

Chapter 2:

What Crime Maps Do and How They Do It

What crime maps do

Maps are often thought of solely as display tools. In fact, maps have a wide-ranging role in the process of research, analysis, and presentation. Mapping is most effective when those broad capabilities are recognized and used to their fullest extent. The map is the end product of a process that starts with the first-responding officer's report that is processed by data entry personnel, entered into a database, and transformed into a symbol on paper. In this narrow interpretation, a map is merely a picture or part of a database. But maps can be useful in other ways. MacEachren (1994) and MacEachren and Taylor (1994), following DiBiase (1990), noted the distinction between visual thinking and visual communication in the use of maps and graphics (figure 2.1).



Visual thinking

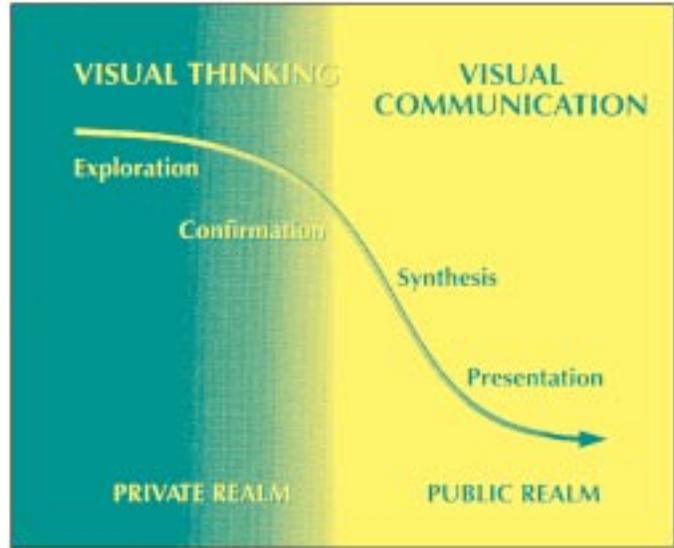
In *visual thinking*, the map is used to generate ideas and hypotheses about the problem under investigation. By inspecting a map, for example, we may notice a relationship, or correlation, between environmental factors that otherwise might have gone unnoticed. This correlation may be *vertical* in the sense that we see connections between different phenomena, such



Figure 2.1

The roles of graphics in the research process: Visual thinking and visual communication.

Source: DiBiase, 1990.
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as crimes, land uses, and demographics. Alternatively, we may see a *horizontal* relationship in which we recognize a common factor across a particular crime type, such as graffiti in similar types of crime locations. Visual thinking is a *private* activity involving exploration and confirmation.

In the *exploratory* phase, maps may be crude and are not intended for display or publication. A computer-printed map of burglary patterns for the most recent week might be marked with handwritten information provided by investigators or with other data not in digital form. Information might be transcribed from a mental map to a paper map. Another possibility is that

the tools of exploratory spatial data analysis (ESDA) are used to find anomalies in data, such as an unexpected cluster of incidents, that could point to unexpected relationships.

At this stage the analyst may generate a formal *hypothesis*, or educated guess, to explain the process producing the observed crime pattern. Did the observed cluster of burglaries pop up by chance? Is there some recognizable cause? Is a serial burglar operating in the area? Do officers in the field have insight to offer? By developing a hypothesis, the analyst is in the mainstream of scientific research, using a venerable methodology—the

Visual Thinking versus Visual Communication

- Visual thinking is abstract and internal. Some ideas for putting data into maps, charts, or other media may never see the light of day.
- Visual communication is a tangible expression of visual thinking. It is putting thoughts about data and processes into a format others can see and understand with minimal effort.



so-called (and awkwardly called) *hypothetic-deductive* method.

Maps and other graphics are integral tools for exploration and hypothesis testing. Do preliminary maps confirm the hunch that a burglary pattern is likely the product of a repeat offender who is using a bus route, and apparently a specific bus stop, to visit a neighborhood and commit his offenses? If so, the preliminary information will help the hypothesis gel into something useful.

At the core of this method is a potentially repetitive process involving:

- **Development of a hypothesis** on the basis of the best available information derived from both theory and field data.
- **Development of a method** for testing the hypothesis, perhaps involving statistical and graphic testing or modeling.
- **Analysis** of the data.

- **Evaluation** of the results.
- **A decision** to accept or reject the original hypothesis.
- **Reevaluation** of the original hypothesis, if it was unsatisfactory. It may be modified to take into account new knowledge. If so, the process begins anew.

The *confirmation* stage tells the analyst whether the hypothesis does indeed have a factual basis that will withstand scrutiny. If it does not, we reevaluate and make necessary adjustments, perhaps gathering more information to add depth to what is already known and to shore up the hypothesis, which itself may now have been modified to take new data into account.

MacEachren (1994) cautions that investigators should realize that maps and other graphics are prone to error resulting from their underlying data, inappropriate design, or even the margin of error

What's Hypothesis Got to Do With It?

Will the typical crime analyst go through the rigmarole of visual thinking and visual communication—plus the process of hypothesis testing? Its not likely, since most analysts work under tough deadlines with inadequate resources. (Just like everyone else!) Also, much of the work is prescribed, routine, and repetitive, leaving little flexibility for research.

So, what's the point? The formal structure outlined here is an ideal model for map-related research—a *paradigm* or *modus operandi*. Thus it is unlikely to be replicated often in practice. Like other models, it provides an ideal guide and enables the analyst to apply whatever parts of the process can be applied in the time available.



introduced by the normal process of abstraction. If possible, the analyst should not rely on any one data source, whether it be a map, field observation, or survey, if other sources can be used to complement each other.

Visual communication

As we move from visual thinking to visual communication, we go from the private realm to the public activities of synthesis and presentation. *Synthesis* implies merging various types of information—in this case, geographic information system (GIS) layers—into a coherent final product. Although synthesizing is essentially scientific, human judgment is at the core of this filtering and refining process.

Synthesis is assisted by the ability to find overlaps (intersections) between layers in a GIS. But even then decisions have to be made about what to put in, what to leave out, and what importance to attach to each layer. A *presentation* puts all the relevant pieces together in a map. The map can be highly persuasive if it provides information germane to the question at hand and is well designed. As MacEachren (1994, p. 9) noted, “People believe maps.”

How crime maps do what they do

A detailed discussion of how maps communicate through processes of visual comprehension is beyond the scope of this guide. However, a few points are made here to explain the underlying process and underscore the idea that people see maps differently due to differences

in, for example, their eyesight, aptitude for visual comprehension, and prior training. A background problem that goes largely unrecognized in the community of mapmakers is that, for some people, maps have no meaning. They may grasp neither scale nor symbolization. As a result, they have no sense of distance, relative or absolute, and are unable to draw meaningful conclusions from a map.

This problem is, in part, a legacy of the disappearance (until recently) of geography from school curriculums. But it may go deeper, seemingly having to do with gender- and race-specific differences in personal mobility that, in turn, may hinder the development of *spatial experience* and reduce individuals’ abilities to take advantage of maps as tools. For example, in the past, women’s traditional roles in childrearing have limited their mobility, thus denying them opportunities to learn geography by directly experiencing places. Race has had a similar indirect effect through the mechanisms of discrimination and depressed economic status. Insofar as minority groups have experienced disproportionate levels of poverty, their mobility has been limited and their geographic learning correspondingly stunted. (See Montello et al., 1999, for a discussion of related questions.) While the police are very geographically aware, in part due to much field experience, individual members of the community may not be. An argument might be made for giving special attention to maps intended for the community. For example, digital photos of landmarks could be embedded in a community map as visual anchors to show residents how the map relates to their environment.



All messages, including maps, are laced with nuance. “The medium is the message,” wrote McLuhan and Fiore (1967), arguing that literate people had been rendered visually incompetent by an excessive dependence on text. Since that famous remark, personal computers have provided an interactive platform, allowing what is, in effect, environmental manipulation on the fly. Maps, text, and data have moved from the realm of the passive to the active and interactive, encouraging perception of the map as a tool rather than as a mere display device.

Peterson (1995) has outlined several theories and models that have been advanced to explain how visual information is processed:

- Stage model.** Visual information moves through three memory stages. The first (*iconic*) is very short and deals with initial recognition. The second (*short-term visual store*) is longer but has less capacity so complexity becomes an issue. Moving from iconic to short-term demands attention. The information is then sent to *long-term visual memory*. Long-term images provide cues to help with recognition of new visual stimuli.

- Pattern recognition theory.** Iconic images are converted into something recognizable through pattern matching.
- Computational model.** This sophisticated three-dimensional model is similar to the process of abstraction in cartography. (For additional discussion, see Peterson, 1995, chapter 1.)

These theoretical considerations are reminders that producing a map is only half the story. We also have to be concerned with how it is interpreted by the intended audience. The storage of cues for the interpretation of visual images in long-term memory means that familiarity provides a substantial advantage in the interpretation of maps. We may be oblivious to the fact that our map is extremely familiar to us but means little or nothing to those who have no reference points in their long-term memory or who have had insufficient time to study and process the details.

Another way of visualizing the process of moving a concept from the analyst to the map user is illustrated in figure 2.2, showing that the cartographer’s and map user’s realities are both abstractions of reality. The cartographer creates a cartographic

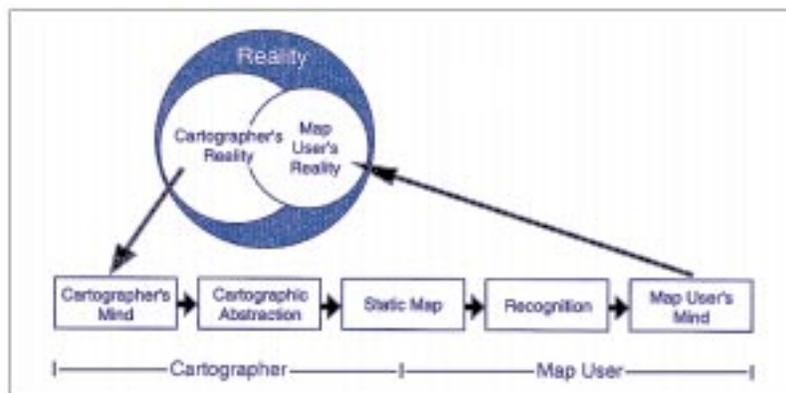
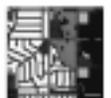


Figure 2.2

A model of cartographic communication.

Source: Peterson, 1995, figure 1.1, p. 5. Adapted by permission of Prentice Hall, Inc., Upper Saddle River, New Jersey.



abstraction and translates this into a map that is read by the map user and transferred to the user's mind.

Choosing a crime map

Chapter 1 characterized thematic maps as falling into the following broad categories: statistical, point, choropleth, isoline, surface, and linear. How do we choose the most appropriate type for mapping crime and crime-related phenomena? Some decisions jump out at us while others are open to interpretation.

For example, if we want to see the precise locations of burglaries for the last month, then we use a point map of addresses of incidents. Or perhaps a city council member has asked the police department for a map summarizing the number of incidents of graffiti per structure by city neighborhoods. This calls for a choropleth map, with neighborhood boundaries making up the geographic units. Links between victim and offender residences demand a linear representation. A generalized picture of crime risk or incidents is seen best with an isoline or surface map, and census information depicting the relationship between poverty and race can be shown using either a statistical or choropleth map.

Because of the infinite potential combinations of crime-related conditions that can be depicted on maps, we can combine map types to put more information on the same map. For example, we can combine *nominal* and *ratio* data, such as a choropleth map of drug-related crime by patrol beats and add the locations of drug markets on the same map. Crime mappers should be aware of the potential for

combining thematic map types, provided that the result is not overloaded with information—or just plain incomprehensible. An overloaded map will have so much information that the eye is unable to take it all in. It will prevent the reader from discriminating between what is important and what is not.

Examples of thematic maps

Perhaps the best way to get a feel for the kinds of maps used to display crime data is to look at examples and to think about why each type of map was selected. A good place to start is the Web site of the National Institute of Justice Crime Mapping Research Center (<http://www.ojp.usdoj.gov/cmrc>), which provides links to police departments across the United States. Another useful Web site is maintained by Hunter College in New York (<http://everest.hunter.cuny.edu/capse/projects/nij/crime.html>). (See the appendix for additional information.)

Thematic maps using point symbols: The dot map

When should point symbols be used? The first prerequisite is that *you have locational detail*—information specific to your points, such as street addresses or coordinates in latitude/longitude or some other system, such as State Plane (explained in chapter 1). The second prerequisite is that *the audience needs locational detail*. If you have point data, but the audience wants information summarized by patrol areas or neighborhoods, then the point data can be added up, or aggregated, to the areas of interest. Examples of point, or dot, maps are shown in figures 2.3 and 2.4.



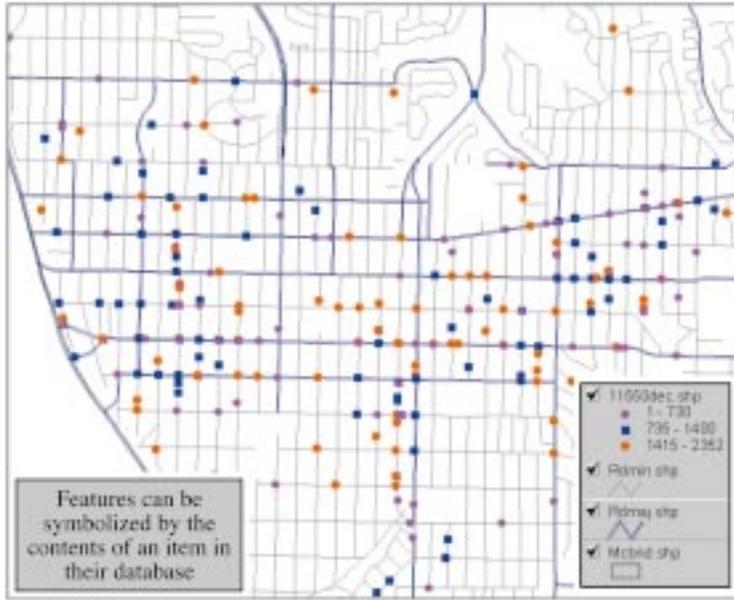


Figure 2.3

A point data map discriminating among three crime categories with different symbols and colors.

Source: San Diego, California, Police Department. Reproduced by permission.

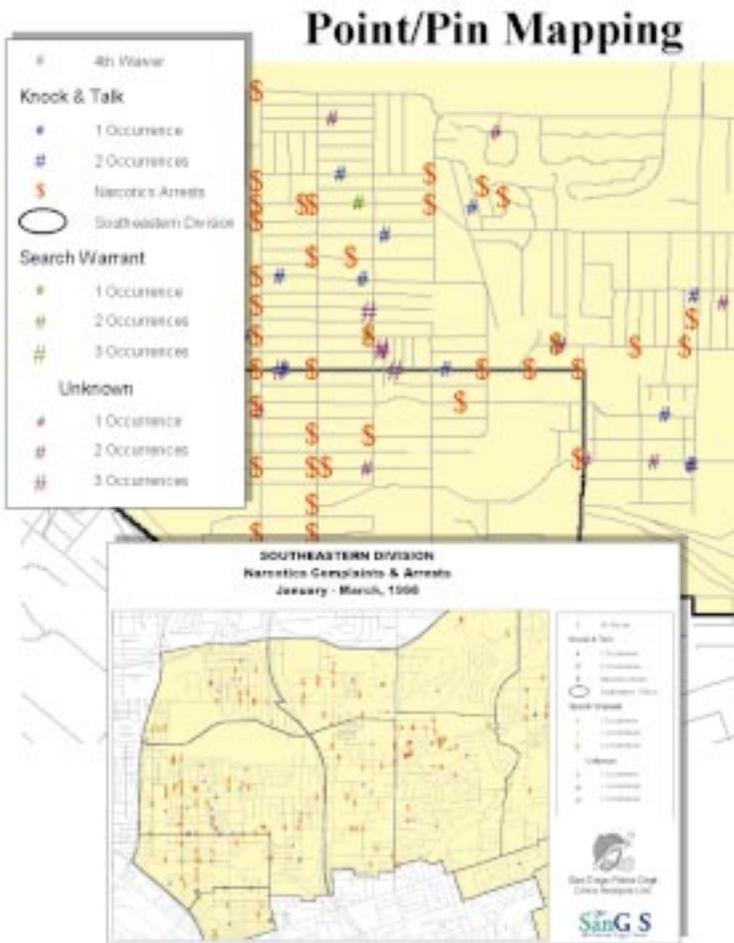


Figure 2.4

A point data map of drug arrests using different symbols and colors.

Source: San Diego, California, Police Department. Reproduced by permission.



What Crime Maps Do and How They Do It

When there are too many points to be mapped, using point data may result in a mess of superimposed points that have little or no meaning. This could happen if calls for service are mapped using addresses in a large city. The point data may need to be summarized by areas to make the data legible. Point maps also get too crowded if long time periods are summarized for more frequent crime categories. Thus, even though you have reasonably precise locational information, aggregation by areas in the form of a choropleth map may yield a more legible map than the presentation of each individual point.

Thematic maps using statistical symbols

At its most primitive, a statistical map consists of raw numbers written in the subdivisions of the map. The advantage is that the reader can see exactly what the statistic is. The downside is that maps designed in this way are difficult to read

quickly. It could be argued that, in effect, they defeat the purpose of the map, which is to facilitate visualization of the data. Admittedly, this form of map does put data in its geographic context, but in an inconvenient format. Cartographers argue that if you want to see only the raw numbers, then a table, not a map, is needed (see next section, “Thematic maps using area symbols”).

Statistical symbols commonly take the form of pie charts, bar charts, graduated circles, or dots representing incident counts (dot density) placed in the relevant map subdivisions (figure 2.5). This allows multiple variables to be mapped at the same time. Examples could include bar charts with bars representing both crime and poverty or graduated circles like those in figure 2.6, showing the U.S. House of Representatives vote on an Omnibus Drug Bill provision requiring a 7-day waiting period for the purchase of handguns. At first glance, the symbols in figure 2.6 look

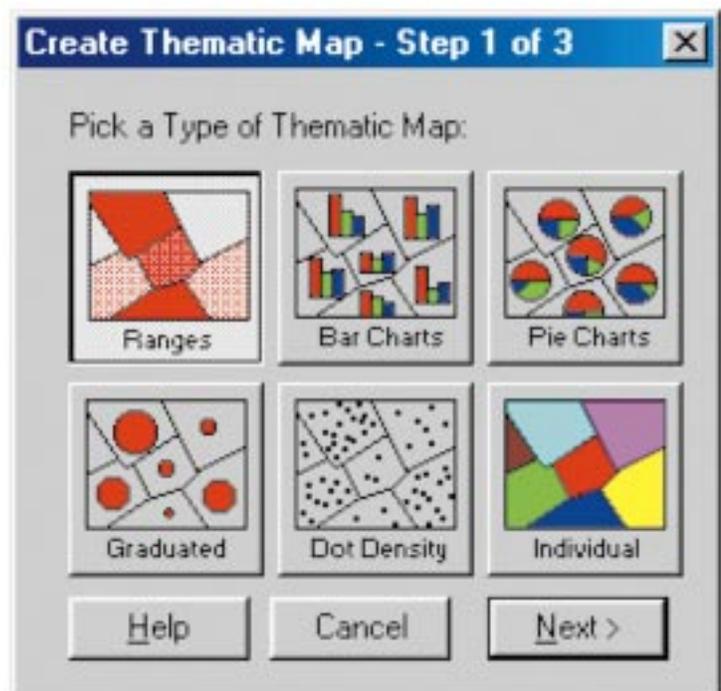


Figure 2.5

Thematic mapping options in MapInfo®, a desktop mapping program.

Source: MapInfo Corporation, Troy, New York.



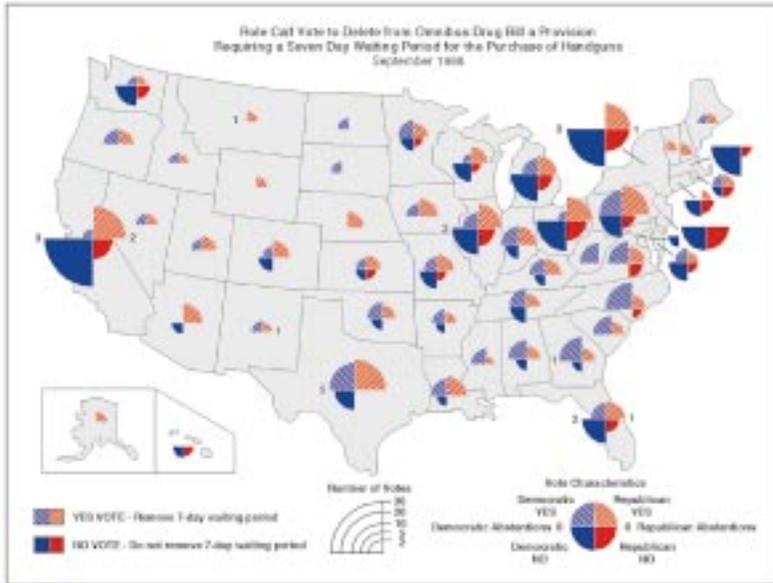


Figure 2.6

A graduated circle map showing a U.S. House of Representatives vote on an omnibus drug bill provision requiring a 7-day waiting period for the purchase of handguns.

Source: T. Rabenhorst, University of Maryland, Baltimore County, Maryland. Reproduced by permission.

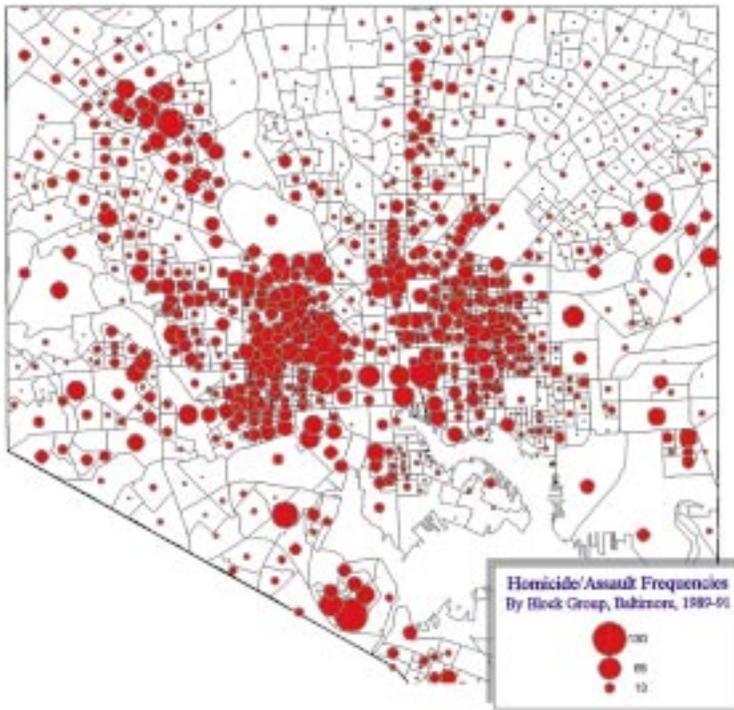


Figure 2.7

A graduated circle map showing aggravated assaults by census block group, Baltimore, Maryland.

Source: Keith Harries from Baltimore City, Maryland, Police Department.

like pies, but circle segments are all 90 degrees. This is actually a graduated circle map, in which the *area* of the 90-degree segments is proportional to the number of yes votes (top part of the circle) or no votes (bottom part of the circle), with the left side of the circle representing votes by Democrats, the right by Republicans.¹ The map shows both nominal data (party affiliation and yes/no votes) and quantitative

data (the number of votes), as well as location of votes by State. Although reading this map takes some effort, it is rich in information and gives that information a clear geographic context.

More typical graduated symbol maps used in crime analysis applications are shown in figures 2.7, 2.8, 2.9, and 2.10. Note that points and proportional circles can be



Figure 2.8

A graduated circle map showing convenience store robberies, Baltimore County, Maryland.

Source: Philip Canter, Baltimore County, Maryland, Police Department. Reproduced by permission.

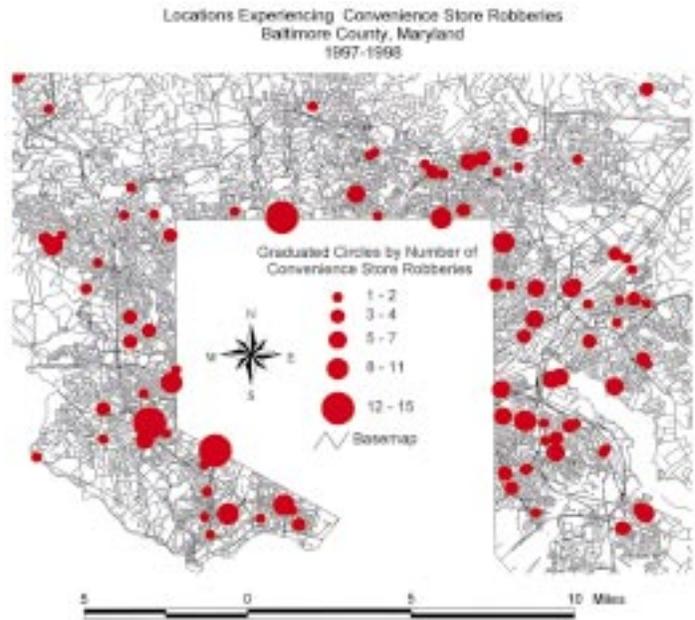


Figure 2.9

A graduated circle map showing robberies in Overland Park, Kansas.

Source: Susan Wernicke, Overland Park, Kansas, Police Department. Reproduced by permission.

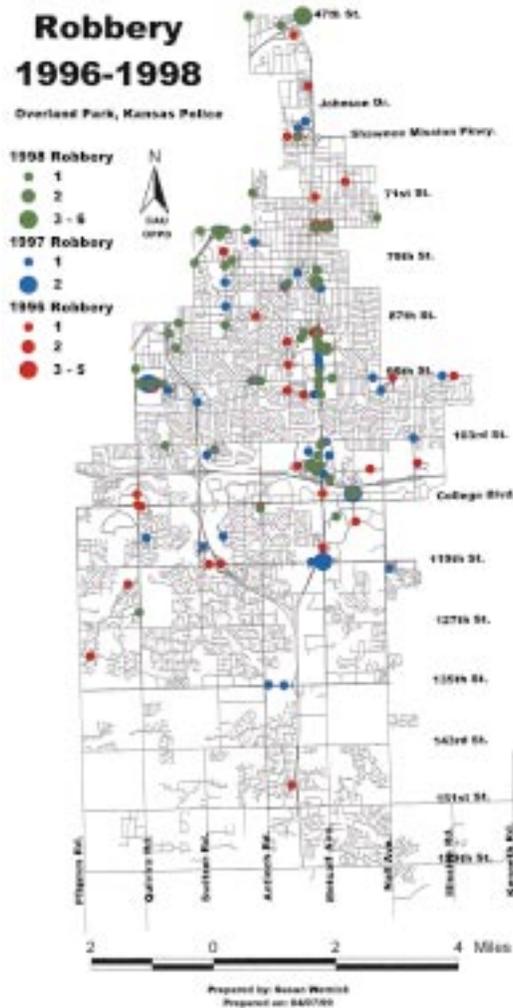




Figure 2.10

A graduated symbol map showing calls for service in a San Diego neighborhood.

Source: San Diego, California, Police Department. Reproduced by permission.

combined if this helps convey the essential information to readers and avoids overloading the map. Note also that the size range for symbols is a judgment call. If the size range is too small, readers will have difficulty extracting meaning from the map. Also, some symbols are more effective than others in conveying the message. Solid symbols probably work best in most cases because they engage the eye more effectively.

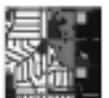
A disadvantage of using statistical symbols on maps is that they may overlap one another and result in an illegible mess. Map design must take into account the final size of the map, the scale to be used, and the possibility of overcrowding.

The use of statistical devices of various kinds on maps is limited only by the analyst's imagination. For example, it may be useful to accompany a map with a scatter diagram showing a collateral relationship, such as calls for service by time of day (chart) and calls for service by location (map). Mapping software offers numerous possibilities because the programs usually

can make both charts and maps and combine them in layouts in useful ways.

Thematic maps using area symbols

When we think of making maps that represent areas, it's the *choropleth* map that usually comes to mind, with administrative or political areas shaded according to their statistical values, whether they are frequency counts, averages, or other relevant measures. When is a choropleth map appropriate? Strictly speaking, mapping total numbers, such as crime counts, using choropleth mapping is unacceptable owing to the misleading impression given by unequal areas. For example, if the largest and smallest areas have the same frequency, they will be shaded the same on the map, which fosters possible misinterpretations based on per capita or density considerations. However, many departments overcome this by using a regular grid for choropleth mapping. This has the advantage of equalizing areas but the possible disadvantage that the units of the grid may not be "natural" local areas.



What Crime Maps Do and How They Do It

In other words, the areas exist only on police department maps and may be difficult to interpret in the field.

For places with boundaries following the rectangular land survey, a grid of square miles (sections) or quarter-square miles will be substantially visible in the local street pattern system. This applies to most areas west of the Appalachian Mountains. East of the Appalachians, survey systems were usually based on irregular “metes and bounds” and do not lend themselves

to grid-based maps, except where cities have a regular block grid. (See also chapter 4, “Definition in geographic space.”) Examples of choropleth maps are shown in figures 2.11 and 2.12.

Choropleth maps are best used for area averages, such as crime rates, population density, and percentages, as well as nominal-scale information such as land use. Care is needed in the interpretation of all maps, and choropleth maps are no exception. Take, for instance, a choropleth

Residential Burglaries in Baltimore County

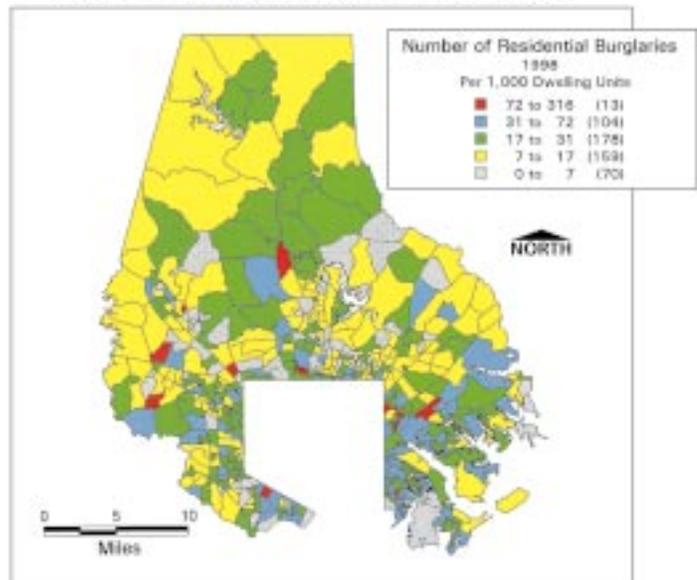
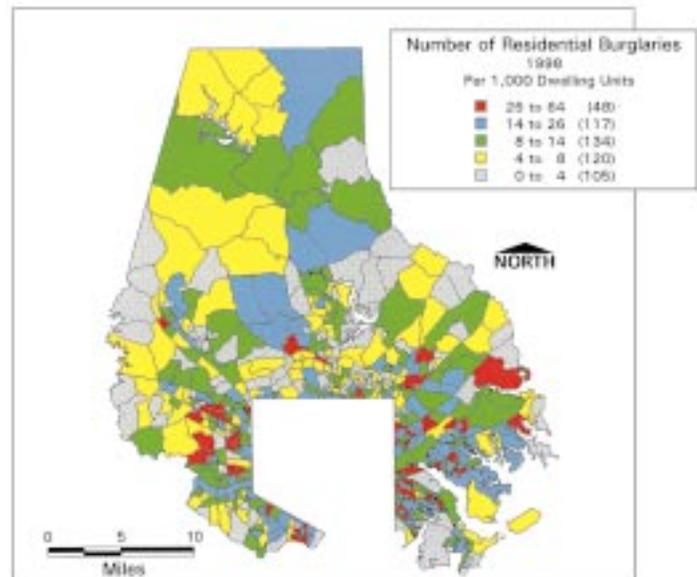


Figure 2.11

Choropleth maps showing residential burglaries in Baltimore County, Maryland.

Source: Philip Canter, Baltimore County, Maryland, Police Department. Reproduced by permission.



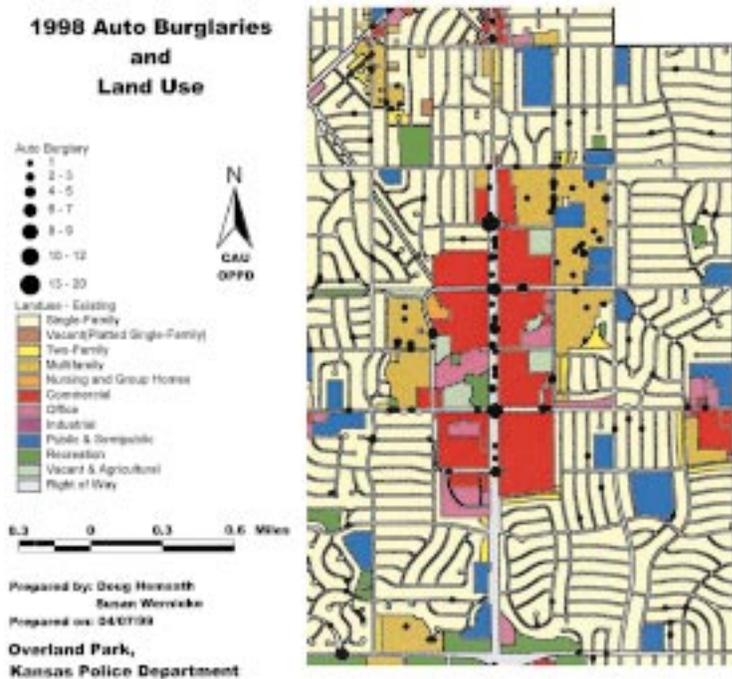


Figure 2.12

A choropleth map showing land uses (choropleth colors) and auto thefts (proportional circles) in Overland Park, Kansas.

Source: Susan Wernicke, Overland Park, Kansas, Police Department. Reproduced by permission.

map of a crime rate based on population. Map values are expressed in terms of numbers of crimes per population unit. But what population? Normally, the residential population as enumerated in the census is implied. What about downtown business areas with negligible residential populations? They still have crimes and the statistical effect is to inflate the crime rate. Is this realistic?

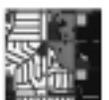
One could take this scenario to the extreme: If small areas are used for crime rate calculation, we may have areas with crimes but no resident population, producing an infinite crime rate! Bear in mind that the crime rate concept is a loose one and

crime rate maps are only an approximation, particularly for smaller areas. Although neither the offenders nor the victims are necessarily residents of the areas where the crimes happen, they would nevertheless be represented in crime rate maps.

Experience has shown that it may be helpful to add a disclaimer note on some maps to point out, where appropriate, that some areas with high crime rates have small or zero residential populations. Another form of this disclaimer would note that rates have not been calculated, or have been intentionally omitted, for areas with small or no residential population. This will have to be handled carefully,

Rule of Thumb

Avoid generating choropleth maps of crime rates for small areas like city blocks because spurious results could be produced for areas where there are crimes but no residents.



however, since some readers may conclude that the police department has something to hide if data are manipulated in what appears to be a selective way.

Note that choropleth maps can be produced in a three-dimensional format with the height of each area proportional to its data value.² The advantage of this type of presentation is visual appeal and vividness. The disadvantages are that it can be difficult to decipher the actual data value, and that a tall column will hide other areas, as is the case in three-dimensional surface maps.

Thematic maps using surfaces

Although crime maps using isolines have been around in some form since the 1960s, they have only recently become widely used.³ This is a result of the availability of algorithms in mapping programs that perform complex calculations at high speed. With the addition of three-dimensional capabilities, surface maps with textured surfaces are now within the reach of most crime analysts. Such maps are tempting as they are visually more appealing than two-dimensional renditions. But the same caveats noted above apply. Just because a surface map or three-dimensional rendition *can* be produced, it does not necessarily follow that it is the most appropriate or useful form for visualizing the data. For example, it may be difficult to add legible landmark icons or even boundaries to a three-dimensional map, depending on factors such as scale and amplitude, or the degree of peakedness, of the map, as well as the angle of view. (See figure 1.14 and chapters 4 and 6 for other examples of three-dimensional maps.)

Ultimately, deciding whether to use a surface map involves balancing scientific and artistic judgment, and in many cases the decision can be made only through experimentation. Fortunately, maps can be produced rapidly with desktop computers, so experimentation can and should be a routine part of the mapmaking process.

Thematic maps using linear symbols

Flows between points are shown with linear symbols, with their width or thickness generally proportional to the volume of the flow (figure 2.13). Maps of this type had their origins in economic geography, first showing passenger flows on Irish railways in the 1830s and, later, commodity flows among nations (Campbell, 1993, p. 264). These maps can be used in crime mapping, to show, for example:

- Links between where vehicles were stolen, where they were recovered, and suspects' addresses.
- Routes between victims' and offenders' home addresses (e.g., Pyle et al., 1974; Frisbie et al., 1977, p. 88).
- Passes along streets by patrol cars to illustrate patrol density.⁴
- Traffic density.

Virtually no flow maps have been seen in the recent literature on crime mapping, even though such maps are in use in police departments. Their absence is not due to lack of data. It may be that the apparent lack of this type of map in the literature is due to the absence of readily



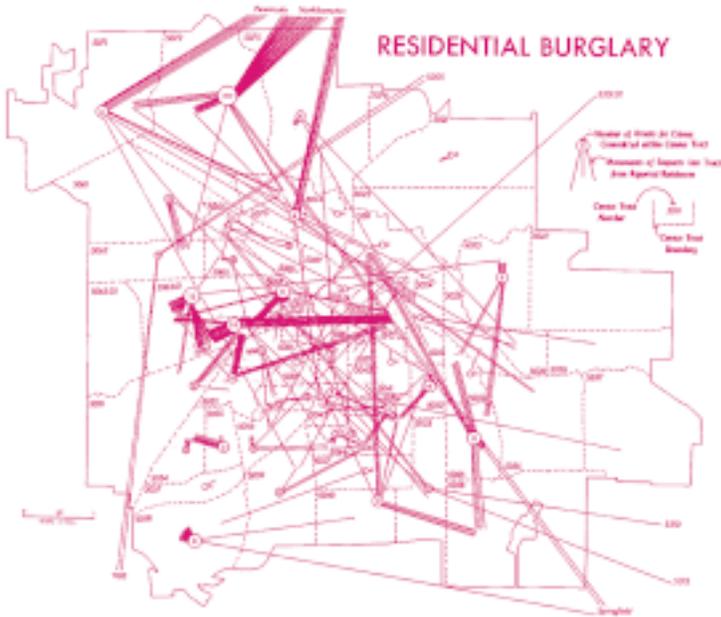


Figure 2.13

A thematic map using linear symbols that shows numbers of residential burglaries, arrests, and suspect movements, Akron, Ohio.

Source: Pyle et al., 1974, figure 42, p. 167. Copyright, 1974, University of Chicago.

available flow-mapping algorithms in the GIS programs most popular among crime mappers. While it is unlikely that flow mapping will ever be a major component of crime maps, it will be increasingly used owing to its obvious utility in limited applications.

Classifying map information

Generally, information on maps is classified in some way; data are not symbolized individually. For example, all burglaries are shown with the same symbol on a point map. It would be absurd to show each crime with its own symbol.

In effect, maps contain two levels of abstraction:

- The overall level of detail and the scale used to present the data.
- The way data are symbolized, because there is a continuum from highly

detailed to extremely generalized in the symbolization process.

To some extent, the choice of scale controls the level of abstraction of the content because it is impractical to load a small-scale (large area) map with local detail. MacEachren (1994, p. 41) argues that for categorical information, “features that end up in the same category should be more similar to one another than features in different categories.”

What does this mean for crime maps? A map of drug offenses might group related drug categories together. Generically related robberies could be put together in the same category and symbolized the same way on a general crime or violent crime map. If a map were specific to robberies, however, symbolization might be separated into commercial and street or weapon type or time of day. This type of adjustment is intuitive and naturally occurs in the crime context where data are typically sorted into categories as part of normal



What Crime Maps Do and How They Do It

processing. But the situation becomes more intricate when moving from nominal and ordinal data to ratio-type data.

It is less obvious how to classify numerical data when several alternatives present themselves. Common mapping software packages offer options, including a default, for grouping numerical data in thematic maps but rarely explain how to choose among these approaches. Dividing up the data range in a way that best represents it involves the abstraction issue again.

Total abstraction would be represented by the use of one shade for all areas on the map. This says that there are data, but little or no specific information is supplied about them. At the other extreme, each area would have its own shade, and if city blocks were shown, the map would have thousands of shades. Obviously, neither of these alternatives is useful, and the solution lies somewhere between.

Greater accuracy dictates the use of more classes of data, although readers pay a price for this in terms of comprehension as the map moves along the continuum of abstraction toward reality and complexity. The underlying question is, What is this map being used for? MacEachren (1994, pp. 42–43) suggests that if we are in the visual thinking stages of exploration and confirmation, we will need more detail (more classes), but as we progress toward synthesis and presentation it becomes

more important to show general trends rather than detail, hence fewer classes. Furthermore, limitations on human visual comprehension must also be taken into account—the limit is about six levels of color or gray scale shading in the context of a map.

Are there natural breakpoints in crime data? For example, in a robbery map of a city we could embed the State, regional, and national robbery rates as breakpoints. This might be informative but could get a political “thumbs down” if the local jurisdiction compares unfavorably. (Conversely, it could be a popular approach.) Choices available to cartographers in common desktop mapping packages are represented by the drop-down menus shown in figure 2.14.

The choices available, and the relative ease of using them, invite experimentation. How will a particular database look when mapped in a particular way? What method conveys the crucial information with the least distortion and best visual impact? Good maps are likely to result from a working environment that encourages experiment because it is ultimately through trial and error that most learning is done. This is said not to invite a “shotgun” approach but, rather, to encourage the responsible testing of options under the assumption that alternative methods of representation are tested for a reason other than the sake of doing something different.

How Many Classes in a Map?

Use no more than six—and not less than four—classes, or shading levels, of data in a choropleth map.



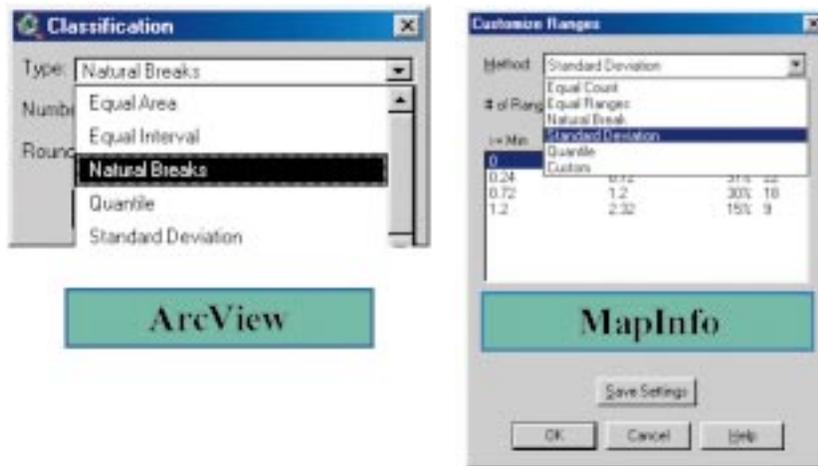


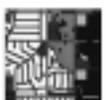
Figure 2.14

Choices for class interval determination as presented in two widely used desktop mapping programs. Left, ArcView®; right, MapInfo®.

Sources: ESRI, Inc., Redlands, California, and MapInfo Corporation, Troy, New York.

Each of the alternatives typically employed in data mapping is introduced here and illustrated in figures 2.15 and 2.16.

- **Equal ranges or intervals.** The data range (difference between maximum and minimum) is calculated and divided into equal increments so that the within-class ranges are the same, such as 1–3, 4–6, 7–9, and so on.
- **Equal count (quantiles).** Approximately the same number of observations is put in each class. The number of classes determines the technical definition of the map (quartile if there are four classes, quintile if there are five classes, and so forth). The term quantile is the generic label for data with observations divided into equal groups. This software option gives the user the opportunity to enter the number of classes desired. (This is the default in MapInfo®.)
- **Equal area.** Breakpoints between classes are based on equality of area rather than equality of range or an observation count. If areas in a choropleth map vary greatly in size, this type of map will differ from an equal count map based on the same data. If areas are roughly equal in size (such as city blocks), the result will be similar to an equal count presentation.
- **Natural breaks.** In this approach, gaps or depressions in the frequency distribution are used to establish boundaries between classes. This is the default in ArcView®, which employs a procedure known as *Jenks' Optimization* that ensures the internal homogeneity within classes while maintaining the heterogeneity among the classes. (For more details, see Dent, 1990, pp. 163–165, and Slocum, 1999, chapter 4.)
- **Standard deviation (SD).** SD is a statistical measure of the spread of data around the mean, or average. In the literature of stocks and mutual funds, for example, SD is often used



What Crime Maps Do and How They Do It

as a risk index, since it expresses the amount of price fluctuation over time. In the context of crime, SD can be a useful way of expressing extreme values of crime occurrence or portraying various social indicators. Generally, classes are defined above and below the average in units of 1 SD. The drawback is that this method assumes an underlying normal distribution, or bell-shaped curve, something of a rarity in social data.

- **Custom.** As the label suggests, this option allows users to determine class

intervals according to their own criteria, such as regional or national norms and thresholds determined for policy reasons.

Table 2.1 summarizes the criteria for selecting methods to define class intervals for maps, providing a guide with respect to data distribution, ease of understanding, ease of computation, and other standards. (For a comprehensive discussion of issues relating to the determination of class intervals for maps, see Slocum, 1999, chapter 4.)

Table 2.1. Criteria for Selecting a Method of Classification

Criterion	Equal Interval	Quantiles	Standard Deviation	Natural Breaks
Considers distribution of data along a number line	P	P	G	VG
Ease of understanding concept	VG	VG	VG	VG
Ease of computation	VG	VG	VG	VG
Ease of understanding legend	VG	P	G	P
Legend values match range of data in a class	P	VG	P	VG
Acceptable for ordinal data	U	A	U	U
Assists in selecting number of classes	P	P	P	G
P=Poor G=Good VG=Very good A=Acceptable U=Unacceptable				

Source: Thematic Cartography and Visualization, T.A. Slocum, 1999, figure 4.7, p. 74. Reprinted by permission of Prentice Hall, Inc., Upper Saddle River, New Jersey.



Maps and statistics: Exploratory spatial data analysis

Some statistical methods have been mentioned in the preceding discussion, and consideration of statistical concepts is unavoidable when considering how best to visualize numerical data. As noted earlier, because we can lie with statistics, we can also lie with statistical maps. Indeed, maps have been used throughout history as propaganda tools (Campbell, 1993, pp. 229–235), so potentially we can have honest error as well as pure cartographic deceit. Perhaps the greatest danger in the mapmaking process is that people tend to believe the information in maps (what MacEachren, 1995, p. 337) called the connotation of veracity), and they also believe that maps are unbiased (the connotation of integrity).

But mapmakers, like other elements of society, are culturally conditioned, selectively including and excluding data according to the values of the responsible parties. Given that maps can harbor many possible errors and biases, both intentional and accidental, it is incumbent on the crime analyst to be aware of possible sources of error and to work to avoid them. Nowhere is there more scope for distortion and misinterpretation than in

the preparation of maps based on numerical data. This is due to the potential complexity of the information and the infinite set of display permutations, whether in raw form or as some derivative measure such as a rate or percentage.

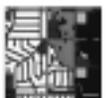
Mapmakers can gain a preliminary understanding of what the numbers mean through the process of exploratory spatial data analysis. It is quite helpful to understand what the distribution of a set of numbers looks like when expressed graphically. Is this a normal (bell-shaped) distribution with most observations clustering around the mean, or average, and a few very low and a few very high values? Is it a skewed distribution with extreme values to the right (high values) or the left (low values)?

In the unlikely event of a normal, symmetrical, bell-shaped distribution, maps created by all of the classing methods look similar. Almost always, however, real-world data are somewhat skewed, and different classing methods produce maps that look different and convey different visual impressions to readers.

Consider in some detail what will happen when different methods are applied to a data set that has a strong positive skew (figures 2.16 and 2.17).

A Note on Skewness

A normal distribution is the familiar bell-shaped curve that is seldom seen in crime data. Most crime data are positively skewed, meaning there is a long right "tail" representing a few high values. Hot spots (high crime areas) are geographic expressions of skewness, which presents difficulties in mapping numerical data. See the box, How Much Exploration? and figures 2.15 and 2.16.



What Crime Maps Do and How They Do It

Let's review each histogram (or frequency curve) and map in figures 2.15 and 2.16, method by method.

- **Equal count.** On the histogram, the right tail (highest values of the distribution) is prominent because there are few extremely high values. Thus, the program has to seek the lower rank-ordered data values (farther to the left on the histogram) to come up with the 13 observations for the class. (Note that the number of observations per class is uneven, ranging from 13 to 17.) The resulting map tends to visually exaggerate the seriousness of the problem because color saturates more map areas.

Best Choice?

Generally, natural breaks or equal intervals will be the best methods for creating area-type maps in crime analysis.

- **Equal range.** Because the distribution is right-skewed, equal range will tend to favor lower data values. The two lowest classes have 23 and 26 members, respectively, while the higher classes have 7 and 3. The map contrasts with the equal count version, now visually minimizing the problem.
- **Natural break.** This method appears to have struggled to come up with natural breaks, which is a problem, along with breaks in awkward places. The result here is quite similar to the equal range breakdown, with cuts between classes shifted to the left (lower values) as compared with the equal

range. It comes as no surprise that the equal range and natural break maps are quite similar.

- **Standard deviation.** Here, the breakdown of class intervals is set with reference to the average, or mean, so that an interval of 1 SD is established to the left of (below) the mean (blue line, 0.47), and above the mean at the same distance. The effect of this on the right-skewed distribution is a symmetrical breakdown, with about as many observations in the lowest (10) and highest (9) classes and in the two middle classes (22 and 18). The visual impression conveyed by the associated map is close to the severity of the

equal count method. This is due to the similar number of observations in the top category.

The basic point to be made from this discussion is that cases that may fall in a

given class by one method may be in a different class by another. The only certainty is that the highest and lowest values will always be in the top and bottom map classes, respectively. What method is preferable? MacEachren (1994, p. 47) noted that, "for any skewed data, quantiles are a disaster for a presentation map!" In the above example, quantiles result in such a large data range in the highest class as to be almost meaningless. Standard deviation classes may be helpful in some situations where the distribution is not extremely skewed.

Note that a frequency curve shows skewness in the rank-ordered data values, but



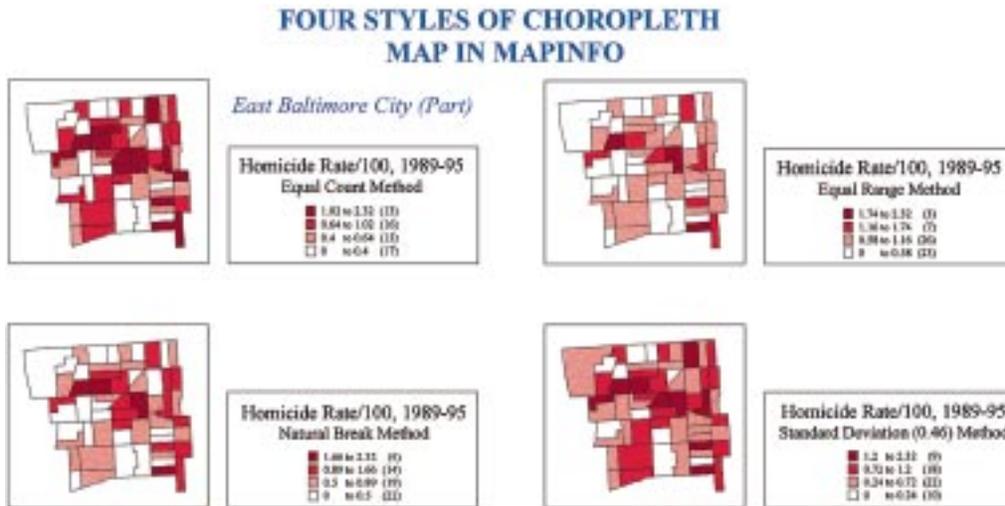


Figure 2.15

East Baltimore City homicide rate in choropleth maps using different methods.

Source: Keith Harries.

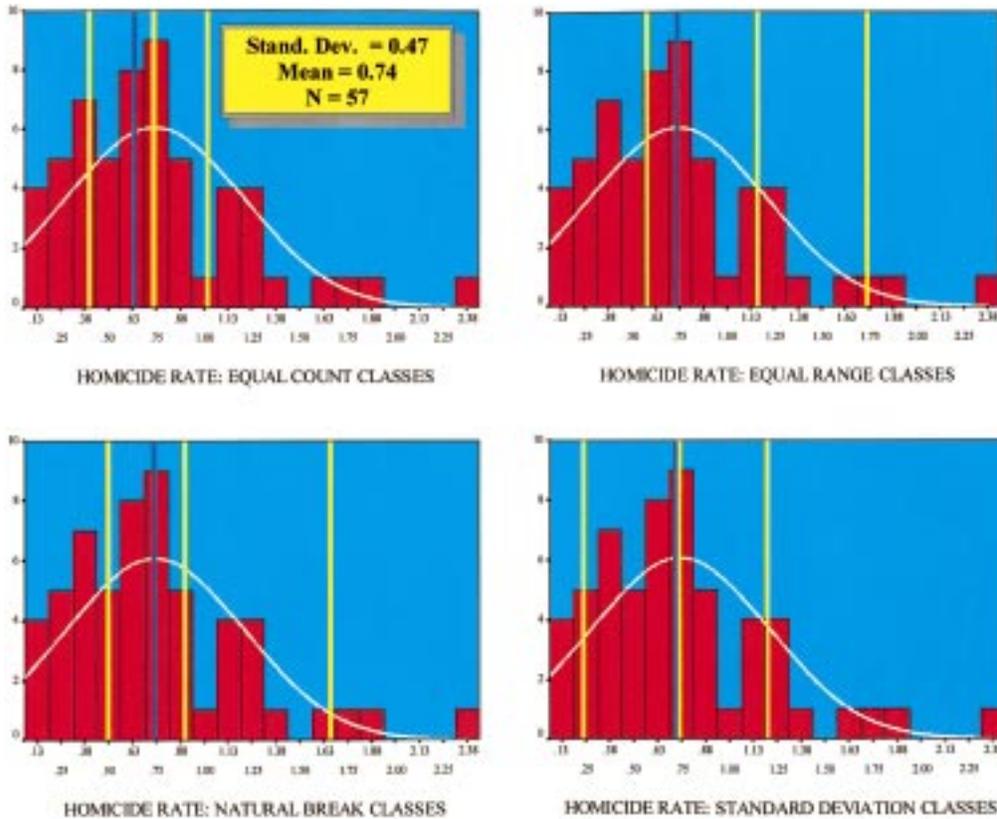
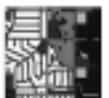


Figure 2.16

Histograms associated with maps in figure 2.15 with class interval breaks (vertical yellow lines) and normal distributions superimposed.

Source: Keith Harries.



only a map can show skewness in geographic space. Are the high values distributed geographically in a random way or clustered? Either method yields useful information. If the high crime rates are clustered, it may indicate a hot spot. If the high rates are random, the net impact on the community may be about the same, but we are now unable to point to a hot spot.

We can see an empirical relationship between map scale and skewness, which is minimized in a small area (large scale) and maximized in a large area (small scale). Think of it this way: A very small area in the community, say 1 square yard, can have no spatial skewness because only one event can happen there. But as the spatial scope increases (smaller scale maps covering larger areas), the potential for skewness increases because there can be bimodal, or split, distributions in space (as well as time). A clump of events can occur in one small area with the rest empty—an extremely skewed pattern.

This is what the crime scene is like on a regional, national, or global scale. Clusters correspond to opportunities presented by the underlying controlling condition, population distribution. At the smallest scale (region or world), the crime map is for all practical purposes the same as the population map, but at larger scales (city or neighborhood) we refine the view and see that the presence of people actually means variations in rates conforming to varied social and physical environmental conditions. Also, at larger scales we will see different patterns depending on the denominators used to calculate crime rates.

Another way to visualize a distribution is the use of a box plot, which shows how data are spread in relationship to the mean, median, mode, and quartiles, with outliers symbolized in a special way. (Outliers are values more than 1.5 box lengths from either the 25th or 75th percentiles.) If we examine the HOMRATE data set using the box plot routine in the Statistical Package for the Social Sciences (SPSS), the result appears as shown in figure 2.17.⁵ Note that the box plot is an alternative way of visualizing the same data shown in figures 2.15 and 2.16. In the box plot in figure 2.17, the red box represents 50 percent of the data values, with the median shown by the bold line across the box. The 75th and 25th percentiles are the top and bottom of the box, respectively. The ends of the Ts represent the smallest and largest observed values that are not defined as outliers. Although the box plot seems to be repetitive, it provides a different perspective on the data—one that complements the more frequently used histogram. (For a detailed explanation, see SPSS documentation, such as *SPSS for Windows Base System User's Guide Release 6.0*, p. 186.)

Only the immediate objective and the available tools limit the amount of exploration and preprocessing crime mappers do. Perhaps the single most important exploratory step is the creation of a histogram, box plot, or comparable graphic with which to visualize the shape of the data and answer the fundamental question: Is it severely skewed or in some other way not normal (e.g., bimodal or double peaked)? How will this affect maps, and what type of map will permit a presentation that minimizes distortion and



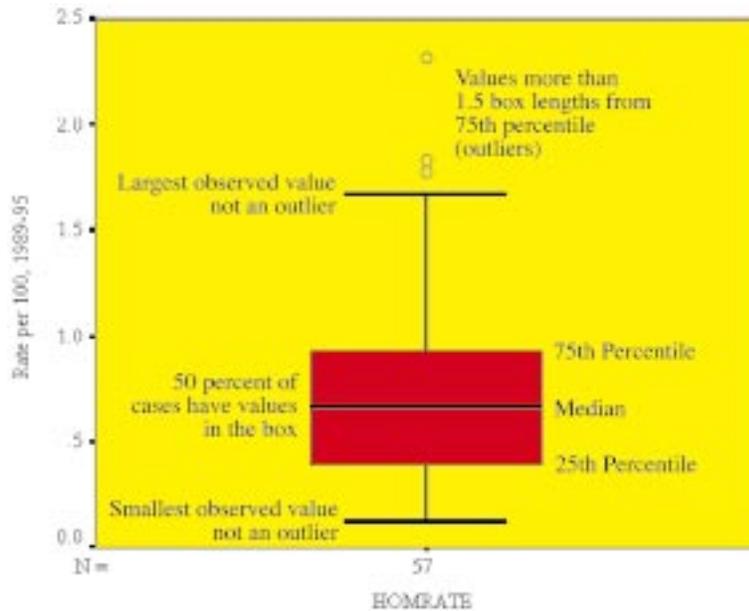


Figure 2.17

A box plot of homicide rate data. Compare with histograms (see figure 2.16).

Source: Keith Harries.

accurately portrays the data? Again, this examination of the data is the ideal. Not all analysts will have the tools or the time to go through this step. Nevertheless, these possibilities are outlined here to raise awareness of what constitutes the best practice.

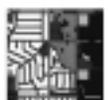
Map design

The field of map design has generated substantial literature in cartography focusing on how people comprehend maps and the impact of various design elements such as symbol size, color, and line thickness. Also of interest is the impact of the arrangement of a map within the map frame as well as the merits and demerits of various types of maps.

Debate continues, for example, over the dominance of choropleth maps to represent numbers. Opponents point to the most obvious choropleth defect: its use of one data value to represent an entire area, an absurdity that becomes acute when

most of a geographic subdivision contains virtually no human activity because of the terrain or the existence of bodies of water.⁶ Muehrcke (1996) quoted Ronald Abler, Executive Director of the Association of American Geographers, who, in 1987, said something to the effect that choropleth maps were an abomination that GIS would soon eliminate through the use of dasymetric mapping.⁷ (The death of the choropleth map has been slow!) However, the increased use of density surfaces in various desktop GIS programs is a move away from such heavy reliance on either dot or choropleth modes of representation and is consistent with the concept of areal averaging—without slavish adherence to political or administrative boundaries.

Map design is at once a technical and an artistic effort. Dent (1990) devotes 5 chapters and about 120 text pages to designing thematic maps; we can give only broad consideration to a few issues relating to typical parts of a map and how they should be organized. The reader is



What Crime Maps Do and How They Do It

referred to the following textbooks for a full explanation, particularly on such details as lettering and labeling: Campbell, 1993; Dent, 1990, 1993; Robinson et al., 1995; and MacEachren, 1994, 1995.

It may be helpful for newcomers to map-making to make a flow chart in which the design of the map is adjusted to ensure that the map fulfills its stated purpose. This activity may become less important

How Much Exploration?

A histogram of the numerical data, as well as statistics for skewness and kurtosis will help determine what kind of map would be most effective and least misleading. Common statistical packages such as SAS® and SPSS® enable the rapid production of these diagnostics. Also, Microsoft Excel and other spreadsheets yield the following statistics as well as a histogram option. (In Excel, see the Tools menu, then Data Analysis.)

HOMRATE*	
Mean	0.74
Standard Error	0.06
Median	0.67
Mode	N/A
Standard Deviation	0.47
Sample Variance	0.22
Kurtosis	1.44
Skewness	1.10
Range	2.20
Minimum	0.12
Maximum	2.32
Sum	42.43
Count (number of block groups)	57.00
Largest (1 case)	2.32
Smallest (1 case)	0.12
Confidence Level (95.0%)	0.12

Interpretation: Values of the skewness and kurtosis are centered at zero. If either is relatively large, a nonnormal distribution is likely. See Norcliffe (1977) for more detail on this, and consult figures 2.15 and 2.16 for graphic interpretations.

*HOMRATE is the homicide rate per 100 persons in a selected part of Baltimore, Maryland. These statistics were used to compile figures 2.15, 2.16, and 2.17.

Source: Keith Harries.



over time as intuition and experience take over from reliance on a formally structured process. Dent (1990, p. 316) lists the following elements of the thematic map, which could serve as a checklist for inclusion:

- Title (or caption).
- Legend.
- Scale.
- Credits.
- Geographic content (showing information that may not necessarily be included in the subject matter of the map, such as orientation or north arrow).
- Graticule (spherical coordinate system: latitude/longitude, State plane).
- Borders and neatlines (the lines that bound the body of a map, usually parallels and meridians).
- Symbols.
- Labels.

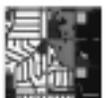
Most of these elements are necessary in a typical crime map. The principal exception is the graticule (spherical coordinate grid), which normally serves no useful purpose.⁸ Also, credits are rarely used because data are likely to be locally derived. However, if data sources are not self-explanatory, credits clarify exactly where the data came from. This information could be listed under the body of the map using the keywords “source” or “data source.” We could add author to the list to assist in the

process of accountability, inconspicuously noting the name or initials of the analyst-cartographer in a corner of the map.

A useful approach to learning more about design is to look at examples of crime (and other) maps that have been deemed acceptable by their respective audiences. Fortunately, there is no shortage of maps, whether on crime or on other phenomena. The easiest access is via the World Wide Web, and the appendix of this guide lists some useful Web site addresses. Chapter 3 uses examples to discuss various applications of crime mapping. Here we confine ourselves to outlining principles.

Dent (1990, chapter 13) has noted several *elements of map composition*: balance, focus of attention, and internal organization.

- **Balance** refers to the need to arrange parts of the map in a way that enhances its visual symmetry. However, the crime cartographer may have little flexibility with respect to balance owing to inherent content limitations. For example, the jurisdiction may be extremely asymmetrical, making it difficult, if not impossible, to map without leaving considerable white space on the paper. Cities with long “shoestring” annexations, like Los Angeles, or States with long panhandles, like Oklahoma, are good examples of difficult map shapes. This problem sometimes can be solved by chopping the city or other area of interest into its component parts. An inset, or miniature map of the whole, is used to show how the pieces fit back together. Another solution is to routinely map individual precincts or districts



under the assumption that the managers of those areas are first and foremost interested in seeing patterns in their areas of responsibility. The drawback to this is that crime patterns do not pay much attention to administrative or political boundaries, so that looking at individual subdivisions in isolation from the rest of the area may cause someone to miss hot spots or other useful patterns by fragmenting them.

- **Focus of attention** is a concept based on the assumption that people read maps like they read the printed page, by moving their attention from upper left to lower right.⁹ Hence the optical center of a map is somewhat above the geometric center suggesting that, ideally, the most significant information should be closer to the optical center. Again, this is easier to manage in theory than in practice. Still, it is a useful concept to bear in mind because crime analysts will sometimes have enough discretion in design that the focus of attention can be exploited to advantage.

- **Internal organization** refers to the alignment of the parts of a map or individual maps on a page or within a frame. Map elements should be arranged in a logical way rather than placed haphazardly on the page. The core contents of the map, for example, should dominate the space, and other elements should be secondary.

According to Dent, contrast also is important to visual perception. Line, texture,

value, detail, and color are powerful tools because they allow map elements to be differentiated from one another. More contrast makes objects stand out, less allows them to fade into the background. *Line* thickness, or weight, can assist in this process, and using more than one line weight on the map can add interest.

Texture can add variety and draw attention to an important part of the map.

Value refers to the use of lighter or darker shades of color, and *detail* draws the eye in. As noted elsewhere, however, detail is a two-sided coin. It adds interest, but when used to excess it can cause clutter and make the map illegible. If a map is to be reduced for publication, fine detail may be completely lost in the reduction process. Experiment with enlarging and reducing on a photocopier to learn more about how this works in practice.

Color is extremely important in the process of area differentiation. It is also a complex issue owing to the physiological, psychological, and physical processes involved. Dent (1990, chapter 16) notes that color has three dimensions: hue, value, and chroma.

- **Hue** is the term given to color labels—red, yellow, and blue, the primary colors—and the millions of permutations derived from them.

- **Value** refers to the degree of lightness or darkness of a color. GIS programs can help you select color values by providing color “ramps” (or series of related shades or values of a hue) in a visually logical sequence ranging along an intensity spectrum. Colors vary



along a continuum from light to dark. For example, reds may range from light pink to deep red, and blues may range from sky blue to navy blue.

- **Chroma** is understood through the concept of color saturation. A less saturated color appears to contain more grays, and a saturated color has no gray and appears as the “pure” color. In photography, some films have a reputation for conveying more saturation than appears in natural scenes (bluer blues, greener greens), “larger than life” color that is pleasing to some viewers but excessive to others.

Choices of color in maps need to be made quite carefully because color may have strong emotional connotations for some readers. For example, should red be used for a map of violent crime, given the symbolic connection to blood? It is tempting to overload crime maps with warm colors, such as red and orange, but the analyst should be mindful of the symbolic effect and the impact this may have on the intended audience.

Just as color makes maps and other graphics come alive, color also enhances our ability to mislead people with maps through the use of inappropriate hues and values. For example, a crime category that is a local political “hot potato” could be visually minimized through the use of

cool colors in subtle shades lacking saturation. The use of color in maps and graphics is complicated by the fact that a significant portion (8 percent of males and 0.5 percent of females) of the population is at least partially colorblind.

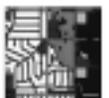
Crime mappers can take advantage of various models of color sequencing. GIS software typically defaults to a part-spectral plan with shades from yellow to brown. In a full-spectral plan, colors range from warm to cool, and in a double-ended plan, data values representing an increase (or above average) are in one color and a decrease (or below average) in another. Increases (or higher values) are typically shown in warmer colors, decreases (or lower values) in cooler (see Dent, 1990, p. 387). GIS software normally permits the customizing of colors to fit your purpose.

Design, abstraction, and legibility

Map design and abstraction are inseparable. The map design defines the level of abstraction to be imposed. “To represent is to abstract,” wrote Muehrcke, and “abstraction frees us from the tyranny of our physical existence” (1996, p. 275). He presumably meant that it gives us license to, so to speak, “mess with reality.” Many of the issues that concern cartographers, such as the degree of distortion on world maps, are of little concern to crime

Using Colors and Shades

- Use darker colors or gray shades for more or higher values.
- Use lighter colors for less or lower values.



What Crime Maps Do and How They Do It

mappers. Where should we focus our attention when it comes to thinking about abstraction in our maps? What can we afford to ignore? Are any map elements indispensable on most crime maps?

Abstraction, the reduction of detail on maps, permits us to design our maps in ways that make them attractive and effective. Abstraction is like the sculptor's chisel—it determines what remains of the raw material and what form the finished product will take. As noted earlier, most map elements are dispensable at one time or another, depending on the context.

First and foremost, the analyst must consider the audience and the medium of presentation. Will the map go to one person and be seen at arm's length? Will it be a page in a report? (If so, will it be in color? How would the map look if it was converted to gray scale?) Will it become a transparency for an overhead projector or a 35-mm slide? Will it be incorporated into a digital projector production in Microsoft PowerPoint® or comparable software?

If a map is to be projected, lettering size and line weight become quite critical. You may have a brilliant map with potentially great visual impact, but if two-thirds of the audience can't read the lettering when it is projected, your creativity is wasted.¹⁰ Also consider the "demographics" of the audience to be addressed: are they younger? older? more educated? less educated? predominantly female?

If the audience is not similar to the general population, some adjustments in map

design may be needed. Research has shown, for example, that there may be subtle differences in the way men and women read maps (Kumler and Buttenfield, 1996).

This begs the corollary question of exaggeration in maps to gain legibility. Sometimes detail must be retained, but this may result in objects running together owing to the thickness of the lines representing them. Line thickness may need to be adjusted and objects may need to be moved slightly to maintain visual separation. Bear in mind that line work on maps often greatly exaggerates the true dimensions of linear features. A typical State highway map may be used as an example. On this map, interstate highways are 1/16th of an inch wide. The representative fraction (RF) of the map is 1:380,160, or 6 miles to the inch, which represents a width of 660 yards. This is probably, on average, double the width of most interstate highways. By comparison, area features such as a city block, a city, or a county, should be accurately rendered because exaggeration is not needed to make them visible.

Even point data generally exaggerate the size of the location at which a crime incident occurred or the address of the victim or offender. Point symbols are actually markers for general locations and should be interpreted as approximations owing to (a) the size of the point symbol and (b) normal problems with address interpolation touched on in chapter 4 of this guide. It is tempting to see point data as the epitome of accuracy, but this accuracy is relative.



Map Design Questions to Consider

- Is this the best map for the stated objective?
- Is the scale appropriate?
- Does the design account for both data representation and aesthetics?
- Could a flowchart ensure the inclusion of all necessary elements?
- Are the sources of data, authors of the map, and date of preparation shown?
- Are balance, focus of attention, and internal organization considered?
- What colors work best?
- Is the map legible in all the contexts in which it will be used (print, slide, fax, PowerPoint®, and overhead transparency)?

Crime mappers might consider using more *perspective symbol landmarks* or *mimetics*¹ to help readers orient themselves, particularly in metropolitan areas (see figures 1.2, 3.25, and 5.9). These symbols are pictorial and characterize the landmarks they represent, such as the use of an airplane symbol to represent an airport or silhouettes of familiar structures, such as a school, church, ballfield, cathedral, city hall, or highrise tower. Such pictorial devices are more important for lay audiences than for police officers, who are familiar with the area, although the assumption that all cops are equally familiar with entire cities or metro areas is a fallacy. We—even cops—are victims of our daily routines and the neighborhoods they take us through. None of us can comprehend entire metropolises, at least not at the level of street name familiarity.

Summary

Chapter 2 has explained:

- What crime maps should do.
- How crime maps do what they do.
- How to choose the right kind of crime map.
- Types of thematic maps.
- How to choose class intervals in numerical data.
- Why data should be explored.
- What is involved in crime map design.
- How crime map design, abstraction, and legibility are related.



What's Next in Chapter 3?

How maps can be designed to address specific issues and audiences, such as:

- Patrol officers.
- Investigators.
- Managers.

How maps can be used:

- To support community oriented policing and problem oriented policing.
- In courts and corrections.
- When communicating with policymakers.

Notes

1. Circle radii are a function of the square root of data values. A slightly larger value ("Flannery's Constant") is used in some programs to take into account visual underestimation of areas (Campbell, 1993, p. 272). This map was custom designed and executed by cartography students under the supervision of Thomas Rabenhorst, Department of Geography and Environmental Systems, University of Maryland, Baltimore County.

2. This is sometimes referred to as a "stepped" surface map as compared with a "smoothed" surface. The former is based on choropleth area subdivisions; the latter is not.

3. For an interesting early example of isolines applied to crime mapping, see Brassel and Utano (1979).

4. A map of this type, which has probably never been produced, would demand data from a global positioning system.

5. SPSS is described at <http://www.spss.com>. Another widely used package, the Statistical Analysis System (SAS), is described at <http://www.sas.com>. See also the Web site for S+ at <http://www.mathsoft.com/splus/>.

6. San Bernardino County, California, about the size of Denmark, is an extreme example. The urbanized part is small, and most of the county is part of the sparsely inhabited Mojave Desert. Yet a choropleth map of population density will show the entire county as having the same density (the average value), giving the visual impression that the desert is populated.

7. Dasymetric mapping ameliorates the areal averaging of the choropleth map by recognizing the internal variation inherent in the subdivisions. The result resembles an isoline map with political or administrative subdivisions superimposed. (For additional information, see Campbell 1993, p. 218.) For an illustration of what Tufte calls the "mesh" map alternative to



the choropleth map, see Tufte, 1990, pp. 40–41.

8. Some police departments rely on a proprietary map system for navigation; embedding that coordinate system in their current mapping applications could be helpful. In Baltimore County, for example, locational references are to the grid of maps published by ADC of Alexandria, Inc.

9. This assumption is culturally conditioned by the way the person reads,

which is itself language dependent. (Arabic is not read in the same way as English, for example.)

10. Take into account the size of the room and how far the back row of seats is from the image. Similar considerations apply if you have a poster-size map to be displayed to an audience.

11. Mimetic symbols mimic the appearance of the real object. (See MacEachren, 1994, pp. 56–57; 1995, pp. 258–259.)

