 64 provides design principles for using graphic variables in maps for basic inventory applications.

Whether the user is exploring data for patterns or creating a presentation for the city council, basic map design principles can help the viewer see what is there more clearly. Good design is particularly useful when the objective is to communicate one or two pieces of very important information in a display. For example, if it is very important to show policy makers that different parks have different capacity levels, staff might change the shape of the symbol that identifies parks as well as its size to show different capacity levels.

Knowledge of design principles can help the user create a highly specialized view of the data as well. Customized views of the data can help viewers identify patterns that might otherwise get lost in the crowd of images and objects found in a GIS display. However, inappropriate use of design principles can focus the viewer's attention on trivial aspects of the data or promote false associations.

Checklist of Design Principles

Basic

- A difference in form between two objects is easier to see than a difference in size.
- Contrast enhances detection.
- Regular, simple geometric forms are easier to detect than asymmetric ones.
- Familiar forms are easier to identify than unfamiliar ones.
- The shape of symbols interacts with their size to affect the interpretation of magnitude.
- A bright background obscures the color of objects.
- A viewer will not be able to discriminate among slight differences in hue when the color areas are not close to each other.

Advanced

- Viewers will not give all parts of a display equal attention. Areas where interpretation is ambiguous and where a great deal of information is displayed will receive greater attention.
- Before attempting to make any other interpretation, viewers will attempt to organize an image into a real-world scene.
- Viewers will try to make sense of any visual image; the need to make sense can easily override accurate perception.
- Viewers will attempt to fill in gaps in an image or complete an image that appears to provide a partial view of a whole object. The details of the image are interpreted in light of the whole image or *gestalt*.
- Previous experience affects the way viewers make sense of an image.
- Viewers perceive the components of images in this order:

  (1) sides or boundaries
  (2) angles
  (3) color

The GIS user must consider the experience of the intended viewer. For example, an audience familiar with transportation symbols can easily read a map that uses those symbols. For this audience, it may be possible to compress a great deal of information within a map display by using an elaborate set of symbols. On the other hand, if the audience is not familiar with transportation symbols, it may be more effective to reduce the amount of information presented in any one map image and use devices such as photo inserts to represent facilities or locations that might otherwise be represented symbolically.

Using Display Tools to Aid Decision Making

To show qualitative differences	Use shape, texture, or color
To show quantitative differences in counts	Use size
To show quantitative differences in rates or intensity	Use graytones or saturation
To show movement	Use symbols that have orientation values

Effective Combinations of Tools	Effective Local Government Use	Potentially Misleading Use
Graytone and area	To show percentage of people who vote in a district.	To show size of the population in an area. People tend to associate depth of tone with intensity rather than magnitude.
Points and size	To show number of people in a neighborhood organization or government department or facility.	To show density of population. Graytones would be more effective.
Lines and size	To show flow capacity of water mains.	To show types of materials being conveyed on different routes. Texture would be more effective.
Texture and lines	To show differences between water, sewer, and other pipes.	To show intensity of use or flow capacity.
Lines and orientation	To show steepness and direction of slopes.	To show flow of water down a slope. Point or symbol size and orientation would be more effective.
Lines and color	To show how different lines service different areas (e.g., blue lines indicate water lines that run north to south).	To show line capacity.

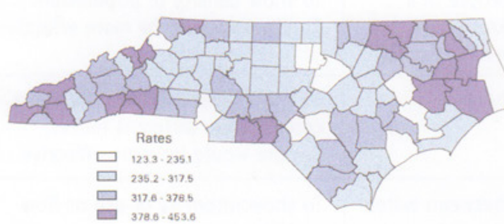
Note: Two common design errors in the use of basic tools include (1) using small points or lines with differences in graytone or saturation, and (2) using bright color contrasts to show quantitative differences.

There is an art to displaying information visually, and sometimes principles contradict each other. However, taken as a whole, the lists on the preceding page suggest ways of emphasizing some information while deemphasizing other information. For example, the GIS user can use large, familiar, simple shapes to draw attention to the key areas of the map. Color adds more emphasis, and, in a multimedia display, movement can be used to draw the viewer's attention, too.

There is one more rule of thumb for effective presentations: When using a series of map displays to communicate a number of pieces of information about the same geographical area, be sure to keep the basic map outline, focus, and scale the same. Because these elements provide a core of recognizable features, keeping them consistent allows the viewer to focus on the new data elements that are being presented in each new map. If the outline, focus, and scale are the same, the series of maps will be more effective in helping the viewer read the "story."

Choropleth

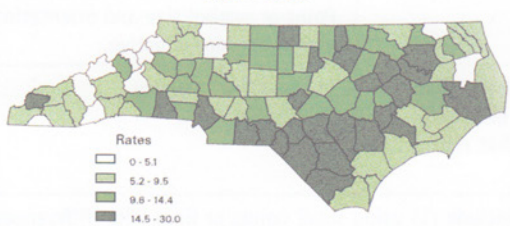
HEART DISEASE DEATH RATES PER 100,000 POPULATION
1991 - 1995



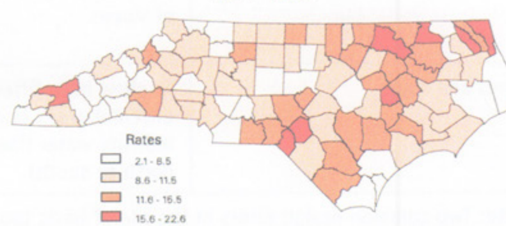
These maps were developed as part of an annual vital statistics report for the state of North Carolina. They are intended to serve as a basic resource for individuals, institutions, and agencies delivering and/or planning health services for the citizens of North Carolina.

Each map shows a five-year rate for the one hundred counties in North Carolina.

AIDS MORTALITY RATES PER 100,000 POPULATION
1991 - 1995



INFANT MORTALITY RATES PER 100,000 LIVE BIRTHS
1991 - 1995



Created by Dianne Enright and Carol Hanchette, North Carolina State Center for Health Statistics, Raleigh, North Carolina, *ESRI Map Book*, Volume 14, p. 58.

Map Types

Choropleth

The most common type of map used for GIS-based displays is the choropleth map that uses color to indicate the level of a particular characteristic (population, property value, and so on).

Isopleth

Isoplethic or contour mapping is used to create continuous areas that have the same or similar conditions. The areas are identified by lines, called isolines, that can be drawn across jurisdictional areas and other features of the geography. Topographic maps, for instance, use isolines to denote elevation. Topographic maps often employ a combination of color and

Isopleth

Kiev, the capital of Ukraine, with more than two million people, is home to one-fifth of the Ukraine population. Industrial emissions from stationary sources adversely affect the city's air quality. Since 1996, the Informational Analytical System has been addressing the prevention of dangerous environmental situations in the Kiev City "ecoGIS-KIEV." The Register of Stationary Emission Sources (RSES) was developed and over the next five years, RSES will monitor environmental risks and emission sources. The system, with its network of workstations, enables environmental protection specialists to compile information about environmental risks, emission source characteristics, and emission source composition in one database.

Created by S. V. Zorin, O. N. Kartavtsev, and A. D. Senchenko, ECOMEDSERVICE, Kiev, Ukraine, *ESRI Map Book,* Volume 14, p. 41.

contours to help the reader quickly identify areas where land is of a particular elevation.

Isopleth maps are useful for identifying areas of similar characteristics that bridge jurisdictional boundaries. When the policy environment involves several jurisdictions, isopleth maps can help policy makers visualize how aspects of a problem or the policy options might be affected by forces beyond their own jurisdiction or area of concern.

Isopleths also show the shape of selected areas, which may not coincide with cadastral boundaries but may be associated with underlying geographic features.

A useful variation of the isopleth for local government use is the isochrone, a map showing the geographic area within a certain number of miles or within a certain number of minutes of a facility.

Scatter Plots

Showing the incidence of events or things using points on a map can provide a very effective display, especially when the plot has a fair degree of geographical accuracy. At the local level, however, officials may need "address-level" data, which in many cases is not available, and when it is available, displaying it may violate citizens' confidentiality.

Cartograms

Cartograms are very useful for displaying geographically based data to policy makers. Cartograms are maps in which a particular exaggeration is deliberately chosen.[2] A GIS can create numerous and varied cartograms, emphasizing different dimensions of geographically referenced databases, on the fly.

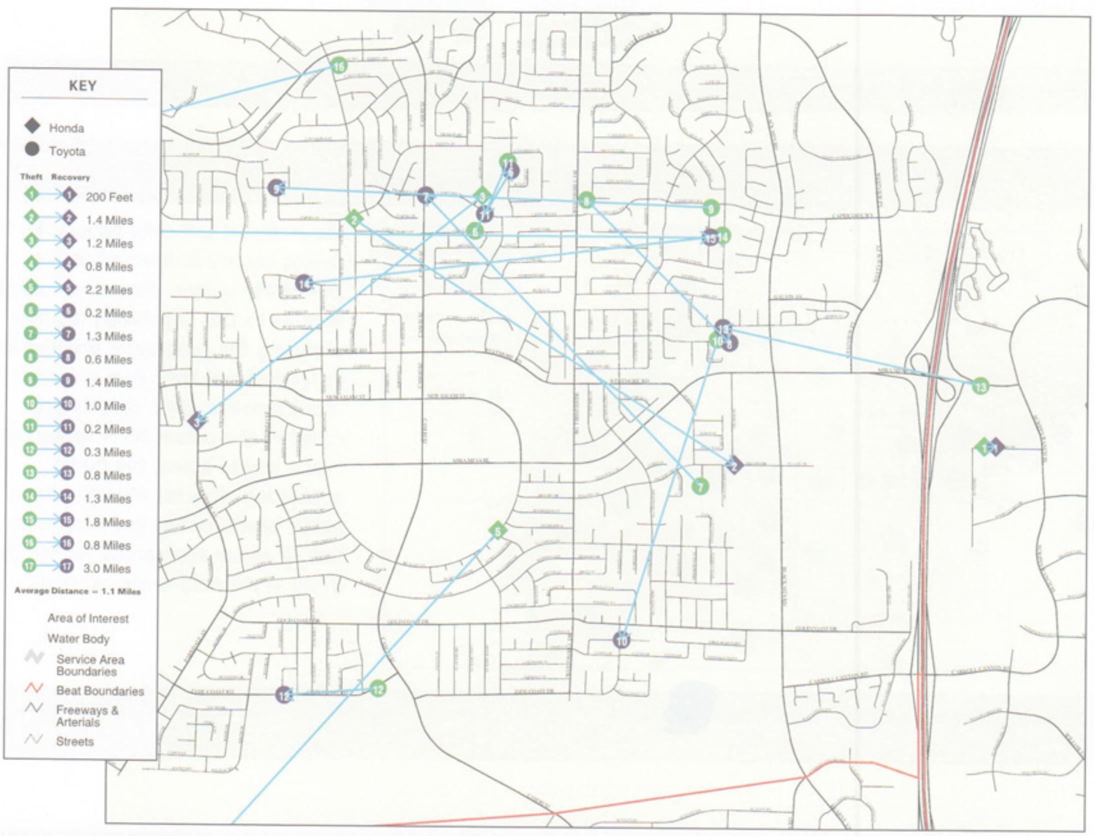
PICTURING THE HARD TO VISUALIZE Traditionally, cartograms have been used to display population size and other elements of human geography that are otherwise hard to see. In the accompanying map of Illinois on the previous page, the size of the dots is proportional to the 1990 population—the higher the population, the larger the dot.

With this type of map, it is fairly easy to make quick comparisons among different cities.

PUTTING MORE DATA IN THE DISPLAY Cartograms can be even more powerful display tools when the designer uses color, shading, graphs, symbols, and even three dimensions to increase the amount of data in a display. The three-dimensional maps on the next page depict the resource-leasing activity in

Scatter Plot

This map shows linkages between stolen and recovered Hondas and Toyotas for the Scripps Mesa Service Area used by the police department in San Diego, California. Interestingly, the average distance between the stolen and recovered vehicles is only 1.1 miles. This map demonstrates the need for a comprehensive analysis that includes tracking the time of day, day of week, and the condition of the recovered vehicle.



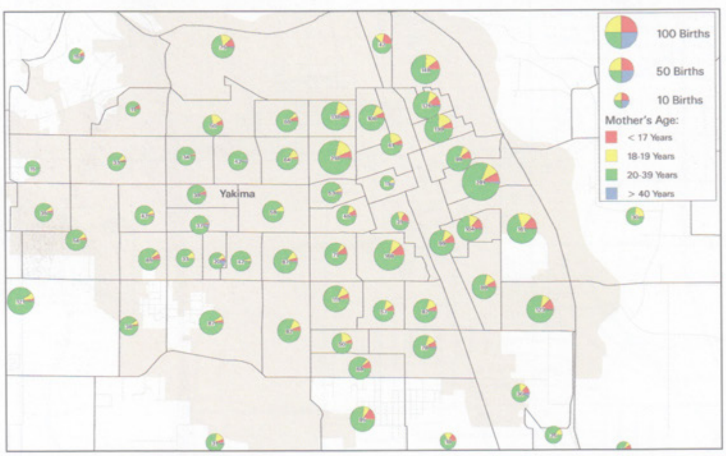
Created by Chad Yoder and Deena Bowman–Jamieson, San Diego Police Department (SDPD) Crime Analysis Unit, San Diego, California, *ESRI Map Book,* Volume 14, p. 16.

Cartogram

This is an example of a traditional cartogram depicting the populations of some of the major cities of Illinois in 1990. The sizes of the dots representing each city are exaggerated according to that city's 1990 population.

Created from the ESRI Maps and Data CD.

Pie-Chart Cartogram



The maternal and child population in Yakima County is diverse and geographically unique. Providing nursing services to this population requires analyzing the geographic distribution of services and their demographic characteristics. Birth records geocoded to the census block group provide a way to assess the target population. This set of maps allows public health nurses and administrators to assure appropriate service delivery at the neighborhood level.

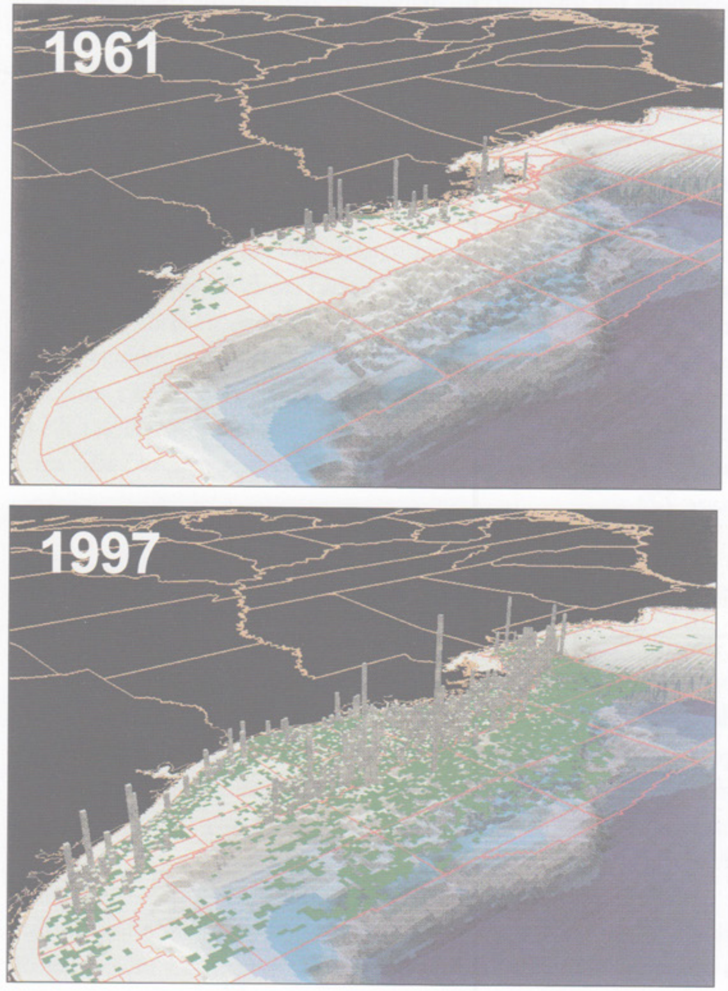
Created by Cynthia Kozma, Diane Patterson, and Michael Vachon, Yakima County GIS and Yakima Valley Memorial Hospital, Yakima, Washington, *ESRI Map Book*, Volume 14, p. 56.

Three-Dimensional Cartogram

The oil and gas resources of the United States Outer Continental Shelf (OCS) in the Gulf of Mexico have contributed to fulfilling America's energy needs for several decades. A biennial record was created of leasing activity and production levels beginning in 1961 and ending in 1997.

The Gulf of Mexico OCS provides about 1.4 billion BOE for domestic consumption each year and generates over $3.5 billion for the federal treasury. The single greatest production level for 1997 was 14.9 million BOE.

Improving technology has enabled explorations for oil and gas resources further offshore in deeper waters. The historical record reflects this trend. The Deepwater Royalty Relief Act of 1995 provides for suspensions of royalties to expedite exploration and development in water depths of 200 meters or more. Lease sales in recent years indicate the industry's willingness to accept the risks of exploration in these deeper waters.



Created by Michelle Morin, Norman Froomer, and James F. Bennett, U.S. Department of the Interior, Minerals Management Service, Herndon, Virginia, *ESRI Map Book,* Volume 14, p. 87.

the Gulf of Mexico for the period between 1961 and 1967. The vertical grey bars represent barrels-of-oil-equivalent (BOE) production levels for the year, and the green markers represent new leases for the year. This is displayed over Gulf of Mexico bathymetry.

Mapping Data for Policy Makers

Mapping for inventory management will usually mean simply identifying the location of specific facilities and associated data. There is no need to exaggerate any particular feature of the image in order to "see" the needed information.

Displaying data that will help shape policy will often require an entirely different process. The user may want to exaggerate features of the data in order to make visible what is for the most part obscure. If the information needed to make a decision were commonly known, or could easily be seen or imagined, there would be little need for GIS analysis and customized displays. Typically, issues reach policy makers precisely because no single policy solution is self-evident (see chapter 2 for a discussion of the circumstances in which GIS is most helpful, particularly the sidebar "When to Use GIS" on page 27).

Emphasizing Map Features

GIS-produced displays can be especially powerful in helping policy makers see what might otherwise be hidden. A well-designed map that focuses the eye on important features of geography and geographic data can be an important decision-making tool. Unfortunately, focus and feature exaggeration can also be used to create displays that are misleading or even dishonest.

An example from a county government illustrates the significance of the GIS user's motives. An environmental consultant for a developer had mapped out the cumulative impact of a series of proposed landfill sites. The consultant used light gray-tones and very small font sizes to indicate the proposed sites. The county commission seemed inclined to approve the proposal.

But at the next commission meeting, the county GIS manager brought in his own map of proposed landfill sites. He had colored the sites and a buffered area around each in bright red and increased the font size several points. The change in the reaction of the commission members was dramatic; they began to question the landfill development proposal and some commissioners changed their minds on the approval question.

Steps Toward Clear Maps

To deal with the problem of misleading data display, GIS users can follow a step-by-step approach:

- Analyze the policy question to identify the important features of the policy environment.
- Select visualization techniques that appropriately emphasize these features and that convey the underlying data at the necessary level of accuracy.
- Integrate data into a small number of displays, but not so few as to make the reading of the GIS display difficult.

A harsh judge might argue that both the consultant and the county GIS manager had "lied with maps," but there is no such thing as a map that is true to some objective reality. All maps reflect the values and perspectives of the mapmaker. Often, for a developer, a proposed landfill is just another business project with little or no impact on the community, while for an environmentalist, the same proposal is a red flag warning of searing harm to Mother Earth.

Categorizing the Data

Well-intentioned but unsophisticated mapmakers can easily produce maps that mislead because of the way the data is grouped. For example, for choropleth maps, the choice of cutoff points for color changes can radically change the display.

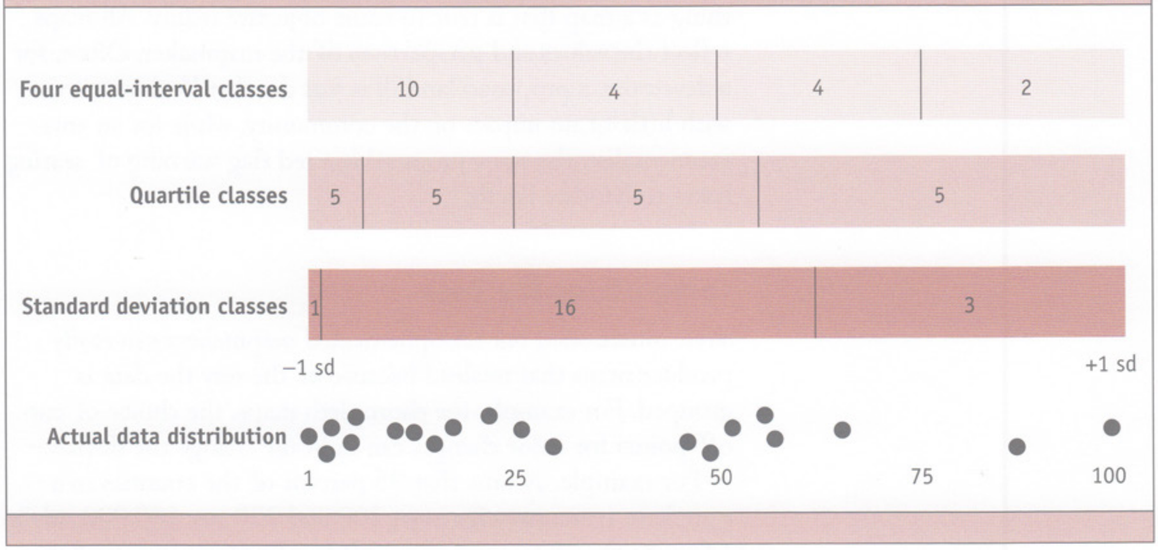
For example, assume that 95 percent of the counties in a state have crime rates between 200 and 220 per 100,000, while a few counties have rates above 800 and a few have rates below 100. To emphasize the uniqueness of the counties with the higher rates, the user might set the trigger point for the color symbolizing high rates at 300. However, if the user wants to deemphasize the uniqueness of the high-crime-rate counties, the threshold for the high group can be set at 210, thus including a large number of counties that fall well within the average range of values.

One of the advantages of GIS is that it allows users to quickly explore a number of different slices of the data, but this flexibility can create misleading displays as well.

Many GIS applications use default values to group data. Three frequently used default settings are equal interval, quartile, and standard deviation.

EQUAL INTERVAL The equal-interval approach divides the range of values into a number of intervals of equal size. For example, if various neighborhoods range in population from 200 to 2,200, four equal intervals would be 200–700; 701–1,200; 1,201–1,700; and 1,701–2,200. If the vast majority of neighborhoods fall into a single interval, the resulting map will make very few distinctions and will convey little information.

GIS Default Classifications for Choropleth Displays



QUARTILE Instead of establishing an equal range of values per interval, quartiles group data so that there is an equal number of data points in each interval.[3] The range of values that fall within this interval is dependent on the data points. A potential problem with this classification scheme is that clusters of similar data points (e.g., similar-size neighborhoods) may be forced into different groups by the mapping software. As the "GIS Default Classifications" figure shows, when the quartile classification scheme is used, data points that cluster around the value of 50 are put into two different classes and are grouped with other data points that have substantially different values.

STANDARD DEVIATION The standard deviation classification of data indicates how much each data point varies from the highest and lowest points. Using standard deviation to segment data is particularly useful if the data is distributed along a bell-shaped or normal distribution curve. When this is the case, slightly more than two-thirds of the data points will fall within one standard deviation above or below the mean. Standard deviation scores highlight which points are exceptional.

Finally, some GIS software will provide a default "best fit" classification based on a formula that finds the natural breaks in the data.

When presented with choropleth maps, policy makers may find it valuable to have the mapmaker display a line graph or scatter plot showing where the actual values lie so that they can judge for themselves whether the mapmaker has fairly displayed the nature of the underlying data.

Avoiding Visual Misperceptions

Map viewers may assume that large areas have more of the value being mapped than small areas. This can pose a problem for choropleth maps, as illustrated by the following discussion.

Two counties in Georgia—Laurens and Clarke—are shaded the same in a property crime rate map. Simply because Laurens County is larger, the viewer's first impression may be that crime is worse in Laurens County. In fact, Clarke County, though much smaller geographically, has a larger population, and (since the rate is the same) a much larger total amount of property crime than Laurens County. However, the contrast in the sizes of the two jurisdictions gives the opposite impression.

If Georgia state legislators want to test a new community-oriented policing (COP) strategy and they are looking for a county where the number of crimes is large enough and concentrated enough to justify a substantial program effort, this choropleth map might lead them to choose Laurens County. Actually, it might be better to put the program in Clarke County, where there is enough total crime to justify the program investment and where greater population density would provide a better test of a COP strategy.

To help decision makers place the COP demonstration project, staff should follow three steps outlined on the next page.

ANALYZE THE POLICY QUESTION The key features of the desirable setting for the COP demonstration are

A A population large enough to allow for statistical analysis of the results

B A high crime rate

C A population (or criminal activity) density suited to a neighborhood-based approach to crime fighting.

SELECT APPROPRIATE VISUALIZATION TECHNIQUES In the Georgia example, a simple choropleth map tends to distort communication about feature A (population) while it conveys information about feature B (high crime rates). A quick solution is to show the map of Georgia using circles of varying sizes to indicate county populations. Now the legislators can immediately see the counties with large populations. The circle for Clarke County will be much larger than that for Laurens County. Next, shading is used to show the crime rate in each county. Clarke and Laurens counties will have the same shading. Finally, the mapmaker can use a scatter plot, in which a dot represents one or more crime incidents, to show the density of crime.

If subcounty-level data is available, an isopleth or a choropleth map might reveal that the southern part of Laurens County contains a pocket where the density of crime is higher than anywhere in Clarke County, suggesting this area for the COP program.

Given detailed data, the isopleth map can go further by displaying the shape of the high-crime area. Isopleths provide an important analytical tool for policy makers by making it possible to relate particular features of the geography or the built environment to other factors. In this example, if one neighborhood shows a sharp drop-off in crime rate within a short distance (illustrated by closely spaced isolines), the drop may be associated with a particular geographic feature (a highway, a cliff, or a fence).

INTEGRATE DATA INTO A FEW DISPLAYS Perhaps the most difficult step in developing an effective visual GIS display for policy makers is integrating the key features of the policy environment that one wishes to communicate visually. Sometimes it is possible to convey all the important features in one display. However, as the number of features grows, the process of integrating them becomes more difficult.

As mentioned earlier, it is crucial to maintain uniformity if more than one display is used to explore or present related information: for example, the area shown, the types of symbols, and the data classification scheme might remain constant while the dates change.

Layered Displays

The map layers in a GIS usually reflect the functional organization and ownership of data among various businesses, government agencies, departments, and bureaus. The dispersed organization and ownership of spatial data has resulted in layering that tends to resemble the distribution of functions in the worlds of government and commerce rather than the more integrated and complex organization of the physical world. However, because a GIS can combine or merge data from several sources (either at the database level or the display level), the user can put the world back together one step at a time, partially or completely.

The design principles already discussed suggest that a partial view of the "world" is frequently more effective in communicating information than a view that is so complex that it fails to communicate any one message effectively. With spatial data organized into layers, the GIS user can choose (or "turn on") some layers while excluding (or "turning off") other layers to achieve the desired effect or to highlight the features that are most relevant to the issue at hand.

When combining layers of data, GIS users should consider the principle known as Occam's Razor, attributed to the medieval philosopher William of Occam (or Ockham). The principle states that one should not increase, beyond what is necessary, the number of entities required to explain anything (or, in modern English, "keep it simple, stupid"). Applying this principle to GIS displays will not always be easy. For example, audiences often need to see an unnecessary layer (e.g., one that has landmarks with which they are familiar) in order to easily relate to the primary focus of the display. Hence, we might want to modify Occam's principle to suggest using as few layers as possible, plus a single additional layer if needed to orient one's audience.

Visualizing Time with Animation

A GIS with multimedia capabilities can add to the cartographer's traditional tool box:

- Sound linked to data. For example, a multimedia display can play a recording of street noise taken from the location the viewer has clicked on a map.
- Three-dimensional displays.[4]
- Transparent layering of views.
- Switches that make some areas fuzzy or foggy to show lack of certainty in the underlying data.
- Blinking and movement of map objects based on a defined characteristic.
- Vibrations based on a defined characteristic.

Multimedia systems allow the user to create maps that help viewers see the composite of data pattern analysis and geography rather than simply data laid on top of a preset geographic plot. GIS technology is supporting a revival of a kind of map—the cartogram—that is especially effective in displaying complex social and economic data. GIS systems enhanced with animation technology are being used to visualize patterns that exist within or across time periods.

In addition to helping decision makers visualize patterns in two- and three-dimensional data that might otherwise remain invisible, animated GIS displays can help users analyze and display patterns that exist only in a time dimension. Although some time variables can be displayed through ordinary static maps, GIS multimedia systems can produce animated maps or displays that allow manipulation of time.

GIS users with multimedia tools can consider four dimensions of time when attempting to discover patterns in time-based data sets.[5]

DURATION In animated displays, the map or display creator can specify how long a viewer will look at a displayed theme, visual, or map window. Animation software allows for very precise control over the duration of any single display (or sequence of displays). Duration can be used to dramatize static data or to display dynamic data.

RATE OF CHANGE When a series of animation frames or displays follows an event or object over time, the animation will allow the viewer to perceive changes in an object's position or attributes (e.g., color, size, texture). Visually, we are able to perceive not just the change itself, but the rate of change (e.g.,

Animation Applications

Application	Animation Example	Local Government Example
To highlight a feature	One feature blinks on and off, while other features remain dormant.	*Quickly finding the right shutoff valve:* The GIS map blinks the location of main-line valves within a particular distance of a reported water main leak.
To show attributes	Duration of a feature corresponds to its size and probability.	*Identifying where zoning violations are most prevalent:* Zoning violation map markers last twice as long in areas where the number of violations is above average.
To allow object to change position	Object symbol moves.	*Addressing questions about when a road project will be finished:* A line is extended to show the completion of various phases of road construction. The progress of future road work can be projected based on the historical rate of change.
To show change in characteristics of an object	An object is redrawn in a different size, color, texture, and so forth.	*Identifying a neighborhood for locating new low-income housing on the basis of trends in a number of indicators:* Map symbols move and change size or other characteristics according to changes in employment, poverty, family status, neighborhood crime, and so forth.
To allow observer to change position	Perspective changes to allow fly-throughs or zooming in and out.	*Informing citizens about a planned development:* Designs or pictures of a proposed development are shown from multiple points of view. Affected citizens can view the development from the angle of their residence.

slow, constant change; fast, constant change; steadily increasing change; steadily decreasing change). Illustrating rates of change can often help illustrate complex data relationships.

ORDER Animation can use order to show a sequence of events to illustrate cause and effect, or a sequence of geographic layers to dramatize other relationships between data. Manipulating other variables at the same time, such as duration or color, can convey additional information.

PHASE Animated presentations can show events that are repeated according to a particular rhythm. One fairly common use of phase is in the presentation of data on a color line or arrow. Weather maps are often animated to suggest the speed of the various jet streams by cycling a spectrum of color through arrows of different lengths and sizes. Because a cycle of color tricks us into seeing movement, we gain understanding of how a dynamic weather pattern may be evolving and what the next phase may be, even though the arrows themselves do not move.

To summarize, animation can be used to highlight static and dynamic data sets in a number of ways, as shown in the table on page 79.

In GIS visualizations, the purposes can vary from setting to setting. Careful planning for creation of the "one best display" is less of a priority than it has been in traditional mapmaking. The primary benefits of a GIS are its ability to provide a wide array of displays to help us see things and patterns of things from multiple perspectives and its ability to help us visually analyze complex relationships that involve multiple forces and factors.

Standards for Symbols and Classification

Maps become useful decision-making tools when mapmaker and viewer agree on the meaning of particular symbols, colors, textures, and the like. Most Americans can quickly gather a substantial amount of information from standard road maps because the icons for state parks, camping grounds, state capitals, and so forth, are familiar, and the conventions for categorizing cities of different sizes are also generally understood. These standard ways of showing data let us make comparisons among different parts of the country or among different cities or counties.

Unfortunately, GIS capabilities have far outstripped the development of standard symbols and data classification schemes for the myriad of new data types that now can be analyzed and displayed using GIS. There are no standard symbols for many of the social and aesthetic features of communities that may become important as policy makers and citizens learn to use the potential of a GIS. The mapmaker has to invent symbols for places that sell particular types of foods, for cultural landmarks, for trees that have community significance beyond the shade they provide—or, within one land-use category, for a community vegetable garden as distinguished from a private ornamental garden or a garden that is owned and maintained by the county government.

When such symbols are first created, viewers have to refer continually to the symbol legend to discover the meaning of the icons. However, over time, if the same set of symbols is used in the same way, they become familiar. Local governments together with regional and state authorities clearly can play an important role in building and standardizing adequate symbol sets.

Paradoxically, standardization may support local control over decision making. Liza Casey and Tom Pederson make a good point: "On the surface, standardization may seem at odds with the intentions to express a neighborhood's uniqueness but uniformity of the mapped elements can provide a context in which decision makers can better discern that uniqueness." [6]

Standardizing on a single color scheme for such things as occupancy status, tax delinquency, or property type makes the significance of this information more obvious and the differences between neighborhoods relative to the displayed elements more immediately apparent. Decision makers typically have little time to review documents, and standardized display vocabularies reduce the time necessary to grasp the idea or ideas being conveyed by the map.

Standardized data classification schemes are likewise needed if policy makers and citizens are to use GIS displays effectively. Philadelphia's experience using GIS technology in its neighborhood planning project is instructive. As neighborhood planning groups used the city's GIS system to map their own neighborhoods, they often developed their own classification schemes for displaying data such as delinquent tax rates. These neighborhood classification schemes were fairly arbitrary. For example, neither of the following two classification schemes from two Philadelphia neighborhoods corresponds to classic schemes of grouping data in equal intervals, in quartiles, or by standard deviation.

Neighborhood A *$s Tax Delinquent*	Neighborhood B *$s Tax Delinquent*
1–500	100–1,000
501–1,500	1,001–5,000
1,501–10,000	5,001–20,000[7]

Besides making it difficult to compare one neighborhood with another, both these classification schemes lead to a GIS display that suggests taxable resources far beyond what are actually available. Because people tend to assume that most of the values within a classification fall close to the middle or average of the classification range, map viewers looking at the first classification—which includes most tax delinquent properties in each neighborhood—will tend to assume that in neighborhood A the average tax delinquent property is $250 and in neighborhood B, $500. In fact, the average is under $100 in both cases. Moreover, because neighborhood B's classification scheme eliminates delinquencies of less than $100, the map of delinquent properties in that neighborhood fails to show numerous deteriorated and abandoned properties and ignores a significant urban problem: the vast majority of the tax delinquent property in Philadelphia is abandoned property that is taxed at \$100 or less per year.

While standard symbols may need to be developed at the national level, classification schemes will be more community specific in many cases. For instance, using the same Philadelphia example, Casey and Pederson suggest that it would be useful to identify all the tax delinquent properties and provide good estimates of the revenue lost due to delinquency, but also to show which properties might be available to the community or to developers through a tax sale. In Philadelphia, properties with \$800 of cumulative tax delinquency can be sold for taxes, so the standard scheme for classifying tax delinquent property in Philadelphia would need a break at \$800.

Classification schemes obviously need to be carefully set by local people. Local governments should consider the need to create meaningful data on different levels: for in-house management, for policy making, and for citizen education and information.

Conclusion

This chapter has outlined some of the issues involved in creating appropriate, effective, and sophisticated visualizations of GIS data. Some of the techniques described (e.g., animation and three-dimensional displays) are unlikely to be introduced widely into local governments in the near future. Most local governments with GIS are currently using only the simplest applications and display capabilities.

Whether they are using sophisticated animated displays or basic overlays, local government managers can exercise good judgment in

- Deciding when and how GIS analysis and displays should be used
- Following sound map design principles and choosing the type and degree of distortion used
- Developing standards for symbols and data classification.

[1] The reader who wants more information on the subject of map design is referred to *How to Lie with Maps,* 2d ed. (Chicago: University of Chicago Press, 1996), and *Drawing the Line* (New York: Henry Holt & Co., 1995), two excellent books by Mark Monmonier that use many examples of good and bad design to show how to present data clearly for government decision making and public understanding.

[2] D. Dorling, "Cartograms for Visualizing Human Geography," in *Visualization in Geographic Information Systems,* Hilary M. Hearnshaw and David J. Unwin, eds. (New York: John Wiley & Sons, 1994), p. 85.

[3] The typical default quantile is a quartile or four equal groups. However, other equal groupings (e.g., septiles, or seven equal groups) are possible.

[4] Three-dimensional views in a two-dimensional display can lead to perceptual ambiguities and inaccurate interpretations of data. In real life we judge depth by changing our viewing position and noticing the speed at which an object moves in relation to our movement. This is not possible in two-dimensional displays. Even displays that use stereo images can lead to error for viewers with corrected vision.

[5] A. MacEachren, "Time as a Cartographic Variable," in *Visualization in Geographic Information Systems,* Hilary M. Hearnshaw and David J. Unwin, eds. (New York: John Wiley & Sons, 1994).

[6] Liza Casey and Tom Pederson, "Urbanizing GIS: Philadelphia's Strategy to Bring GIS to Neighborhood Planning," proceedings of the 1995 ESRI International User Conference.

[7] Ibid