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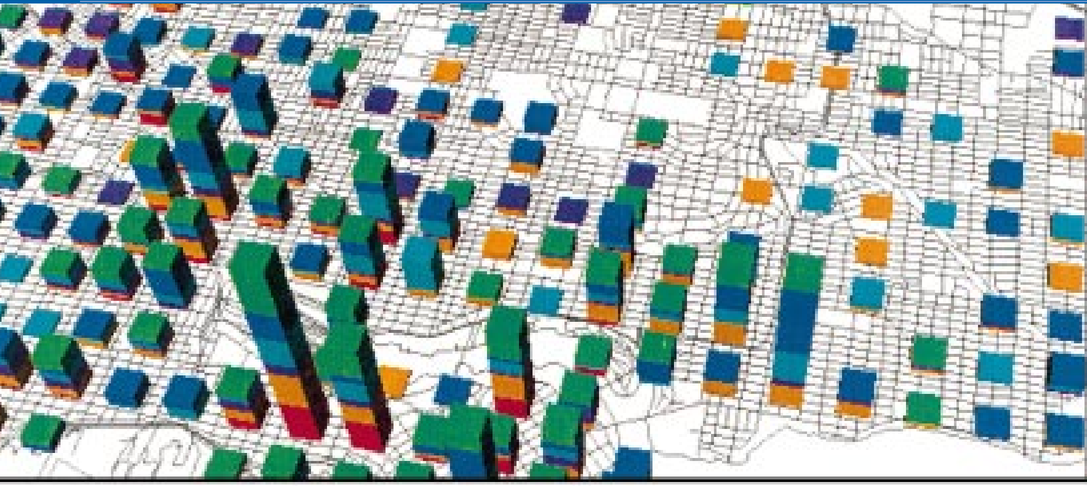
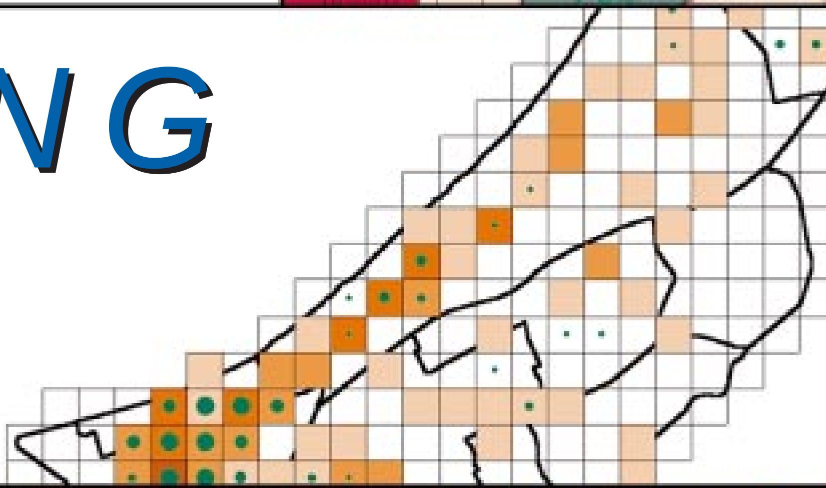
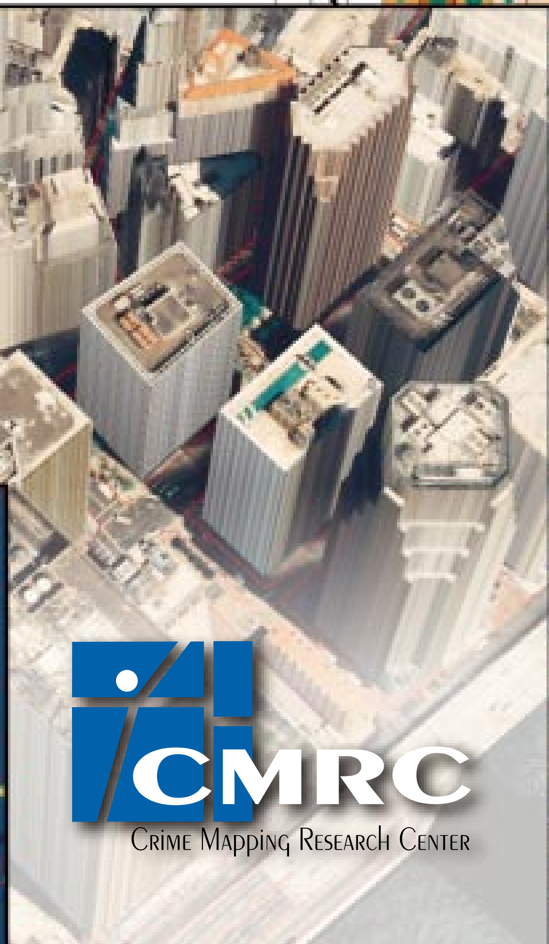
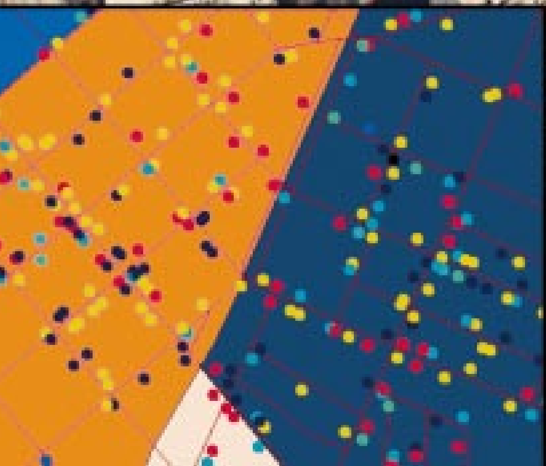


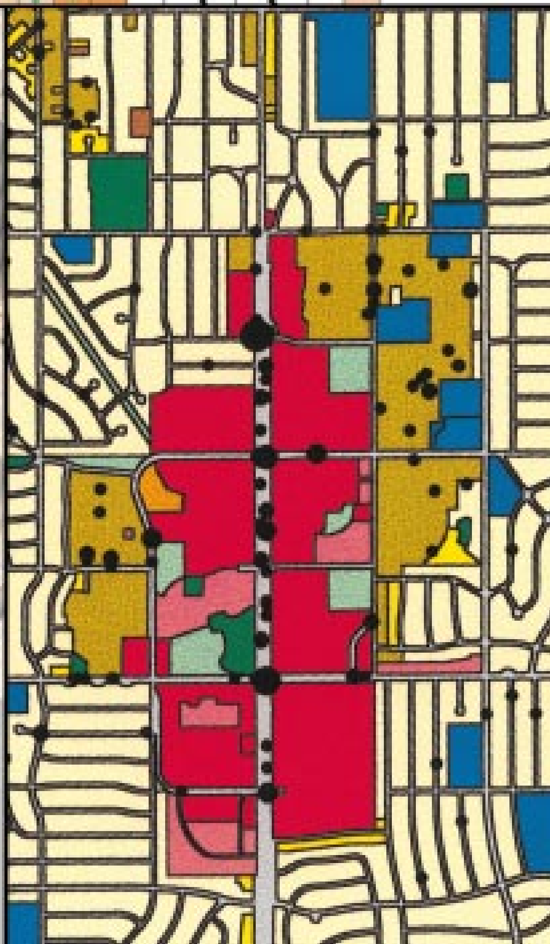
# MAPPING CRIME

## PRINCIPLE AND PRACTICE









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# About the National Institute of Justice

The National Institute of Justice (NIJ), a component of the Office of Justice Programs, is the research agency of the U.S. Department of Justice. Created by the Omnibus Crime Control and Safe Streets Act of 1968, as amended, NIJ is authorized to support research, evaluation, and demonstration programs, development of technology, and both national and international information dissemination. Specific mandates of the Act direct NIJ to:

- Sponsor special projects, and research and development programs, that will improve and strengthen the criminal justice system and reduce or prevent crime.
- Conduct national demonstration projects that employ innovative or promising approaches for improving criminal justice.
- Develop new technologies to fight crime and improve criminal justice.
- Evaluate the effectiveness of criminal justice programs and identify programs that promise to be successful if continued or repeated.
- Recommend actions that can be taken by Federal, State, and local governments as well as by private organizations to improve criminal justice.
- Carry out research on criminal behavior.
- Develop new methods of crime prevention and reduction of crime and delinquency.

In recent years, NIJ has greatly expanded its initiatives, the result of the Violent Crime Control and Law Enforcement Act of 1994 (the Crime Act), partnerships with other Federal agencies and private foundations, advances in technology, and a new international focus. Some examples of these new initiatives:

- New research and evaluation are exploring key issues in community policing, violence against women, sentencing reforms, and specialized courts such as drug courts.
- Dual-use technologies are being developed to support national defense and local law enforcement needs.
- The causes, treatment, and prevention of violence against women and violence within the family are being investigated in cooperation with several agencies of the U.S. Department of Health and Human Services.
- NIJ's links with the international community are being strengthened through membership in the United Nations network of criminological institutes; participation in developing the U.N. Criminal Justice Information Network; initiation of UNOJUST (U.N. Online Justice Clearinghouse), which electronically links the institutes to the U.N. network; and establishment of an NIJ International Center.
- The NIJ-administered criminal justice information clearinghouse, the world's largest, has improved its online capability.
- The Institute's Drug Use Forecasting (DUF) program has been expanded and enhanced. Renamed ADAM (Arrestee Drug Abuse Monitoring), the program will increase the number of drug-testing sites, and its role as a "platform" for studying drug-related crime will grow.
- NIJ's new Crime Mapping Research Center will provide training in computer mapping technology, collect and archive geocoded crime data, and develop analytic software.
- The Institute's program of intramural research has been expanded and enhanced.

The Institute Director, who is appointed by the President and confirmed by the Senate, establishes the Institute's objectives, guided by the priorities of the Office of Justice Programs, the Department of Justice, and the needs of the criminal justice field. The Institute actively solicits the views of criminal justice professionals and researchers in the continuing search for answers that inform public policymaking in crime and justice.

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Mapping Crime: ***Principle and Practice***

***Research Report***

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# *Mapping Crime: Principle and Practice*

*Keith Harries, Ph.D.*

**December 1999**
**NCJ 178919**

NIJ

Jeremy Travis
*Director*

Nancy La Vigne
*Program Monitor*

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# Acknowledgments

Without the generous cooperation of many people in various settings, including police departments and universities, the variety of examples and particularly illustrations presented in this guide would not have been possible. Some individuals who should have been acknowledged below may have been inadvertently omitted, and I apologize if that is the case. Among those who must be singled out for special recognition are the following (in alphabetical order):

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Ultimately, all these efforts to spread the blame are in vain, and the author accepts full responsibility for errors, omissions, and misinterpretations.

# Foreword

In 1997, when the National Institute of Justice (NIJ) was planning to create its Crime Mapping Research Center (CMRC), we convened a 2-day strategic planning meeting to seek advice on the Center's goals, direction, and mission. Before the meeting, we had assumed that many agencies were already using mapping and that NIJ's goal would be to encourage the field to move beyond descriptive mapping (e.g., pin maps) toward analytic mapping. The meeting helped us recognize that another goal must be to assist the large number of agencies that are not using mapping.

Keith Harries, who received one of the first grants from CMRC, has prepared this comprehensive guide for agencies that are in the early stages of using geographic information systems (GIS). His words are directed to law enforcement professionals who have a little knowledge about GIS and want to learn more about its benefits and limitations.

He has collected more than 110 maps to illustrate how GIS is used. These pictures express the truth of the phrase "one picture is worth a thousand words."

Dr. Harries' guide is not designed to stand alone. Law enforcement agencies will need other curriculum materials as well—especially software manuals—but it will be a starting place. Additional materials and links to other sources of information can be found at CMRC's World Wide Web site (*http://www.ojp.usdoj.gov/cmrc*). As a clearinghouse of information about crime mapping, CMRC also sponsors a listserv (*listproc@aspensys.com*), which has more than 640 subscribers, and an annual conference, which draws more than 700 attendees.

Today about 13 percent of law enforcement agencies are using GIS regularly to analyze their crime problems, and we are certain to see this number increase significantly as more and more agencies begin using computerized crime mapping to identify and solve their crime problems. We hope this guide will help them get started. For agencies that are already using crime mapping technology, we hope this guide will spark ideas about new ways to use it.

**Jeremy Travis**
*Director*
*National Institute of Justice*

# Preface

This guide introduces the science of crime mapping to police officers, crime analysts, and other people interested in visualizing crime data through the medium of maps. Presumably most readers will be working in law enforcement agencies, broadly interpreted to include courts, corrections, the military police, and Federal agencies such as the FBI, U.S. Bureau of Alcohol, Tobacco and Firearms, National Park Service, U.S. Customs Service, and U.S. Secret Service, as well as police departments. The material is designed primarily for those who know little or nothing about mapping crime and who are motivated to learn more.

This is *not* a guide to software. Nowhere is there more than a word or two on how to do anything technical involving a computer. A purely technical guide would quickly be out of date, and a guide that served one set of software devotees would not serve others. Technical guidance is best sought from the manuals and interest groups specific to each software package.

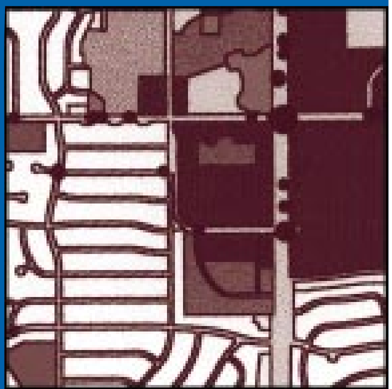
What *will* be found here is a broad approach addressing the kinds of questions crime mapping can answer and how, in general terms, it can answer them. Caveats are given from time to time, notably the caution against uncritically accepting all the default settings that crime mapping software so conveniently provides.

Most readers will not read this guide from cover to cover. Some will concentrate on application-oriented material. Others will have an interest in the history of crime mapping, realizing that where we have been can help us figure out where we are going.

The presentation employed in this guide leans heavily on examples. Indeed, the guide is made up of examples with the words draped around them. Crime analysts and researchers from across the United States and from Canada and the United Kingdom have contributed. Without their help, this guide would be an empty shell. I am extremely grateful to all who donated their work so graciously, and a partial listing of these kind souls is found in the acknowledgments.

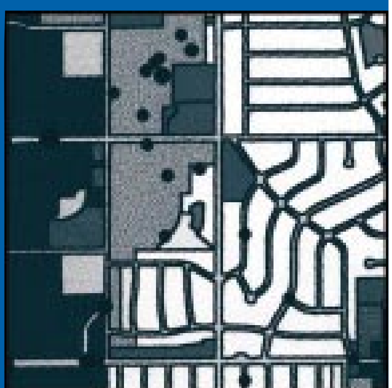
**Keith Harries**

# Contents

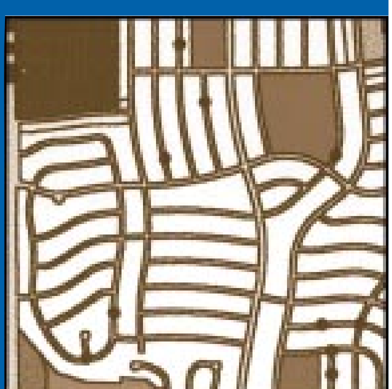


# Chapter 1:
# Context and Concepts

## From pins to computers



Crime mapping has long been an integral part of the process known today as *crime analysis*. The New York City Police Department, for example, has traced the use of maps back to at least 1900. The traditional crime map was a jumbo representation of a jurisdiction with pins stuck in it (figure 1.1). The old pin maps were useful for showing where crimes occurred, but they had serious limitations. As they were updated, the prior crime patterns were lost. While raw data could be archived, maps could not, except perhaps by photographing them.[1] The maps were static; they could not be manipulated or queried. For example, it would have been difficult to track a series of robberies that might overlap the duration (a week or month) of a pin map. Also, pin maps could be quite difficult to read when several types of crime, usually represented by pins of different colors, were mixed together. Pin maps occupied considerable wall space; Canter (1997) noted that to make a single wall map of the 610 square miles of Baltimore County, 12 maps had to be joined, covering 70 square feet. Thus pin maps had limited value—they could be used effectively but only for a short time. However, pin maps are sometimes still used today because their large scales allow patterns to be seen over an entire jurisdiction in detail. Today, "virtual" pin maps can be made on the



computer, using pins or other icons as symbols (figure 1.2).

The manual approach of pin mapping gave way during the past decade or so to computer mapping—specifically, *desktop* computer mapping. For decades before desktop computer mapping, the process was carried out on gigantic mainframe computers using an extremely labor-intensive process. First, much labor was involved in describing the boundaries of the map with numbered coordinates on punched cards. Then came the labor of keypunching the cards, followed by a similar process of coding and keypunching to put the data on the map.

Recognizing all the work needed to produce a map on the computer, many potential *cartographers*[2] (mapmakers) concluded that computer mapping was too labor intensive. They were right—it was a "royal pain." It was productive only if many maps were needed (making it worthwhile to prepare the *base map*, or boundary map, of the jurisdiction), and if the personnel necessary to do the data coding and keypunching were available. Few organizations could afford the luxury.

Since the mid-1980s, and particularly since the early 1990s, when computer processing speed increased dramatically, desktop mapping became commonplace

**Figure 1.1**

Pin maps.

*Source: Keith Harries. University of Maryland, Baltimore County, Baltimore, Maryland.*

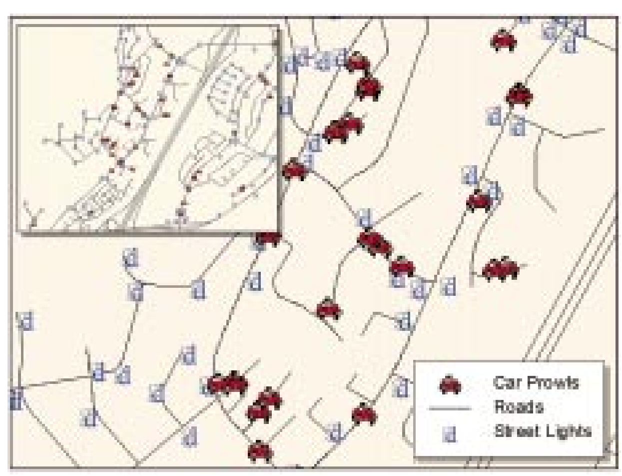



**Figure 1.2**

A "virtual" pin map.

*Source: SanGIS and the San Diego Police Department Crime Analysis Unit.*

and fast, aided and abetted by the concurrent availability of cheap color printers. What a partnership! Only a generation earlier, maps on paper (as compared with the pin maps on walls in police departments) had been drawn by hand using india ink[3] and special pens, with templates for lettering. If a mistake was made, the lettering had to be scraped off the paper with a razor blade. If shading was needed, Zipatone® patterns were cut to fit the area and burnished to stick. Those were the days? For character building, perhaps!

What does all this have to do with mapping crime today? A newfound access to desktop mapping means that more individuals than ever before have the task—or opportunity—to produce computer maps. Also the huge demand for maps means that most crime analysts, police officers, and others involved in mapping crime have received no formal training in mapmaking—the science called *cartography*. A body of accepted and useful principles and practices has evolved over the long history of mapmaking. Most cartography texts contain those principles but have no regard for the special needs of the crime analyst, police officer, manager, or community user of crime maps. The goal of this guide, therefore, is to provide a guide to cartography that is adapted to specialized needs and speaks the cartographer's language.

This guide is not intended to stand alone, isolated from evolving developments in crime mapping. Ideally, it should be used in conjunction with other materials and approaches. In 1998, for example, a group working with the support of the Crime Mapping Research Center (CMRC) at the National Institute of Justice developed a national curriculum for crime mapping. Much information contained in this guide can be found fleshed out in the curriculum and other materials disseminated by CMRC. Readers are strongly encouraged to visit the CMRC Web site at *http://www.ojp.usdoj.gov/cmrc*.

## Ancient history: Cartography and crime mapping

Conclusive evidence from clay tablets found in Iraq proves that maps have been around for several thousand years—perhaps tens of millennia (Campbell, 1993). Evidently, the need to display geographic data is basic and enduring. Nowhere is the need for maps more compelling than in the field of navigation, whether for an epic around-the-world voyage or for a rookie cop's struggle to find an address in a city map book. Maps for navigation can be matters of life and death, and the inability of early navigators to locate themselves accurately on the

**Maps**

- *Are pictures of information about areas and places.*
- *Help us visualize data.*
- *Are like the proverbial pictures worth a thousand words.*
- *Enable information to be seen at a glance.*

surface of the Earth have often spelled disaster, as described vividly in Dava Sobel's book *Longitude* (1995).

Fortunately, crime mappers do not have to be concerned about such epic matters. However, mapping crime is a scientific activity—an application of the broader scientific field of cartography, which has undergone a transformation with the advent of geographic information systems (GIS). Many mapmakers now see cartography as a branch of information technology. A decade or so ago, cartography was much broader in scope than GIS with applications in fields as diverse as surveying, navigation of all kinds (including orienteering and highway mapping), geology, space exploration, environmental management, tourism, and urban planning. Today, however, the convergence of cartography and GIS is nearly complete. Both are tools in a broad range of applications, reflecting the most important use of maps—to communicate information.

Crime mapping, as noted at the beginning of this chapter, has quite a long history. Phillips (1972) pointed out that "hundreds of spatially oriented studies of crime and delinquency have been written by sociologists and criminologists since about 1830. . ." and recognized three major schools:

- The **cartographic** or **geographic** school dominated between 1830 and 1880, starting in France and spreading to England. This work was based on social data, which governments were beginning to gather. Findings tended to center on the influence of variables such as wealth and population density on levels of crime.
- The **typological** school dominated between the cartographic period and the ecological period that would follow in the 20th century. The typologists focused on the relationship between the mental and physical characteristics of people and crime.
- The **social ecology** school concentrated on geographic variations in social conditions under the assumption that they were related to patterns of crime.

The social ecologists recognized and classified areas in cities with similar social characteristics. Shaw and McKay (1942) produced a classic analysis on juvenile delinquency in Chicago. This work is generally recognized as the landmark piece of research involving crime mapping in the first half of the 20th century. Shaw and McKay mapped thousands of incidents of juvenile delinquency and analyzed relationships between delinquency and various social conditions. Work by the "Chicago school" of researchers also delineated an urban model based on concentric zones, the first attempt to develop a theory to explain the layout of cities (Burgess, 1925). Other significant contributors to the ecological school included Lander (1954), Lottier (1938), and Boggs (1966).

Most likely, the first use of computerized crime mapping in applied crime analysis occurred in the mid-1960s in St. Louis (McEwen and Research Management Associates, Inc., 1966; Pauly, McEwen, and Finch, 1967; Carnaghi and McEwen, 1970; for more discussion, see chapter 4). Ironically, professional geographers were late getting into the act. Early contributions came from Lloyd Haring (who organized a seminar on the geography of crime at Arizona State University around 1970), David Herbert in the United Kingdom, Harries (1971, 1973, 1974), Phillips (1972), Pyle et al. (1974), Lee and Egan (1972), Rengert (1975), Capone and Nichols (1976), and others. Among the most remarkable (and little known) pieces of research emphasizing crime mapping were Schmid and Schmid's *Crime in the State of Washington* (1972) and Frisbie et al.'s *Crime in Minneapolis: Proposals for Prevention* (1997)(figures 1.3 and 1.4). The latter, in particular, was notable for bridging the gap between academic crime mapping and analysis/applications specifically aimed at crime prevention. Early computer mapping efforts used line printers as their display devices, so their resolution was limited to the physical size of the print characters. This precluded the use of computer maps for the representation of point data, at least until plotters that were able to draw finer lines and point symbols came into more general use. (For an excellent review of early map applications in crime prevention, see Weisburd and McEwen, 1997, pp. 1–26.)

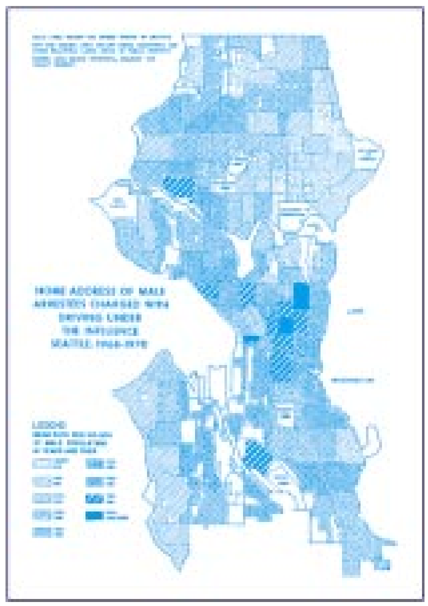


**Figure 1.3**

A map showing home addresses of male arrestees charged with driving under the influence, Seattle, Washington. 1968–70.

*Source: Schmid and Schmid, 1972, figure 7.14, p. 311.*

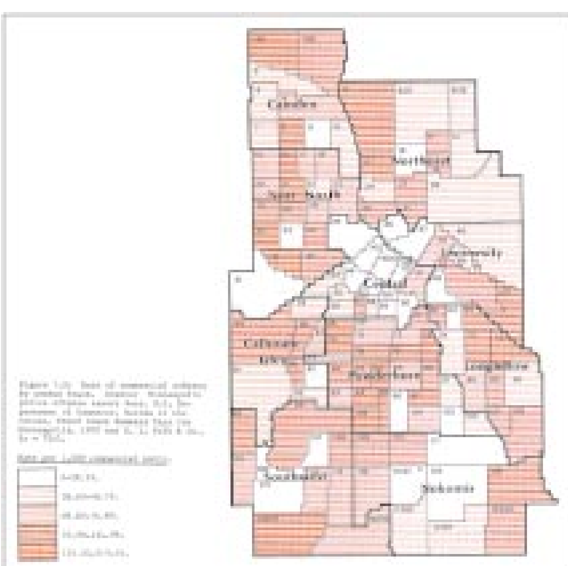



**Figure 1.4**

A map showing the rate of commercial robbery by census tract, Minneapolis, Minnesota. Line printer technology.

*Source: Frisbie et al., 1977, figure 7.2, p. 122.*

Even as late as 1980, the breakthrough into widespread GIS-style crime mapping was about a decade away. It was necessary to wait for improvements in desktop computer capacity, printer enhancements, and price reductions before desktop mapping could become an everyday, broadly accepted phenomenon.

To illustrate how matters have improved, a snippet of personal history is offered. In April 1984, the author bought his first personal computer, a Kaypro 10 manufactured by Digital Research, Inc. This wonder ran at 4 megahertz and had 64 kilobytes of random access memory (RAM) and a 10-megabyte hard drive. ("How could you ever use all that storage?" friends asked.) It also had a tiny monochrome display and ran on the CP/M operating system, the precursor of Microsoft DOS. And all this for the rock-bottom price of $2,795 in 1984 dollars. The Silver Reed daisy wheel printer purchased to complement the computer was $895 (extra daisy wheels were $22.50 each, tractor feed for paper was $160), and the 300k-baud rate modem was $535. After adding a few other knick-knacks, getting started in personal computing cost almost $5,000 (again, in 1984 dollars).

By comparison, the typical RAM in 1999 is perhaps 1,000 times larger (64 megabytes), the processor speed is 100 times faster (at least 400 megahertz), and hard drives routinely are 100 times bigger (10 gigabytes), all at a lower price. It was this type of computing environment that would facilitate the entry of GIS into law enforcement (and elsewhere) and permit cartographic principles and practices to be used on a day-to-day basis. Mapping crime has come into its own primarily because of advances in computing that, in turn, have facilitated GIS applications. Apart from all the obvious advantages, a major benefit is that computer mapping allows free rein to experiment, a luxury denied in the old days of manual mapping. Are you wondering what a certain map design would look like? Try it out. You don't like it? Start over and have a new map in minutes.

## Mapping as a special case of data visualization

Desktop computing has put graphic tools within the reach of virtually everyone. Preparing a publication-quality graphic, statistical or otherwise, was an arduous process a generation ago. Today it is much easier, although the process still demands considerable care and effort. This new ease and flexibility have broadened our perspective on graphics as tools for the visualization of information. This has happened because people no longer have to devote themselves to one specialized, time-consuming methodology, such as cartography. Now, maps can be produced more easily, and the computer has in effect freed people to produce *other* kinds of graphics as needed, such as bar charts, scatter diagrams, and pie charts.

The downside to such ease of production is that it is just as easy to produce trash as it is to create technical and artistic perfection. Famous graphics authority Tufte (1983, chapter 5) referred to what he called "non-data-ink," "redundant-data-ink," and "graphical paraphernalia"—all summed up by the term "chartjunk," a concept equally applicable to maps and charts. An exemplary map, according to Tufte, was prepared by Joseph Minard in 1861 to depict the decline of Napoleon's army in Russia in 1812–13 (figure 1.5). Tufte noted that "it may well be the best statistical graphic ever drawn" (Tufte, 1983, p. 40). What makes it so good is that it shows six variables with extraordinary clarity and without the use of color variation. The width of the bands is proportional to the number of troops, starting with 424,000, which was reduced to 100,000 by the time they reached Moscow. The map shows attrition on the return trip (with vertical rays expressing temperatures on selected dates) that left only 10,000 men still alive when the army returned to the starting point. The fact that the map illustrates the devastating loss of life further adds to its drama.

Today's simplified graphics-producing environment helps put maps in perspective. Maps are but one way of representing information, and they are not always the most appropriate mode. If information about places is being represented, maps may be the best format. However, if no geographic (place-to-place) information is present, such as when all the data for a city are combined into one table, there is nothing to map. The whole jurisdiction is represented by one number (or several numbers, each representing the city as a whole), so the map, too, could portray only one number. In this situation, a bar chart simply showing the relative levels of each crime category would be the best choice.

What does it mean to say that maps are a form of visualization? Simply that a map is data in a form that we can see all at once. Books or tabulations of data are also visualizations in the sense that we assimilate them visually, but they are labor-intensive visualizations. Maps and other graphics are essentially pictures of information, those proverbial pictures "worth a thousand words." If they are well done, they convey their message more or less at a glance.

## Mapping as art and science

Like other forms of visualization, maps are the outcome of scientific activity: hypothesis formulation, data gathering,

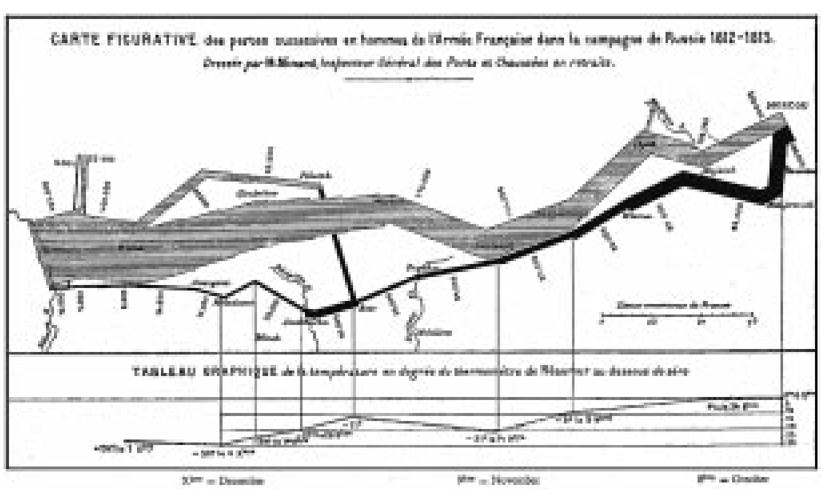



**Figure 1.5**

Minard's 1861 map of Napoleon's advance to and retreat from Moscow.

*Source: Tufte, 1983, p. 41. Reproduced by permission.*

analysis, review of results, and evaluation of whether the initial hypothesis should be accepted or rejected in favor of a modified version. This cycle, known as the *hypothetic-deductive process*, is used throughout science as a fundamental tool. It is a universal paradigm, or model, for scientific investigation.

Constructing a map involves taking a set of data and making decisions consistent with the hypothetic-deductive process. Decisions need to be made about the kind of map to be prepared, how symbols or shading will look, how statistical information will be treated, and so forth. These decisions must be based on the objective to be achieved, including consideration of the target audience. Certain scientific principles can be applied. For example, if we are preparing a shaded map with a range of statistical data to be divided equally, then a simple formula can guide us:

*Range in data values ÷ Number of classes.*

Thus, if the range (difference between maximum value and minimum value) of data values is 50 and it has been determined that 4 classes, or "subranges," of data would be appropriate, each will span 12.5 units. This simple example demonstrates an elementary cartographic principle.

However, this science provides no help with elements of map design, such as choice of colors, symbols, or lettering, and the arrangement of map elements on the page or within a frame. These elements are pieces of the art of cartography and are just as important to the overall purpose and effectiveness of the map as the scientific elements. A map that is scientifically perfect may be ineffective if it is an artistic disaster.

Art and science may merge imperceptibly and confound one another in unfortunate ways. For example, oversized symbols or lettering may draw attention to parts of the map that should be understated or less emphasized from a purely scientific perspective. A poor choice of colors or intervals for statistics can also make a big difference. Thus the scientific mission of the map can be subverted through inappropriate artistic choices, and poor choices on the science side can similarly affect the artistic elements. In cartography, as in medicine, art and science are inseparable. The perfect map blends art and science into an effective tool of visual communication. Figure 1.6 shows elements of weaker (middle figure) and stronger (bottom figure) map design. The chart (top figure) known as a *histogram* accompanying the maps shows an approximately normal (bell-shaped) distribution of scores on an index representing the association between violence and poverty in a neighborhood of Baltimore. The scores have a mean, or average, of zero and a measure of spread around the mean (standard deviation) of 1.0. Technically, this means that the census block groups in the range –1.0 to +1.0 are not significantly different from the average. Those with scores lower than –1.0 or higher than +1.0 are considered relatively extreme. We may wish to map the extremes because they could convey information of value in community policing—areas with a strong link between poverty and violence may warrant special allocations of crime prevention and social service resources.

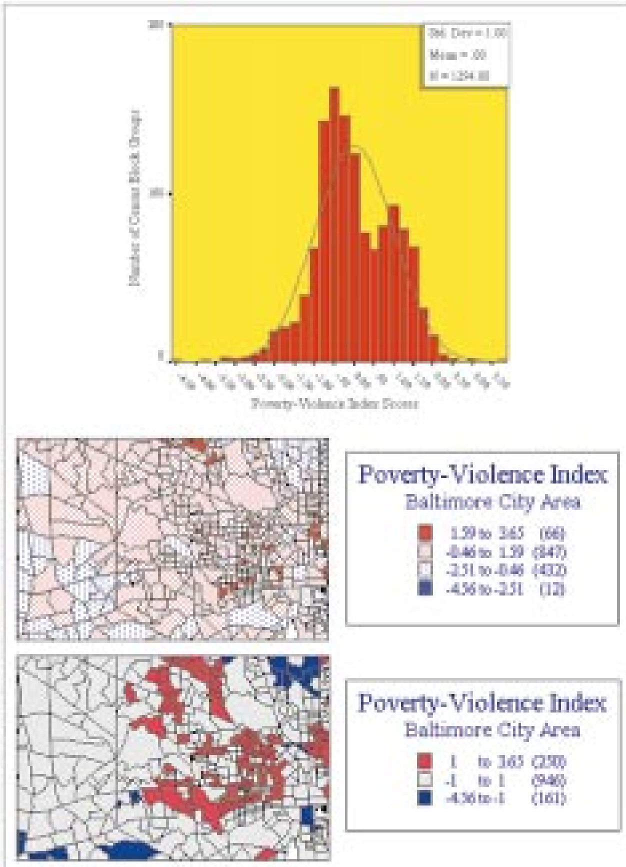



**Figure 1.6**

Examples of maps with differing impact depending on design.

*Source: Keith Harries.*

If the objective of the map is to represent the high and low extremes, then the bottom figure does a much better job than the middle one, both in terms of how the data are divided and how they are symbolized with colors. The bottom figure divides the data into standard deviation units such that the blue and red values are the focus of attention. In the middle figure, the visual message is almost lost in a combination of a poor choice of colors and shading symbols and a confusing division of the data into classes. The visual messages conveyed by the maps are different, yet the underlying geographies and statistics are identical. This example emphasizes the importance of the map as a medium for the interpretation of information. Subjective choices relating to both the art and science content of the map are critical.

Figure 1.6 also reminds us that it is just as easy to lie with maps as it is to lie with statistics. (Remember the three kinds of lies: lies, damn lies, and statistics—and maps, perhaps?) "Lying" may be a bit strong. It is more likely that the compiler of the map misleads readers by choosing inappropriate designs rather than by intentionally falsifying information. This may happen on several levels, the most basic being that the author of the map created it to achieve an objective different from that experienced by the readers. Next are issues related to data manipulation and cartographic art. Ultimately, the possibilities for misrepresentation and misinterpretation are virtually infinite. The key question is whether these problems are fatal flaws with respect to specific maps.

## Maps as abstractions of reality: Benefits and costs

Maps try to display some aspect of reality. But like books, movies, television, or newspapers that try to do the same, they fall short (figure 1.7). The only perfect representation of reality is, after all, reality itself. ("You had to be there.") All else is, to a greater or lesser degree, an abstraction. Abstractions present choices. How much abstraction can we tolerate? How much information can we afford to lose? The fundamental tradeoff is:

- More abstraction equals less information (farther from reality).
- Less abstraction equals more information (closer to reality).

The tradeoff can also be viewed this way:

- More abstraction equals greater simplicity and legibility (more effective visual communication).
- Less abstraction equals greater complexity, less legibility (less effective visual communication).

In our quest to represent reality as faithfully as possible, we may be tempted to put too much "stuff" in our maps or other graphics. This may give us maps that have a lot of information but that may be illegible junk heaps. Usually, the abstraction-reality

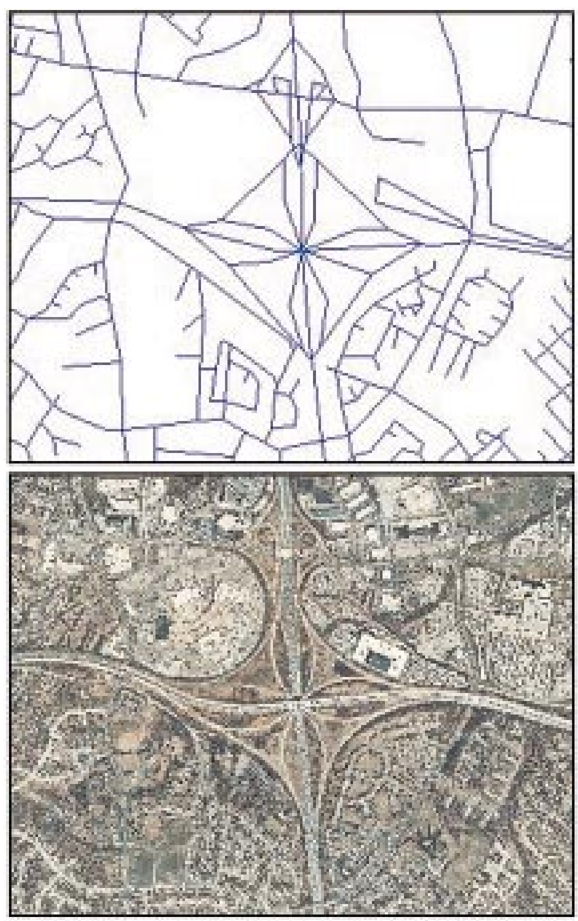


**Figure 1.7**

Maps showing the contrast between more abstraction ("stick" streets—top) and less abstraction (an aerial photograph of the same area—bottom).

*Source: Orthophotography: Baltimore County, Maryland, GIS Unit, March 19, 1995 (Phase II), pixel size 1", compilation scale 1" = 200'. Reproduced by permission.*

tradeoff should tilt us in the direction of simplicity. Better to have one or two important points clearly understood than to have utter confusion pushing readers toward anger and frustration. Worse yet, that confusion may cause readers to draw incorrect conclusions. That outcome could be worse than no map at all.

Consideration of this tradeoff should be part of the map production process. With practice, it will become "second nature" and will not need much thought. But for the novice, it is an important issue calling for thought and perhaps discussion with colleagues. Reading Tufte (1983, 1990) will raise awareness.

## Crime incidents: Measuring time and space

Crimes happen—everything happens—in *both* time and space. Vasiliev (1996) has suggested that time is a more difficult concept than space. Spaces and locations can be seen and measured quite easily by means of simple reference systems, such as x-y coordinates. Time, however, is harder to grasp, and maps have represented time in multiple ways (Vasiliev, 1996, p. 138), including:

- **Moments.** Providing times of events in geographic space. When did crime incidents occur and where?
- **Duration.** How long did an event or process continue in a specific space? For example, how long did a crime rate remain above or below a certain level in a particular area? How long did a hot spot (an area of high crime) persist?
- **Structured time.** Space standardized by time (for example, shift-based patrol areas, precincts, and posts).
- **Distance as time.** We often express distance as time. "How far is it?" "About 20 minutes." More to the point, perhaps, is concern with response times. In practice, a fixed, maximum permissible response time corresponds to the maximum distance feasible for patrol units to drive. Another application would be an investigation to see whether a suspect could have traveled from the last place he was seen to the location of the crime within a certain time period.

Specialized activities, such as policing, have their own unique perspective on time and space; thus, the elements of Vasiliev's typology will vary in their relevance from time to time and place to place.

There is no question that time is an important element in crime mapping owing to the time-structured way in which things are organized in police departments—by shifts. Patrol area boundaries may differ by shift, commanders may call for maps of crime by shift, and resources may need to be allocated differently by shift. Maps may need to be prepared on a weekly, monthly, quarterly, or annual basis to illustrate trends. Time-based maps may be further refined temporally by adding the shift dimension. Crime data could be mapped vertically, in effect stacking (merging) maps on top of each other, using different symbols for different time periods. Alternatively, a different map could be prepared for each time period. All these modifications can be automated by using GIS.

The importance of selecting appropriate time periods for mapping cannot be overemphasized. For example, a map covering a month may mask noteworthy week-by-week variations. Or weekly maps could hide day-to-day changes. Mapping intervals selected for administrative convenience may not be the best for analytical purposes. For example, the calendar week may be best for police department convenience, but local events, such as an industrial holiday, a sporting event, a plant closure, or some seasonal phenomenon may cut across administrative time units and may also have relevance to crime frequencies. Related questions are, How much time elapses before a map is out of date? All data are obsolete sooner or later, but when is sooner? When is later? These decisions are quite subjective and call for a "feel" for the data under review.

Another aspect of mapping crime in time and space relates to the representation of change. One of the most crucial questions asked in police departments is, How has crime changed in this neighborhood in the last week or month or year? Maps can help answer this question by symbolizing change in several possible ways, such as by showing crime as a "surface" with peaks representing high levels of occurrence (gray areas) and valleys low levels (red areas) (figure 1.8). This approach borrows from the methodology of the topographic map, on which the land surface is represented by contour lines, each

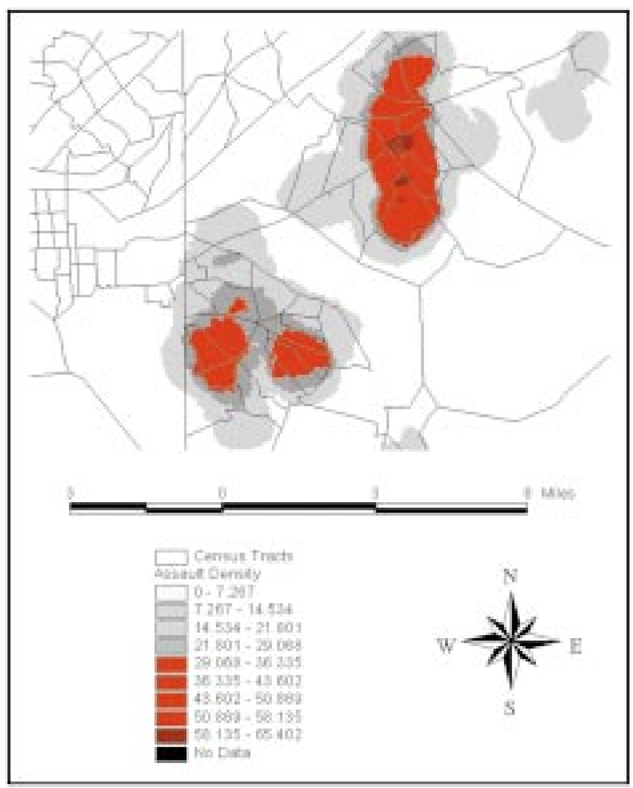



**Figure 1.8**

A representation of the aggravated assault "surface" in part of Baltimore County, Maryland. Red and darker shading indicate higher assault densities.

*Source: Keith Harries.*

joining points of equal elevation. On the crime surface map, areas of declining crime can be shaded differently from those with increases. Crime mappers are limited only by their imagination when representing time and space in two dimensions or simulated three dimensions.

As usual, we should keep an open mind. Some space-time data may be best represented with a "non-map" graphic, or a combination of map and statistical graphics, such as precinct bar charts or pie charts embedded in a map of precincts. Here we come full circle, back to cartography as art and science and to the abstraction/detail tradeoff. Only crime mappers can decide, probably on the basis of some experimentation, which graphic representations are best for themselves and for their audiences.

# Map projection

## What is it?

A fundamental problem confronting mapmakers is that the Earth is round and the paper we put our maps on is flat. When we represent the round Earth on the flat paper, some distortion (perhaps a lot, depending on how much of the spherical Earth we are trying to show) is inevitable. Map projection is so called because it assumes that we have put a light source in the middle of a transparent globe (figure 1.9). The shadows (grid) made on a nearby surface are the *projection*.[4] Their characteristics will vary according to where the surface is placed. If the surface touches the globe, there will be no distortion at that point or along that line in the case of a cylinder being fitted over the globe,

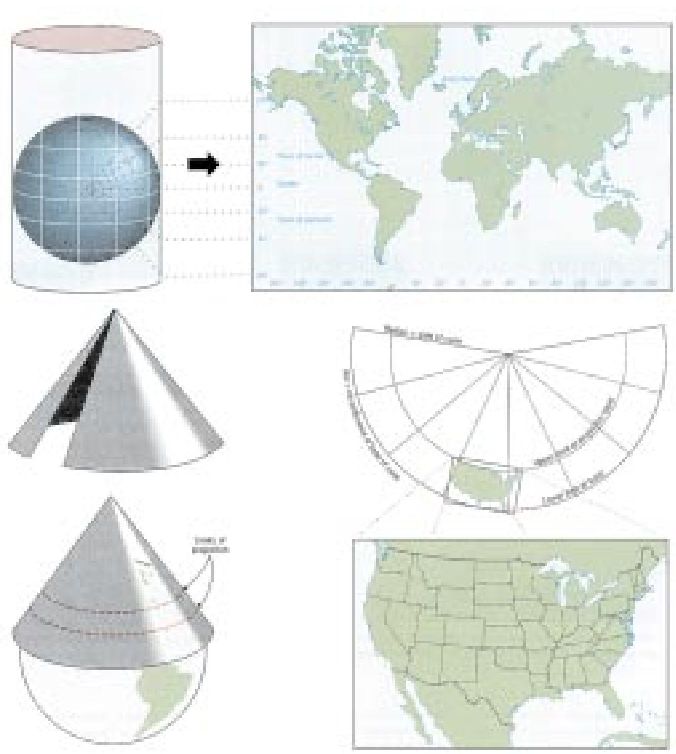


**Figure 1.9**

Diagrams showing cylindrical and conical projections. Shadows of the globe's grid lines on wraparound paper; a cylindrical projection results (top). Construction of a conic projection (middle and bottom).

*Source:* H.J. Blij, *Human Geography: Culture, Society, and Space*, Fifth Edition. New York, NY: John Wiley & Sons, Inc., ©1996, Figures R7 and R8, pages R6 and R7. Reprinted by permission of John Wiley & Sons, Inc.

touching along the Equator. Away from the point or line of contact, distortion increases. Among the most common projections are the cylindrical (already described) and the conical, for which a cone is fitted over the globe, like a hat, with the top of the cone over the pole (see figure 1.9). The cylinder or the cone is cut and flattened to create the map. The cylindrical projection tends to have much more distortion at high latitudes (closer to the poles) compared with the conical.

The better known projections include the venerable *Mercator* [5] (useful for navigation), the *Albers conical equal-area* [6], and the *Lambert conformal conic* [7] (the last two are frequently used for U.S. maps). Another well-known format is the *Robinson*, now the default world map projection used by the National Geographic Society. Its advantage is that it minimizes high-latitude distortion of areas compared with most other cylindrical projections. U.S. States are typically represented by either the Lambert conformal conic or the *transverse* [8] Mercator, depending on the size and shape of the State. For example, Dent (1990, pp. 72–73) noted that for Tennessee a conical equal-area projection would be appropriate, with its standard parallel (the line of latitude where the projection cone touches the State) running through the east-west axis of the State. Projections are a highly technical branch of cartography, and readers who want to learn more are referred to standard texts in cartography such as Campbell (1993), Dent (1990), and Robinson et al. (1984).

## Why we don't need to worry

Map projections are vitally important for cartographers concerned with representing large areas of the Earth's surface owing to the distortion problem and the myriad choices and compromises available in various projections and their numerous specialized, modified forms. But crime analysts do not need to be overly concerned with map projections because police jurisdictions are small enough so that map projection (or Earth curvature) is not a significant issue. However, there is the possibility that analysts will deal with maps with different projections and that those maps will not fit properly when brought together. Streets and boundaries would be misaligned and structures misplaced. However, this misalignment can also occur for reasons unconnected with projection, as explained below. Although crime analysts do not need to worry about projections per se, a related issue, *coordinate systems*, generally needs to be given more attention because the analyst probably will encounter incompatible coordinate systems.

What are the differences between projections and coordinate systems? *Projections* determine how the latitude and longitude grid of the Earth is represented on flat paper. *Coordinate systems* provide the x-y reference system to describe locations in two-dimensional space. For example, latitude and longitude together are a coordinate system based on angular measurements on the Earth's sphere. But there are other ways of referring to points. For instance, all measurements could be based on distances in meters and compass directions with respect to city hall. That would also be a coordinate system. Distances in feet and directions could be based on the police chief's office as a reference point. The following discussion provides some details on commonly used coordinate systems.

## Coordinate systems

### What are they?

Coordinate systems allow users to refer to points in two- or three-dimensional space. You may have heard of Cartesian geometry, named for the 17th-century French mathematician Descartes, the founder of analytic geometry and the Cartesian coordinate system. In two dimensions, we usually refer to two principal axes, the *x* (horizontal) and *y* (vertical). If necessary, we add the *z* axis for the third dimension. Points are located by referring to their position on the scales of the x and y (and z) coordinates. Diagrams usually known as scatter diagrams, or scatter plots (figure 1.10), are based on Cartesian coordinates, with their origin in the lower left corner.

Things get a bit more complicated when the coordinate system is applied to the spherical shape of the Earth.

### Latitude/Longitude

For the Earth's sphere, angular measurements must be added to the x-y coordinate system. *Latitude* angles are measured from the center of the Earth between the Equator and poles, 90 degrees north and south, with the Equator as 0 degrees and each pole 90 degrees. *Longitude* angles are also measured from the center of the Earth, 180 degrees east and west of the Prime Meridian running through the Royal Naval Observatory in Greenwich, England,[9] a location fixed by international agreement in 1884. So all of the United States is described in degrees north latitude and west longitude. For example, New Orleans is located at approximately 30 degrees north latitude and 90 degrees west longitude. Latitude lines are also known as *parallels* because they are, in fact, parallel to one another, and longitude lines are called *meridians*, as in "Prime Meridian." State boundaries west of the Mississippi River are predominantly

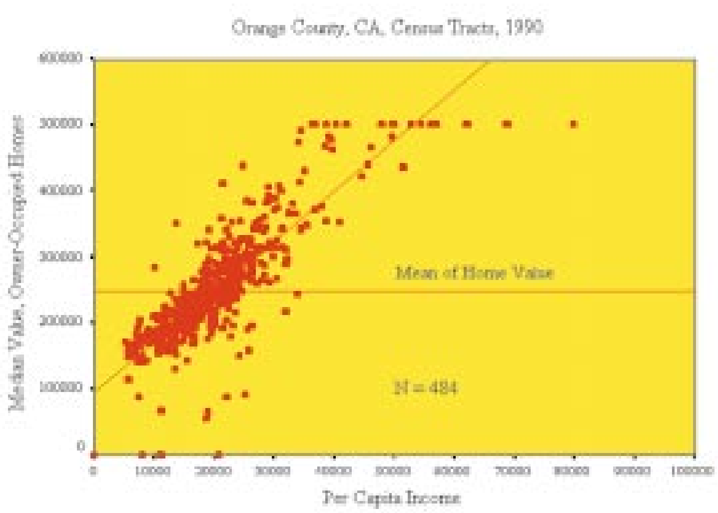



*Figure 1.10*

A scatter diagram showing the relationship between per capita income and median value of owner-occupied homes by census tract in Orange County, California, that illustrates the use of x-y coordinates.

*Source: Keith Harries.*

made up of segments of meridians and parallels. For example, the longer western border of Oklahoma is a segment of the 100th meridian.

### State Plane and Universal Transverse Mercator

As noted previously, appropriate map projections have been adopted for each State, yielding "Earth" projections with coordinates based on latitude and longitude, the universal reference system. But these "latitude/longitude" references, as they will be referred to, are quite cumbersome, given that they are in degrees, minutes, and seconds.[10] Two principal alternative coordinate systems are found in addition to latitude/longitude: the *State Plane Coordinate System* and the *Universal Transverse Mercator* (UTM).

The State Plane Coordinate System was devised for greater user convenience, with a rectangular grid superimposed over the latitude/longitude graticule, producing *State plane coordinates* expressed in meters, yards, or feet. In effect, this system assumes that the individual States are flat so they can be described by plane geometry rather than the spherical grid. For local applications, this use of plane geometry is acceptable because error due to failure to take Earth curvature into account is not significant over relatively small areas such as police jurisdictions.

Large States are divided into zones with separate grids for each to avoid the distortion problem. Texas, for example, is divided into the North, North-Central, Central, South-Central, and South zones; Louisiana into North, South, and Coastal. Typically, the origin, or zero point, for a State plane system is placed in the southwest corner, just like the scatter plot shown in figure 1.10, to avoid the inconvenient possibility of having to express coordinates in negative numbers. The origin is also placed outside the study area for the same reason.

The UTM system is used to refer to most of the world, excluding only polar regions, and consists of 60 zones, north-south, each 6 degrees of longitude wide. Each zone has a central meridian, and origins for each zone are located 500,000 meters west of the central meridian. A sample location in Texas (the capitol dome in Austin) is shown in figure 1.11. This example specifies that the dome is 621,161 meters east of the central meridian of zone 14 and 3,349,894 meters north of the Equator, the latitude of origin. The acronym NAD will appear in references to the State plane and UTM coordinate systems. NAD stands for *North American Datum*, a reference system that was based at a Kansas ranch in 1927. Demands for greater accuracy and more accurate surveying made possible by satellites led to a new NAD in 1983, hence the reference in figure 1.11 to NAD 83 UTM coordinates.

### Why we do need to worry

Crime mappers using computerized data from different sources may run into a problem resulting from different data sets being digitized (assigned their x-y coordinates) in, or converted to, incompatible coordinate systems or even incompatible projections. The most frequent conflict is likely to be between latitude/longitude and State plane coordinates owing to the

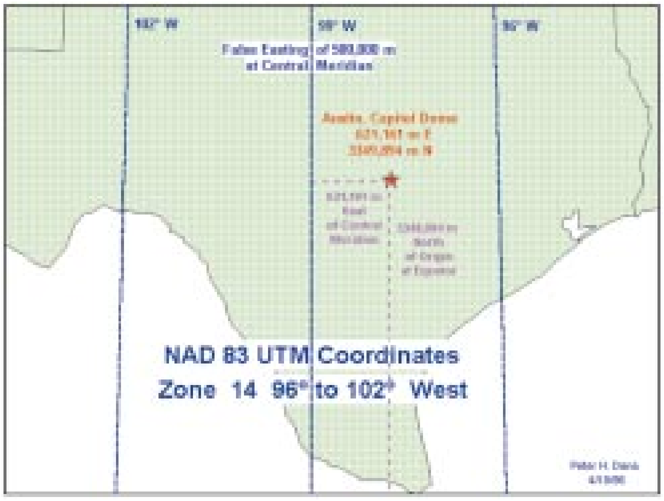



**Figure 1.11**

An example of a Universal Transverse Mercator (UTM) location.

*Source: Peter H. Dana,* The Geographer's Craft Project, *Department of Geography, University of Texas at Austin. Reproduced by permission. Visit Dana's Web site dealing with coordinate systems:* http://www.utexas.edu/depts/grg/gcraft/notes/coordsys/coordsys.html.

likelihood that locally developed data (often in State plane coordinates) will be mixed with data from more general sources, probably expressed in latitude/longitude. We saw that New Orleans is referenced as 30 degrees north latitude and 90 degrees west longitude in the latitude/longitude system. But if we refer to it using the State plane system, it is in the Louisiana South Zone, with coordinates 3,549,191 feet east of the origin and 592,810 feet north of the origin. Clearly, if we try to put the State plane data on a map set up for latitude/longitude, ugly things will happen. (What usually happens in a GIS is that the map goes blank.[11])

Data sets placed together on a map should have compatible projections and compatible coordinate systems. Fortunately, GIS software permits conversion from one projection to another and from one coordinate system to another, so the problem, if it does arise, is reasonably easy to fix. But if incompatibilities are not recognized at the outset, they can be quite frustrating. Positive action to check the projection and coordinate properties of a new data set is recommended because the coordinate system may not be apparent initially.

## Map elements: The usual bits and pieces

Generally, maps have the following elements that help provide consistency and comprehensibility for readers.

- **A title** (or caption) to describe the map.
- **A legend** to interpret the content of the map, such as the symbols and colors.
- **A scale** to translate distance on the map to distance on the ground.
- **Orientation**[12] to show compass direction.

However, a review of maps in cartography texts and elsewhere reveals the inconvenient fact that these conventions are often overlooked. Context should dictate whether some or all of these elements are included.

For example, in a situation in which maps of the same jurisdiction, or parts of it, are produced and distributed to the same audience on a repetitive basis, a label telling readers the area would be a waste of ink. But if the map were intended for wider distribution to audiences that might not know what they were looking at, a caption or heading would be appropriate. Similarly, scale may be redundant when the users of the map are educated to the spatial relationships on the map, often through years of field experience. Orientation, too, is unlikely to be critical in locally used crime maps, for which north is almost always "up." It may be worth noting that Minard's map of Napoleon's army (see figure 1.5) has no orientation, and if you want to be picky, it has no legend per se.

Indeed, a legend is perhaps the only somewhat (but not entirely) indispensable map element. Readers need to be absolutely sure what map data mean, and the legend is the only reliable guide to this information. Some maps may be so simple that a legend is not necessary. An example would be a map showing points, each of which represents a residential burglary. The heading or caption of the map (such as, "Locations of residential burglaries in St. Louis, September 2000.") can contain the necessary information and override the need for a legend.

This discussion may imply that one can be slapdash about map elements, but that implication is not intended. Careful consideration should be given to whether a particular element should be included; if an element is included, it must contain complete and accurate information. (For further elaboration, see "Map design" section in chapter 2.)

## Types of map information

Maps can provide a rich variety of information, including but not limited to location, distance, and direction as well as pattern for maps displaying point or area data. Each type of data means different things to different users.

- **Location** is arguably the most important of all the types of information to be represented on, or gleaned from, a map from the perspective of a crime analyst. Where things have happened, or may happen in the future, is the most sought after and potentially useful piece of information because it has so many implications for investigators and for the allocation of patrol and community resources, in addition to utility in the realms of planning and politics.

- **Distance** is not much use as an abstract piece of information. It comes to life when translated into some kind of relationship: How far did the victim live from the place where she was robbed? What is the maximum distance police cars can travel within a specific urban environment to provide acceptable response times? How far could a suspect have gone in a particular time period?

- **Direction** is most useful when considered in conjunction with distance, although it is not typically an important piece of map information in crime analysis unless it relates to other relevant processes or conditions. It is generally used in a broadly descriptive context, such as "the hot spot of burglaries is spreading to the west," or "serial robberies are moving southeast," or "the east side is becoming a high-crime area." In the example shown in figure 1.12, serial robbers were found to have a tendency to migrate south from Baltimore along the major highways.

- **Pattern** is an especially useful concept in crime analysis, as so much of what crime analysts do involves describing or analyzing the pattern of crime occurrences. Pattern can be a powerful investigative tool because the way points are arranged may tell us something about the process driving that arrangement. Patterns are usually classified as *random*, *uniform*, *clustered*, or *dispersed*. In a random arrangement, points are just as likely to be at any place on the map as at any other. Points are distributed haphazardly around the map. A uniform distribution has points that are equally spaced. Alternatively, we can say that in a uniform distribution the distance between neighboring points is maximized. In a clustered pattern, points are clumped together with substantial empty areas.

It is tempting to assume that the nonrandom distributions (uniform and clustered) automatically mean that some interesting underlying process is at work, providing useful information about crime. This may or may not be true. For example, burglaries show up in a cluster, suggesting a hot spot. But further investigation shows that the cluster corresponds to a neighborhood with a dense population, so the high frequency is no more than an expression of the geography of risk. The terms describing the types of patterns are subject to some semantic confusion. For example, what does *dispersed* mean? A dispersed pattern could be random or uniform. Is "less dispersed" the same as "clustered"? Various indexes have been developed to measure regularity, randomness, and dispersion. For additional reading, see, for example, Taylor (1977, chapter 4) and Hammond and McCullagh (1974, chapter 2).

Line data (for networks, for example) and both *discrete* and *continuous* areal distributions are additional types of data.

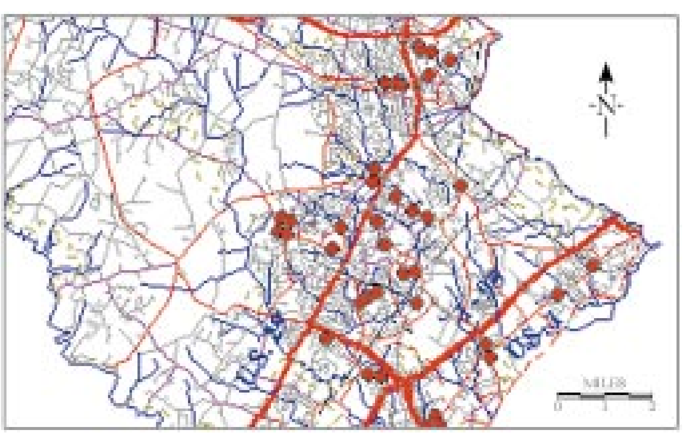



**Figure 1.12**

A map of selected robberies in Howard County, Maryland, concentrating along the U.S. 29, U.S. 1, and I–95 highway corridors. The Baltimore-Washington area Regional Crime Analysis Program has used maps like this to help apprehend serial robbers who cross county lines. For a full account of this process, see Mishra, 1999.

*Source: Keith Harries.*

- **Line data.** Linear features or processes can be abstracted on maps. The Minard map (see figure 1.5) did this by symbolizing the flow of troops to Moscow and back. The street maps used to map crime also contain line data that show points on streets, indicating the linear arrangement of incidents. A map connecting places where vehicles are stolen to the places where they are recovered is prepared with lines connecting the places. Or a line map might connect victim addresses to suspect addresses. Traffic flow can be shown with lines proportional in thickness to the flow (again like Minard's map in figure 1.5).

- **Discrete distributions.** When point data are combined within unit areas such as precincts, patrol areas, census tracts, or neighborhoods, each area is separated from the others; it is "discrete." Mapping by discrete areas can be used to reorganize the point data into a context that may have more meaning for a specific purpose. For example, commanders may want to see the distribution of drug offenses by patrol beat to decide how workloads should be assigned. This could be measured by *density,* which expresses how often something happens within an area. A common application is *population per square mile,* for example. Density also is used increasingly frequently to describe crimes, and population density data can provide additional explanation of the risk or rate concepts in public forums. Graphic representations of this general type, mapping data by administrative or political areas, are known as *choropleth*[13] maps. (A more detailed explanation is given in chapter 2.)

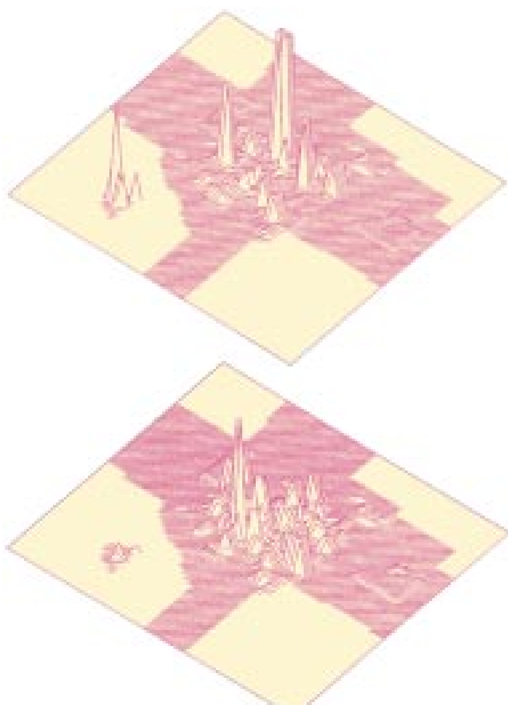
- **Continuous distributions** are used less in crime analysis than discrete distributions, but they can be useful and are finding more frequent application in conjunction with, for example, commonly used software such as *ArcView® Spatial Analyst*. Continuous distributions are phenomena found in nature, such as the shape of the land (topography), temperature, and atmospheric pressure. All places on Earth (above and below sea level) have topography and temperature, and all places above sea level (and a few on dry land below sea level) have atmospheric pressure. Thus it makes no sense to represent these conditions on maps divided into areas such as counties or cities, except for reference purposes.

What does this have to do with crime mapping? It is sometimes useful to assume that crime can be represented as a continuous distribution to prepare a generalized statistical surface representing crime density. This can provide a "smoother" picture of crime that can be enhanced by adding three-dimensional effects (figures 1.13 and 1.14). This implies an acceptance of the tradeoff between loss of detailed locational information from the point map and the smoothed, generalized picture provided by the quasi-continuous presentation. This smoothed version may have the advantage of better legibility than the original detail. Another advantage of a surface smoothed across jurisdictions is that it may vividly illustrate that political boundaries have little or no meaning for criminals.

## Scale

Maps are miniature representations of part of reality. *Scale* tells us how miniature they are. Scale is commonly expressed as a ratio, in words, or as a bar graph located somewhere in the map frame. A ratio states the scale as a unit of map distance compared with distance on the ground. This is referred to as the *representative fraction* (RF). Thus an RF of 1:10,000 means that 1 unit of linear measurement on the map represents 10,000 of those units on the ground. Units are interchangeable; for a 1:10,000 map, 1 inch on the map equals 10,000 inches on the ground, 1 centimeter on the map equals 10,000 centimeters on the ground.

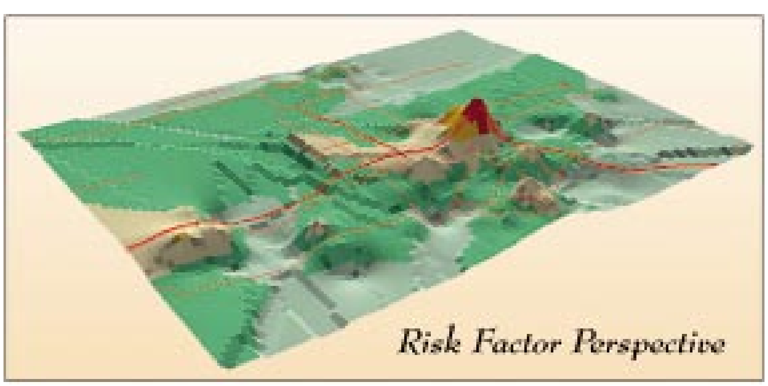
Scale terminology can be confusing. For example, large-scale maps and aerial photographs used by local governments (and quite likely to be used by crime analysts) are often at a scale of 1:2,400. If expressed in inches and feet, this is



### Figure 1.13

Early (1976) three-dimensional maps of Tulsa, Oklahoma, using the SYMVU program. The robbery rate is based on the population (top) and number of persons per dwelling unit (bottom). The bottom map illustrates the point that the denominator in crime rates does not have to be population.

*Source: Harries, 1978, figures 43 and 44.*




### Figure 1.14

A contemporary three-dimensional map of Redlands, California. The vertical dimension portrays the relative risk of crime across the city.

*Source: Redlands Police Department. Reproduced by permission.*

equivalent to 1 inch equaling 200 feet. Hence users often refer to the maps simply as “200 scale.”

## Large scale or small scale?

The distinction between large scale and small scale is also a source of confusion, but there is a simple rule to help us understand. Look at the representative fraction. If it is a large fraction, the map scale is large, and vice versa. For example, I open my National Geographic *Atlas of the World* and flip through it until I come to a map of the world. The scale is expressed in words as follows: “Scale 1:66,300,000 at the Equator.” This is extremely small scale, as 1/66,300,000th of something is not much. A few pages farther, I come to a map of the upper midwestern States of the United States. Its scale is expressed as “1:2,278,000”—a fraction 29 times larger than that for the world map. As scales get larger and larger, we move from the realm of “maps” to what we customarily refer to as “plans,” such as 1:20, where 1 unit on the map (plan) equals 20 units on the ground or the floor plan. These very large-scale renderings are the domain of the architect or engineer rather than the cartographer.

Scale has implications for the interpretation and meaning of maps. Implicit in the concept of scale is the now-familiar tradeoff between abstraction and detail. Small scale implies more abstraction, large scale less. Evidence from cognitive psychology cited by MacEachren (1995) suggests the importance of progressing from small scale to large scale when presenting maps of different areas, the principle of *global-local precedence*. In other words, if you were to prepare maps for the entire jurisdiction and also for a small part of it, the best mode of presentation would put the smaller scale map (the entire jurisdiction, perhaps in the form of a satellite image) first. The smaller area (larger scale) would follow this.

Another implication of scale is that crime data will look different at different scales, such as citywide and beat levels. The same data will appear to be more spread out (less dense) at the scale of the beat and more crowded (more dense) at the citywide scale. But in reality densities (crimes per unit area) are the same on both maps. What has changed is scale.

Scale also has implications for data collection. If maps are to be large scale, detailed data collection is appropriate. But small-scale maps are incapable of representing fine detail, so if the only scale available for a specific purpose is small, collecting data at the micro level is pointless. The detail will be lost on a map incapable of showing it. The converse is also true. Gathering data at the ZIP Code level will be too coarse a scale on a map showing street addresses.

### Rules of Thumb for Map Scale

- *Small-scale maps show large areas.*
- *Large-scale maps show small areas.*

## Maps of crime: Thematic maps

What is a thematic map? Quite simply, as the label suggests, it is a map of a theme or topic. Thematic maps have almost infinite variety and include most of the maps in the media showing, for example, the spread of fire ants, the status of sales taxes by State, or world population density. Thematic maps are like a comprehensive toolkit—we can select a topic and then choose from many possible ways of converting the data into a legible map that effectively communicates with the intended audience. Thematic maps may be *quantitative* or *qualitative*.

- **Quantitative** maps portray numerical information, such as numbers of crimes in an area or crime rates.

- **Qualitative** maps show nonnumerical data like land use types or victim/ offender characteristics, such as male or female, juvenile or adult.

Crime analysts use both quantitative and qualitative maps. Thematic maps can include four kinds of measurement data: *nominal*, *ordinal*, *ratio*, and *interval*. (For a more detailed explanation, see any basic statistics textbook, such as Burt and Barber, 1996.)

- **Nominal** measurement names or labels items in unordered categories, such as race. If a map shows homicide victims by race, it is a qualitative thematic map. Mapping by race, age group, or marital status puts labels on groups without ranking them as higher or lower or better or worse. (Quantitative information can also be inferred from this type of map. For example, the number of incidents affecting racial groups by areas can be counted, thus combining qualitative and quantitative interpretations. Types of measurements are often mixed on maps.)

- **Ordinal** measurement classifies incidents, victim or offender characteristics, or some other attributes (perhaps areas) according to rank. Thus patrol areas or precincts might be ranked according to their crime rates, their incidence of complaints, or the average seniority of officers. This involves only sorting and evaluating the data according to their relative values so that subjects can be ranked. How much the subjects differ is not considered. Thus we can put qualitative characteristics on an ordinal scale, such as a hierarchy of police areas based on size, with districts above precincts, which are in turn above patrol beats.

- **Ratio** scales, such as distance in inches, feet, yards, millimeters, meters, and so forth, start at zero and continue indefinitely. Zero means there is none of it and 20 means there is twice as much as 10. For example, the homicide rate is 3 per 10,000 persons in the city. Crime analysts will use nominal, ordinal, and ratio scales for these data but are very unlikely to use the fourth kind of measurement, *interval*.

- **Interval** scales show values but cannot show ratios between values. Temperature is a good example. We can measure it, but we cannot say that 80 degrees is twice as warm as 40 degrees, since the starting points of both the Fahrenheit and Celsius scales are arbitrary—that is, they are not true zeros. A possible exception to the assertion that crime analysts will not use interval scales could be *seriousness weighting*. (See Wolfgang et al., 1985a and 1985b, for more on this topic.)

Thematic maps come in considerable variety and will be examined in more detail in chapter 2. Each type represents some kind of data best. Information with address-level detail calls for one kind of thematic map, whereas data measured only at the neighborhood, precinct, or census tract level require a different approach. Examples of various ways in which thematic maps can be designed are contained in the following categorization of thematic maps:

- **Statistical** maps use proportional symbols, pie charts, or histograms to visualize the quantitative aspects of the data. Typically, the statistical symbols are placed in each subdivision on the map, such as patrol areas, census tracts, neighborhoods, or wards. Such maps can be quite difficult to read if they contain a large amount of detail, particularly when many geographic subdivisions and several attributes of the information are being mapped. Nominal data, such as the race of victims as proportions in precinct-based pie charts, can be represented on a statistical map.

- **Point** (pin) maps use points to represent individual incidents or specific numbers, such as when five incidents equal one point. (Aggregating multiple incidents to single points would be done only on a small-scale map.) A map showing locations of drug markets by types of drugs prevalent in each is an example of a point map with nominal scale data. Point maps are probably the most frequently used maps in policing, as they can show incident locations quite precisely if address-level data are used.

- **Choropleth** maps show discrete distributions for particular areas such as beats, precincts, districts, counties, or census blocks. Although point data can give us the best detail in terms of where events happen, information may be needed for areas in summary form that has meaning in terms of planning, management, investigation, or politics. Note that point data and choropleth representations can both be put on the same map, if it is appropriate and the result is not a garbled mess. For example, burglary (point) data could be put over neighborhood boundaries (choropleth data) or any areas representing police geography. Also, choropleth maps can be given a three-dimensional appearance by making each area into a raised block, with the height of the block representing the relevant data value.

- **Isoline** is derived from “iso,” the Greek prefix for equal, and refers to maps with lines that join points of equal value. Physical geography is replete with isoline maps that use the following: *isobars* (equal barometric pressure), *isohyets* (equal rainfall), *isotherms* (equal temperature), *isobaths* (equal depth), and, in a rare departure from use of the iso prefix, *contour* lines to join points of equal elevation. The form most likely to be used in crime analysis is the *isopleth* (equal crowd), in which data for areas, such as crimes per neighborhood or population density, are calculated and used as control points to determine where the isolines will be drawn.[14] (See Curtis, 1974, for an example of an isopleth map of homicide, rape, and assault in Boston.)

- **Surface** maps can be regarded conceptually as a special case of an isoline presentation. Such maps add a three-dimensional effect by fitting a raised surface to data values. Typically, an arbitrary grid is placed over the map and the number of incidents per grid cell are counted. These counts form the basis for what is, in effect, an isopleth map that is given its third, or Z (vertical), dimension derived from the isoline values. The resulting map is rendered as if it were being viewed from an oblique angle, say 45 degrees. (If it were to be viewed from overhead, like a normal map, the surface would be lost and the map would appear to be a flat contour map.) Such continuous surface maps can make a powerful visual impact, but they have dual disadvantages in that data values are hard to read on the map and detail behind data peaks is lost (see figures 1.13 and 1.14).

- **Linear** maps show streets and highways as well as flows using linear symbols, such as lines proportional in thickness to represent flows. Apart from base maps of streets and highways, crime mappers use linear maps infrequently—the most common application is vehicle theft investigation showing connections between the place of theft and place of recovery.

## Data, maps, and patterns

The stage is set. We have a truckload of data, computers, software, and printers. Provided our data have been gathered in a form that permits computer mapping (or have been converted to such a format; see chapter 4), we are at least technically ready. It should be noted at this point that computer mapping is not "plug and play" but is more akin to word processing—the data have to be entered and sentences (read "maps") composed. Similarly, we will not be able to do computer mapping until we have data in a format that the program can understand. Also, many choices will have to be made. Automated mapping is automated only up to a point. (When you put your car on cruise control, someone still has to steer!)

Before we plug it all in and start mapping, it might be helpful to pause and think about the reasons underlying the patterns we observe and map. Those patterns must be generated by specific conditions and processes, and theories can be employed to help us understand them.

Each type of crime tends to be influenced by different conditions. For example, shoplifting is the outcome of circumstances different from those that produce homicide. Even within crime types, there are qualitative differences in circumstances. For example, a drug-related homicide may be the result of a conflict over turf or unpaid debts, whereas a domestic homicide may be the product of long-simmering animosities between partners.

Crimes may have distinctive geographic patterns for two underlying reasons that often overlap:

- First, crimes must have victims, and those victims (or their property) have definite geographic coordinates at any given moment, although these coordinates can shift, as in the case of vehicles.
- Second, some areas in cities, suburbs, or rural areas have persistently high rates of crime, so that for certain neighborhoods there is a rather permanent expectation that crime is a major social problem. For example, Lander's (1954) research on Baltimore revealed high rates of juvenile delinquency to the east and west of downtown from 1939 to 1942. Some 60 years later, the pattern has changed a little but is basically the same.

A broad-based discussion of the causes of crime is beyond the scope of this guide, and the reader is referred to the substantial literature of criminology for guidance. However, we can consider issues with more obvious geographic implications, and we can do this by moving along a continuum of scale from the *macro* to the *micro* level.

On the *macro* scale, interpreted here to mean national or regional, geographic variation is apparent for some crimes, notably homicide, in the United States. Although the pattern has decayed somewhat in recent decades, a stream of research has addressed what has been called by some the southern violence construct (SVC), the tendency for high rates of homicide to be concentrated in the South. Similar regional variations are seen in other countries. In India, for example, high homicide rates are seen in the densely populated northern states.

On the *intermediate* scale, we see variations in crime rates among cities, although much of the apparent variation can be explained by boundary effects. In other words, "underbounded" central cities (where the urbanized area spills over beyond the city limits) tend to have high rates, since their territories exclude low-crime suburbs. Conversely, "overbounded" cities (such as Oklahoma City) tend to have low rates. However, by no means are all explanations of rate variation necessarily found in boundary anomalies. Cities differ in social structure, traditions, mores, the strength of various social institutions, and other conditions relevant to potential criminality. These include economic conditions, the impact of gangs, and gun and drug trafficking. The wide variation in homicide rates among cities is represented by figure 1.15, which also reinforces the point that similar *numbers* of incidents may yield vastly different *rates*. (For an interesting example of interurban comparisons examining multiple factors, including gangs, guns, and drugs, see Lattimore et al., 1997.)

On the *micro* or intraurban scale, a broad array of environmental factors must be taken into account if crime patterns are to be understood. Arguably, the most important general principle is usually known as *distance decay*. This is a process that results from another behavioral axiom, the *principle of least effort*, suggesting that people usually exert the minimum effort possible to complete tasks of any kind. Distance decay (see also chapter 6) is the geographic expression of the principle of least effort. As shown in figure 1.16, the relationship between the number of trips and distance is represented by a line showing that people take many short trips but few long ones. This principle has been observed to apply to a broad range of behaviors, including shopping, health care, recreation, social visiting, journeying to work, migration, and last but not least, journeying to crime. It is possible to create families of distance-decay curves to represent different classes of movement behavior. For example, shopping trips can be divided into *convenience* and *comparison* types. Convenience shopping is characterized by many very short trips because most people will get items such as milk and bread from the closest possible source. Comparison shopping occurs when buyers need big ticket items such as appliances, cars, houses, and college educations. Longer trips in search of more expensive goods and services are thought to be worthwhile because price savings produced by better deals will pay for the longer distances traveled, at least in theory.

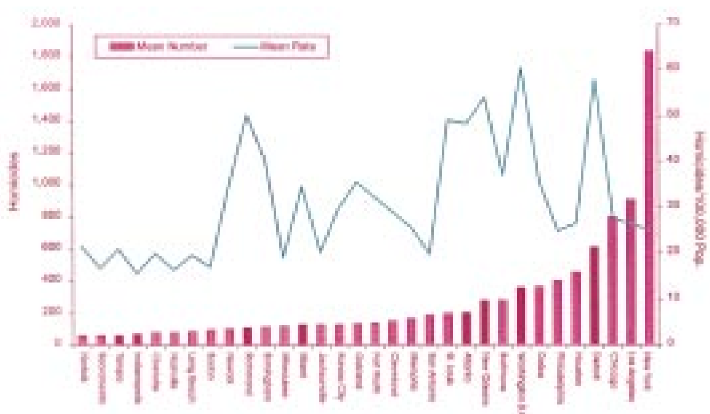


**Figure 1.15**

A chart showing mean annual homicide counts and rates for 32 U.S. cities, 1985–1994.

*Source: Lattimore et al., 1997, figures 2–4, p. 10.*

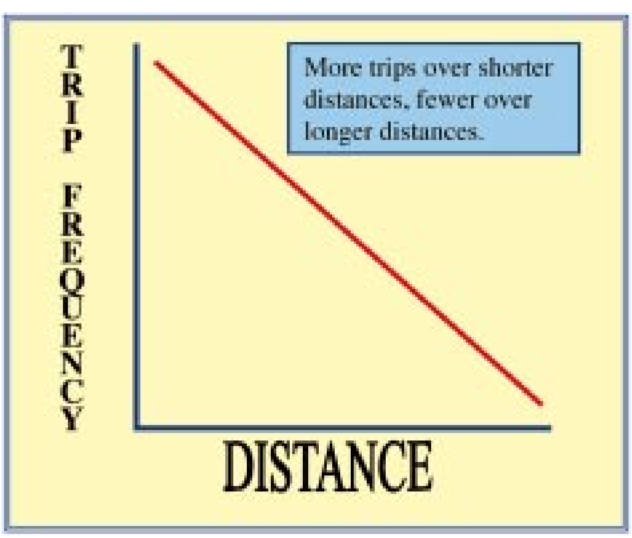



**Figure 1.16**

A diagram representing the relationship between distance and the intensity of interactions, also known as the *distance-decay concept*.

*Source: Keith Harries.*

Similar reasoning might be applied to criminal movements, although not enough data have been published to permit much in the way of generalization. The pioneering work of Frisbie et al. (1977), in Minneapolis, showed that more than 50 percent of residential burglary suspects traveled less than half a mile from their homes to their targets. Commercial burglars went somewhat farther, with some 50 percent of incidents occurring within 0.8 miles. Stranger-to-stranger assaults had a wider range, with the cumulative 50-percent threshold not accounted for until a radius of about 1.2 miles from the offenders' homes. Commercial robbers also reached the cumulative 50 percent of incidents at about 1.2 miles. However, a larger proportion of the commercial robbers traveled longer distances compared with those who committed the other crimes, presumably to locate suitable targets and also to avoid the recognition that may come with robbing the corner store. Travel distances tend to reflect population density and other characteristics of the physical environment (such as the geography of opportunities)[15], so it is unlikely that distance-decay curves for crimes could ever apply universally. Nevertheless, the concept of distance decay is still a useful one, even if curves for specific crimes cannot be calibrated very accurately.

Although journeys to crime vary among crime types and with the demographic characteristics of offenders, targets or victims tend to be chosen around the offender's home, place of work, or other often-visited locations. If your home is burglarized, the chances are that the burglar is a not-too-distant neighbor. The long-established prevalence of violence among intimates is further confirmation of the idea that most interactions—including negative ones—occur at short range.

Distance decay is a useful general concept, but a detailed understanding of the fine points of local crime patterns demands detailed local knowledge. Where are the neighborhoods that are experiencing the greatest social stress? What are the patterns of mobility of the population? Who are the movers and shakers in the drug and gang scenes, and do their movements affect crime patterns? What changes are going on?

## Other theoretical perspectives

Two of the more compelling theoretical perspectives deal with *routine activities* (Cohen and Felson, 1979; Felson, 1998) and *criminal spatial behavior* (Brantingham and Brantingham, 1984). In the routine activities interpretation, crimes are seen as needing three ingredients: a *likely offender,* a *suitable target*, and the *absence of a guardian* capable of preventing the criminal act. Guardian is broadly interpreted to mean anyone capable of discouraging, if only through his or her mere presence, or interceding in, criminal acts. The mention of guardians begs discussion of the *density paradox*. This refers to the idea that, on the one hand, high population densities create a high potential for crime because people and property are crowded in small spaces. There are many likely offenders and suitable targets. On the other hand, surveillance is plentiful, and criminal acts in public spaces are likely to be observed by others, who, however unwittingly, take on the role of guardians. Crime can be prevented or reduced by making people less likely to offend (by increasing guilt and fostering development of the "inner policeman" who tames criminal impulses), by making targets less available, and by making guardians more numerous or effective. The process of making targets less available in various ways has become known by the generic term *situational crime prevention* (Clarke, 1992).

Putting the routine activities approach and its sibling, situational crime prevention, into a geographic context involves asking how each element is distributed in geographic space. Where are the likely offenders? (What is the geography of the youthful male population?) Where are the suitable targets? (What is the geography of convenience stores, malls, automated teller machines, poorly illuminated pedestrian areas?) Where are the guardians? (What is the potential for surveillance, both formal and informal, of targets or areas that may contain targets? Where are the public or quasi-public spaces that lack surveillance and are ripe for graffiti and other incivilities?)

The perspective that focuses on criminal spatial behavior develops a scenario in which the motivated (potential) criminal uses *cues*, or environmental signals, to assess victims or targets. Cues, or clusters of cues, and sequences of cues relating to the social and physical aspects of the environment are seen as a *template* that the offender uses to evaluate victims or targets. Intimately tied to this process is the concept of *activity space,* the area in which the offender customarily moves about and that is familiar to him or her (Brantingham and Brantingham, 1984).

At the micro level of analysis, these concepts are useful in that it is known that activity spaces vary with demographics. For example, younger persons tend to have constricted activity spaces. They do not usually have the resources to travel far. Historically, women have had more geographically limited activity spaces than men due to the higher probability that men would work farther from home and that their jobs would be more likely to give them greater mobility. This is less true today but is still valid to some degree.

Analysts considering crime patterns from a theoretical perspective might think in terms of putting the crimes of interest through a series of "filter" questions. The most obvious is the question, How important is geography in explaining this pattern? (Is the pattern random, or not? If not, why not?) Can routine activity theory or criminal spatial behavior theory help explain this pattern? Is this pattern normal or unusual for this area? If the pattern is an anomaly, why is this? What resources can be brought to bear to better understand the social and other environmental dynamics of the area of interest? Analysts can take their intimate knowledge of the local environment and develop their own set of diagnostic questions, which could be the foundation of an analytic model.

The basic point of this section is to suggest that a systematic approach to analysis rooted in theory may yield more consistent results with a deeper level of explanation. This is not to say that analysts need to be preoccupied with whether their work is consistent with all the research ever done but, rather, to advocate a thoughtful research design consistent with some of the more widely accepted concepts in the field. As noted, this short explanation cannot do justice to the rich array of material dealing with theory in this realm. Readers who may wish to follow up should consult Eck and Weisburd (1995) and the other references cited previously.

## A note on cartograms

Maps that distort geography to emphasize a specific type of information are called *cartograms* to imply a combination of map and diagram. The media often publish maps showing world or U.S. population data as cartograms, with the areas of countries or States proportional to their populations. Cartograms may also represent linear data by showing travel time, for example, rather than physical distance between places.

Cartograms have not found widespread application in crime mapping, although they could be useful. For example, urban subdivisions could be shown with their areas proportional to the number of crime incidents. The major limitation in using cartograms for crime data is the lack of software availability to permit their easy preparation. Historically, cartograms have been labor-intensive projects, each needing to be custom drawn. When viewed from a cost-benefit perspective, the novelty and impact of cartograms for crime data have not been seen as worth the cost.

## Reminder: Information is inevitably lost in the process of abstraction

Cartographer Mark Monmonier (1991) pointed out that the three fundamental elements of maps—scale, projection, and symbolization—can each be distorted. In creating the abstraction called a map, loss of information is taken for granted. Given that there will be information loss, the question is whether we are properly representing the "residual" information left after the data are reduced to manageable proportions. As noted earlier in this chapter, our maps may "lie" as a result of sins of omission or commission. We may forget to do something and get errors as a result, or we may do something that creates errors—or both.

Because all abstractions lie in some way, we come full circle to the awareness of both art and science in cartography. As crime mappers, we should maintain a background awareness that we may make artistic (design) decisions that obfuscate. We may make scientific decisions that misinform. Could our map sidestep a degree of accuracy that it might otherwise have achieved? (How should these data be *pre*processed? Should the mean or median be used to characterize these data?) More often than not, only the analyst/cartographer knows for sure how truthfully a map conveys its message, so she or he has considerable ethical responsibility.

## A note on the maps in this guide

Please note that the publication process puts some limitations on the quality of the maps used as examples in this guide. While crime analysts are typically able to produce high-quality maps, often in large format for display purposes, we are limited here to small maps that were usually in larger format when produced. Fortunately, we are able to produce maps in color, which helps enliven the visual message and also helps to convey the various concepts involved. Loss of definition occurs in some cases because the original has been scanned or resized, or both. In some cases, only a low-resolution original was available, yielding a low-resolution reproduction.

Thus most of the maps seen here are compromised in some respects and are unlikely to be the perfect exemplars that we would prefer. Perhaps "do as I say but not necessarily as I appear to have done" would be a fair warning! Ideally, of course, maps should be clear and crisp with appropriate shading or symbolization and legible labels and headings. If that is not the case here for any of our examples, please accept our apologies. The original authors of the maps who have so generously consented to their use here are not to blame for any shortcomings in their reproduction or adaptation.

Purists may be shocked by the presentation of so many maps that lack some of the basic elements normally considered essential in map design, such as a scale, a north arrow, or even a legend. Relatively few maps have what may be called classic good looks. The maps used here were often selected for their ability to illustrate one central point, and strict conformity to classic design criteria was not seen as a critical determinant for inclusion. Indeed, had the strict classical criteria been enforced, this volume would not exist because, as noted elsewhere, few maps in any field go by the book. It would have been necessary to modify most maps to make them conform to strict standards, and this was simply impractical.

Some maps identifying specific neighborhoods in specific cities in sufficient detail to permit the possible identification of individual residences have been constructed using hypothetical data or have been otherwise fictionalized to preserve privacy. It is not my intent to present accurate renditions of crime patterns in specific cities but, rather, to illustrate elements of design and map application. No map reproduced here should be used as a reliable guide to actual crime patterns in actual places.

## Summary

Chapter 1 has explained:

- What this guide is about and how crime mapping fits in the historical context of mapmaking.
- Why cartography is both an art and a science.
- Why it is important to balance costs and benefits when considering map design and production.
- That maps can represent information relating to both time and geographic space.
- The meaning and significance of map projections and coordinate systems.
- The traditional elements that help provide consistency and interpretability in maps.

- The types of information provided by maps.
- Measurement systems and their relevance to mapping.
- The meaning of the term "thematic map."
- The ethical responsibilities of crime mappers.
- The difficulties associated with the black and white reproduction of maps that were originally in color.
- The importance of thinking about the causes underlying the patterns that we map and analyze.
- The meaning and possible application of cartograms in crime mapping.
- Why we should realize that we can lie with maps just as we can lie with statistics.

**What's Next in Chapter 2?**

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

## Notes

1. Photographs were not very useful because they had to be enlarged to an impractical size to be legible.

2. From the Latin *c(h)art(a)* and Greek *graph(os)*, something drawn or written, hence "chart drawing."

3. India ink is a mixture of lampblack and glue.

4. This grid is also known as a *graticule*, a term meaning the spherical pattern of meridians (north-south longitude lines) and parallels (east-west latitude lines). See Campbell, 1993, p. 23.

5. *Mercator's* projection, developed by and named for Gerhardus Mercator (1512–1594), a Flemish cartographer, is useful for navigation because a straight line on the map represents a true direction on the Earth's surface.

6. *Equal-area* projections, as the name implies, accurately represent area, but not shape. This type of projection shows area distributions such as vegetation, in which the area shown is critical.

7. *Conformal* projections retain correct shapes. An added advantage is that, if shape is retained, so is direction.

8. *Transverse* Mercator has the projection cylinder fitted horizontally—i.e., east-west, rather than tangentially to the Equator or north-south.

9. Latitude is relatively easy to determine with reference to "fixed" objects such as the North Star or the Sun. Longitude, as noted earlier, poses greater difficulties. It is known that the 360 degrees of longitude divided into the 24 hours of the day means that each hour is equivalent to 15 degrees of longitude. Thus if the time at a known point could be maintained on a ship at sea, longitude could be calculated based on the time difference as established locally from the occurrence of the noon Sun. The problem, until John Harrison's invention of the reliable marine chronometer in 1761, was that no clock was able to retain its accuracy under the difficult conditions of a sea voyage. The extraordinary saga of Harrison's success is found in Sobel (1995). (I learned more than I cared to about this problem on a trip on a 30-foot sailboat from Honolulu, Hawaii, to Santa Barbara, California, when the crew forgot to set the chronometer on leaving Honolulu. The crew always knew their approximate latitude by using a sextant but never knew their longitude. Fortunately, they kept moving east and eventually bumped into North America.)

10. In case inquiring minds want to know, 1 nautical mile, or "knot," is equivalent to 1 minute of latitude, or 1,852 meters (6,076.12 feet). One nautical mile is also equivalent to 1.1507 statute miles (Dent, 1990, p. 40).

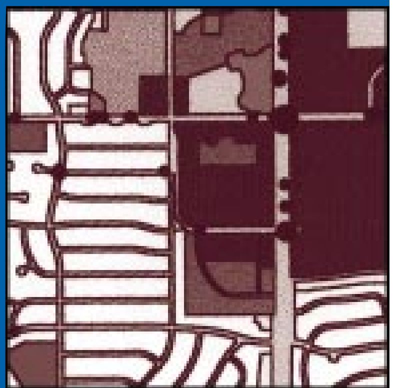
11. This happens because a GIS will try to put both locations on the same map in the originally specified map units. This may result in the map changing to extremely small scale (see explanation of scale in this chapter) as the GIS tries to make State plane coordinate values into degrees of latitude/longitude, placing the new data far, far away. The GIS may try to show data for small areas in Brooklyn and what it reads as Afghanistan or Antarctica on the same map.

12. The term *orientation* is derived from medieval T-in-O maps. The "O" was the world ocean; the "T" was formed by the Mediterranean Sea (vertical), the Don River (left top of the T), and the Nile River (right top of the T). Paradise in this style of map was typically at the top, in the east. Hence the verb to "orient" a map came to mean adjusting it to its proper direction in relationship to the Earth. Today, however, we orient a map so that north is at the top, which is something of a misnomer (Campbell, 1993, pp. 246–247).

13. From the Greek *choros* for place and *plethos* for fullness or crowding, hence "area crowd."

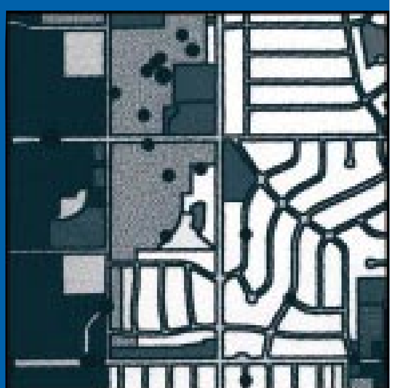
14. Isolines based on continuous data, such as temperature or topography, are referred to as *isometric* lines. Actual measurements can be made to provide control points instead of averaging points over areas.

15. The term "geography of opportunities" refers to the idea that the world offers abundant possibilities for crime that may be more complex than we realize at first glance, encompassing both qualitative and quantitative dimensions. For example, although rich neighborhoods may not offer *more* opportunities than poor neighborhoods for, say, property crime, each opportunity may offer the perpetrator higher value because the goods stolen may be worth more.



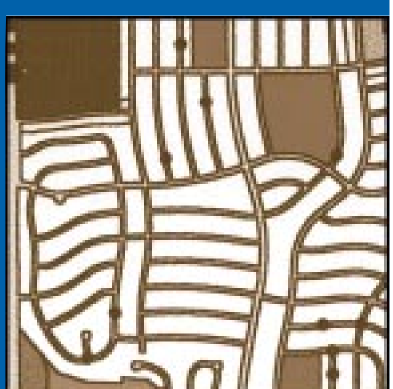
# Chapter 2:

# 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

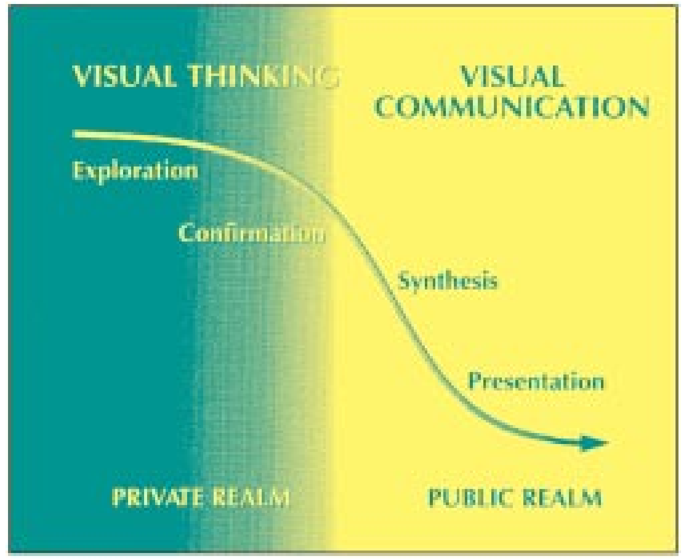



**Figure 2.1**

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

*Source: DiBiase, 1990. Reproduced by permission.*

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? It's 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 massage," 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

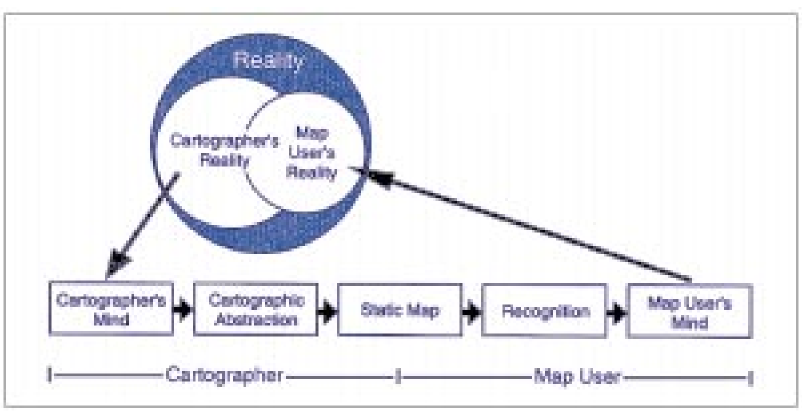



**Figure 2.2**

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.*

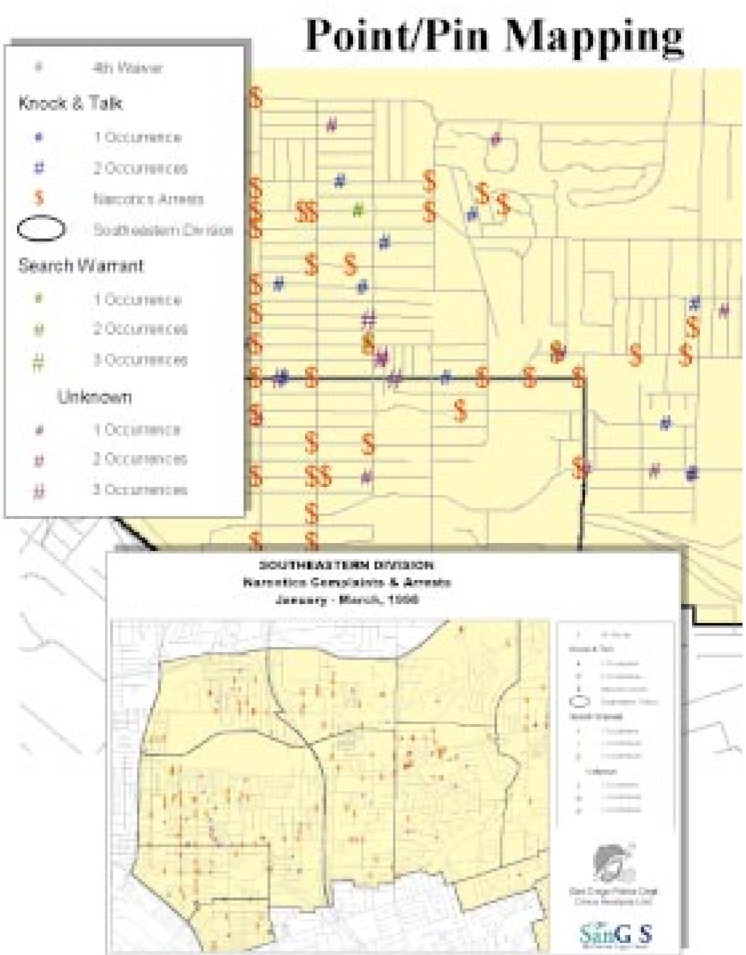



*Figure 2.4*

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

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

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

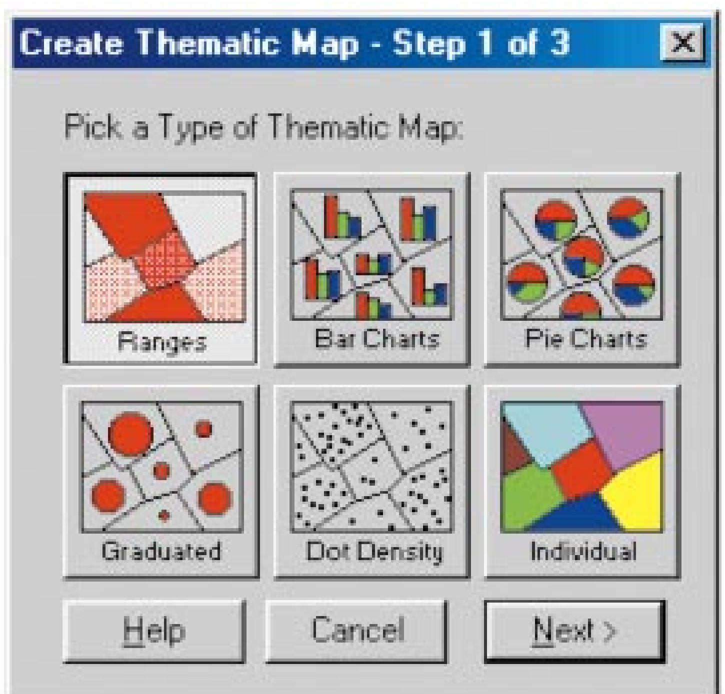



**Figure 2.5**

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

*Source: MapInfo Corporation, Troy, New York.*

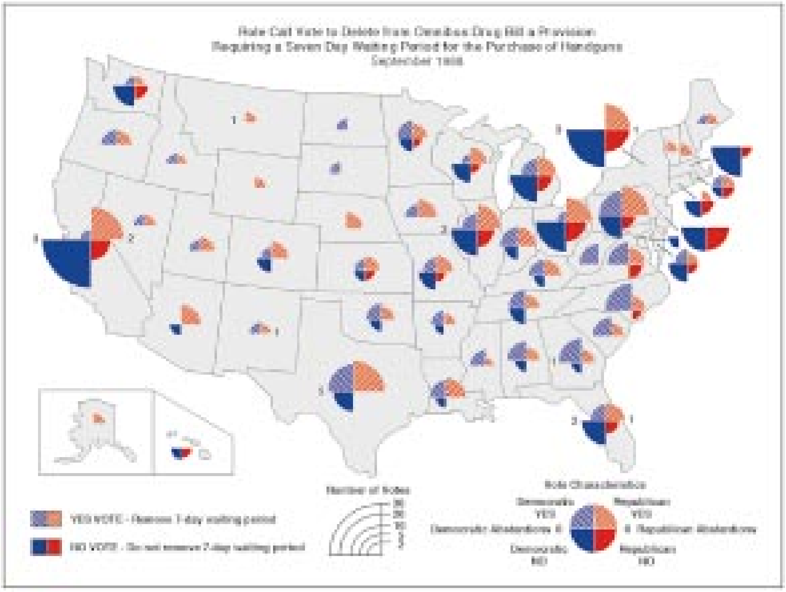


**Figure 2.6**

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.*

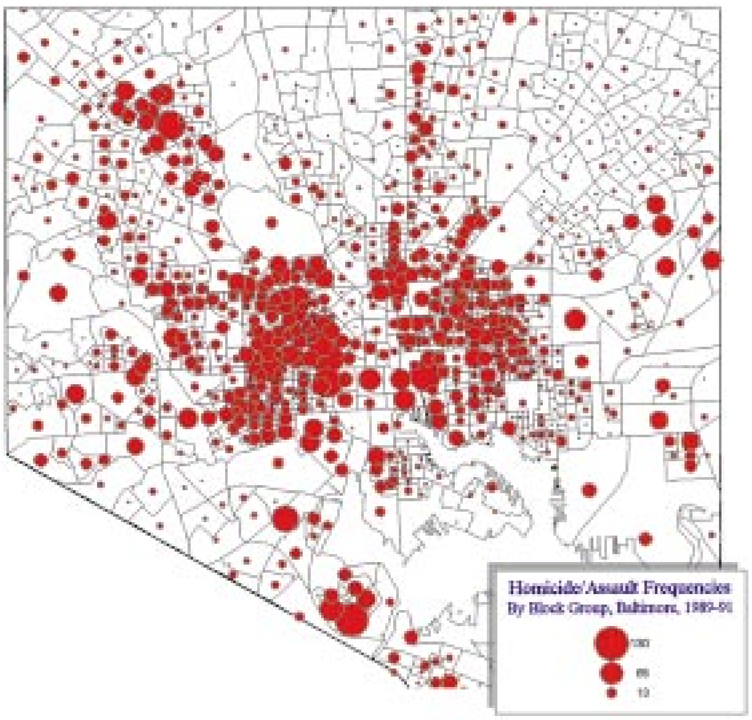


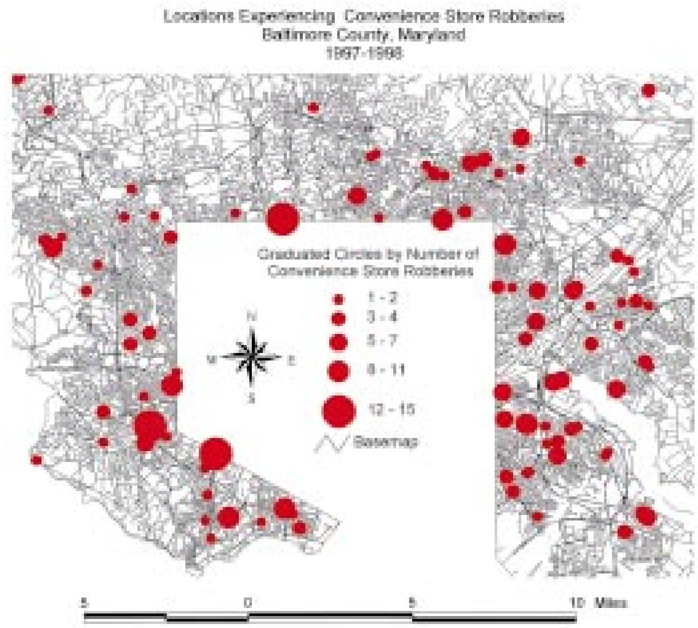

**Figure 2.7**

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.

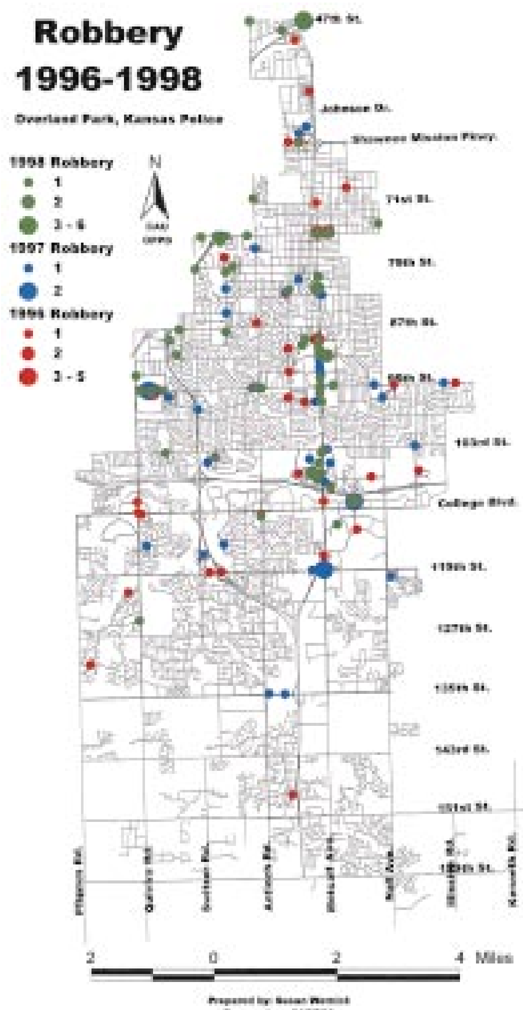
More typical graduated symbol maps used in crime analysis applications are shown in figures 2.7, 2.8, 2.9, and 2.10. Note that points and proportional circles can be




## 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.*

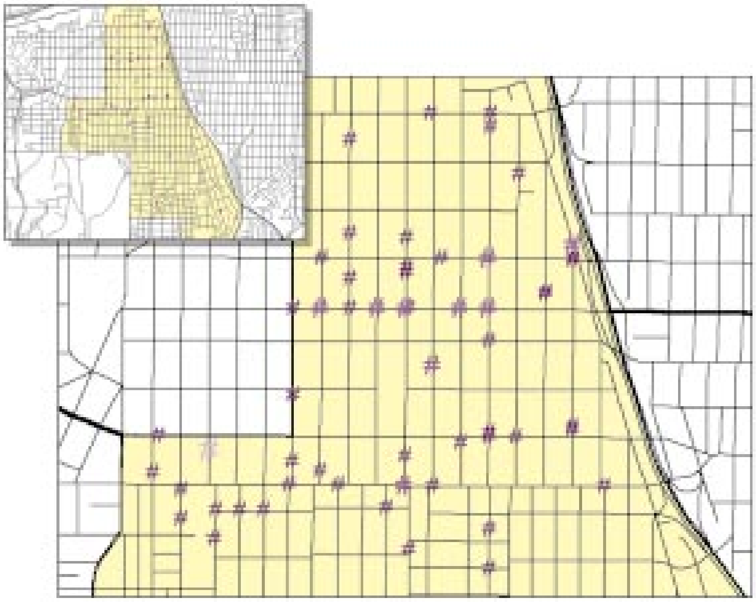


**Figure 2.10**

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.

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

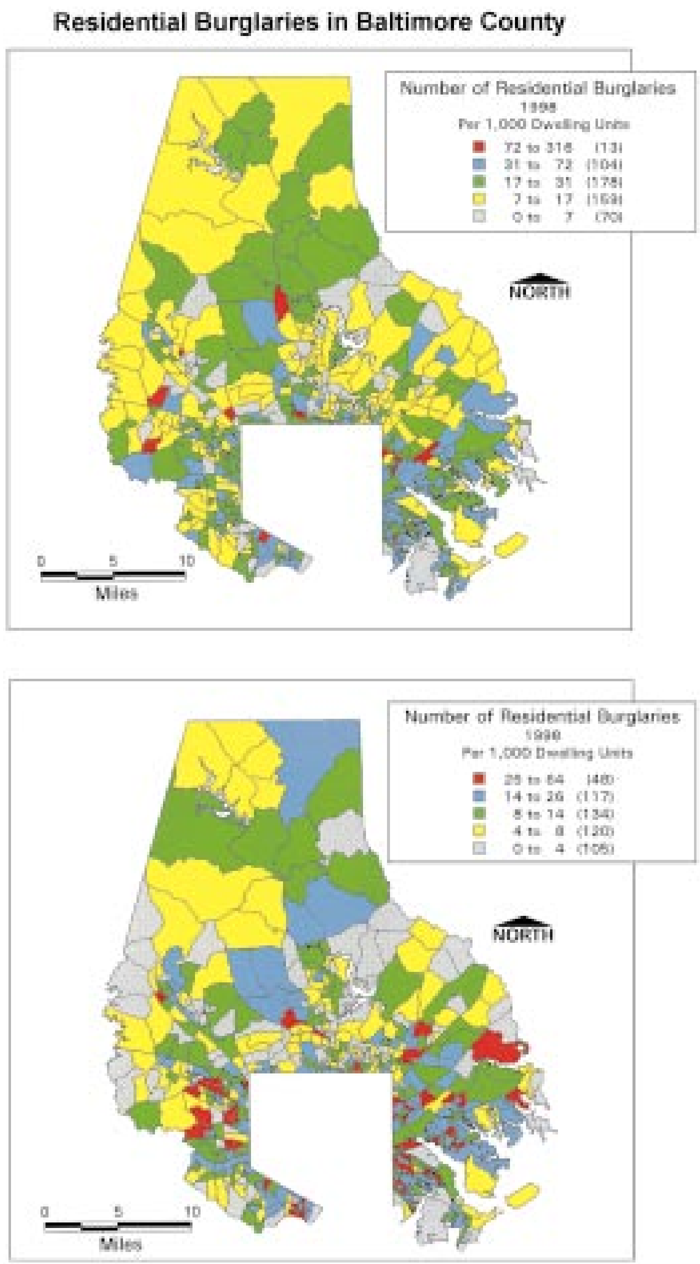



**Figure 2.11**

Choropleth maps showing residential burglaries in Baltimore County, Maryland.

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

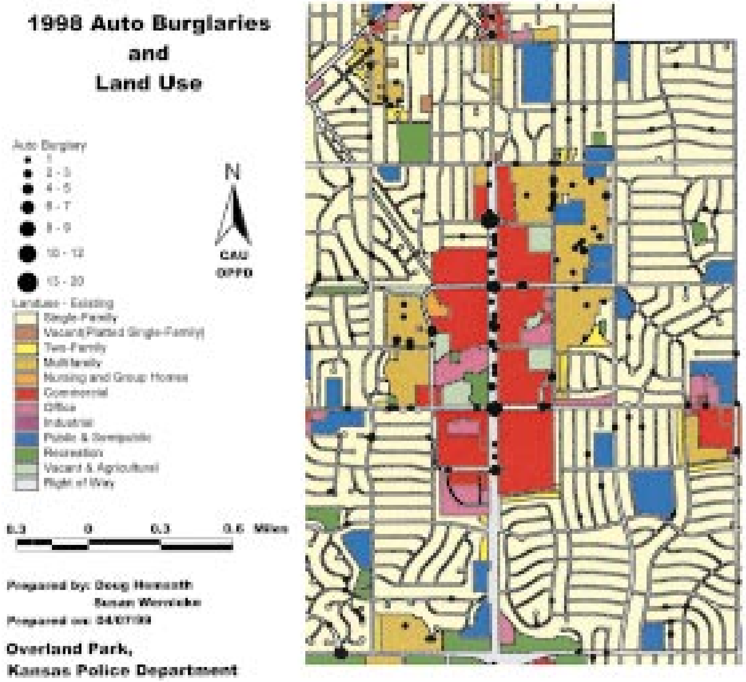



**Figure 2.12**

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

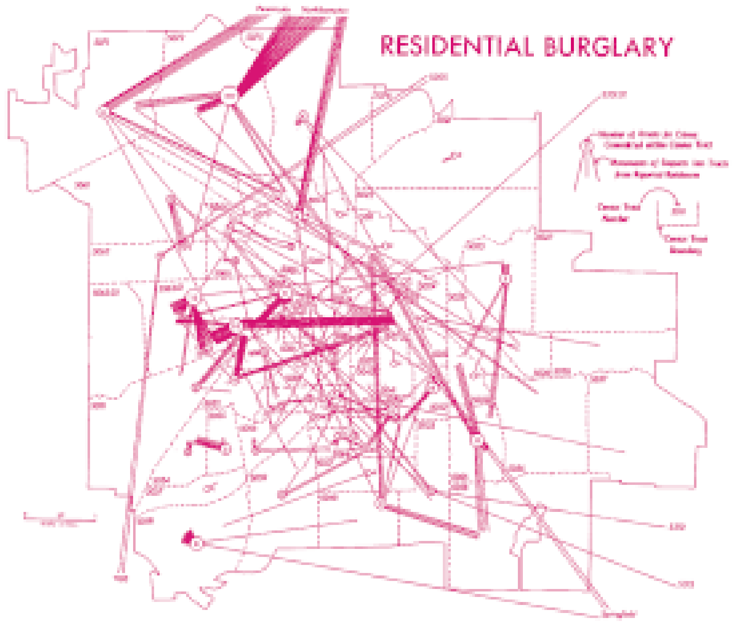



*Figure 2.13*

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 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.*

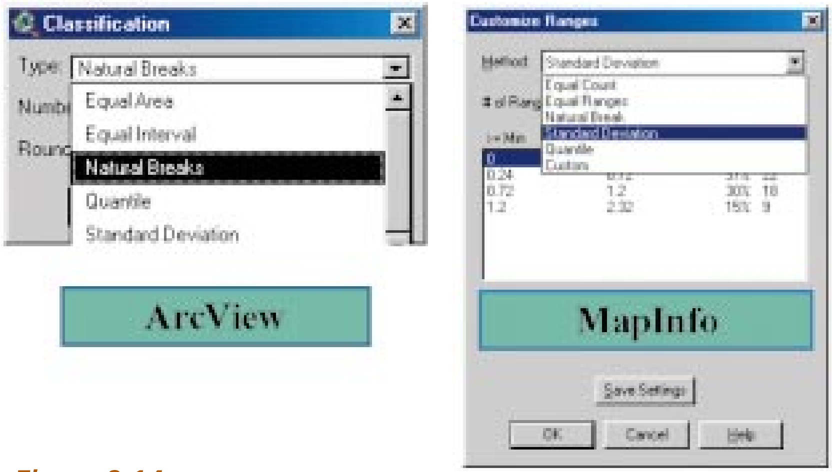



**Figure 2.14**

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 know 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 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.*

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

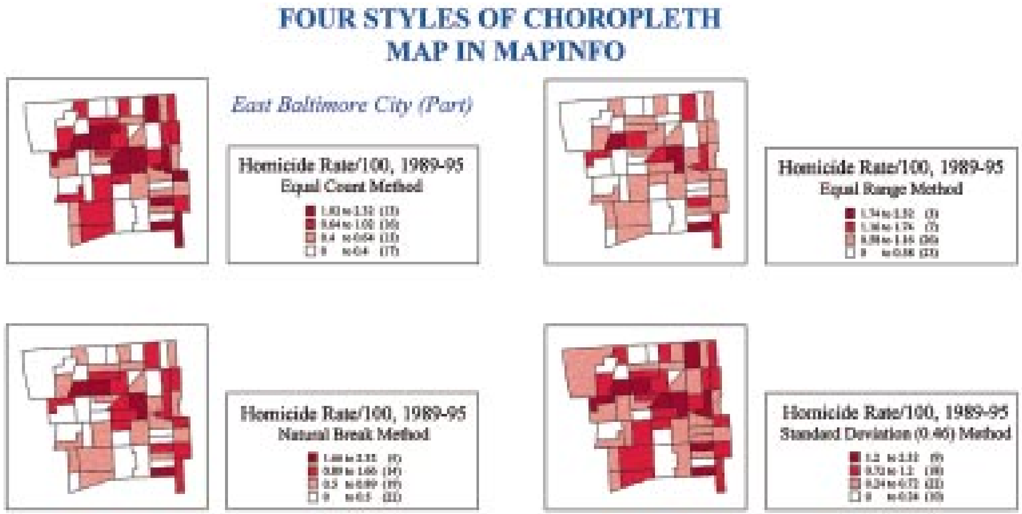



***Figure 2.15***

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

*Source: Keith Harries.*

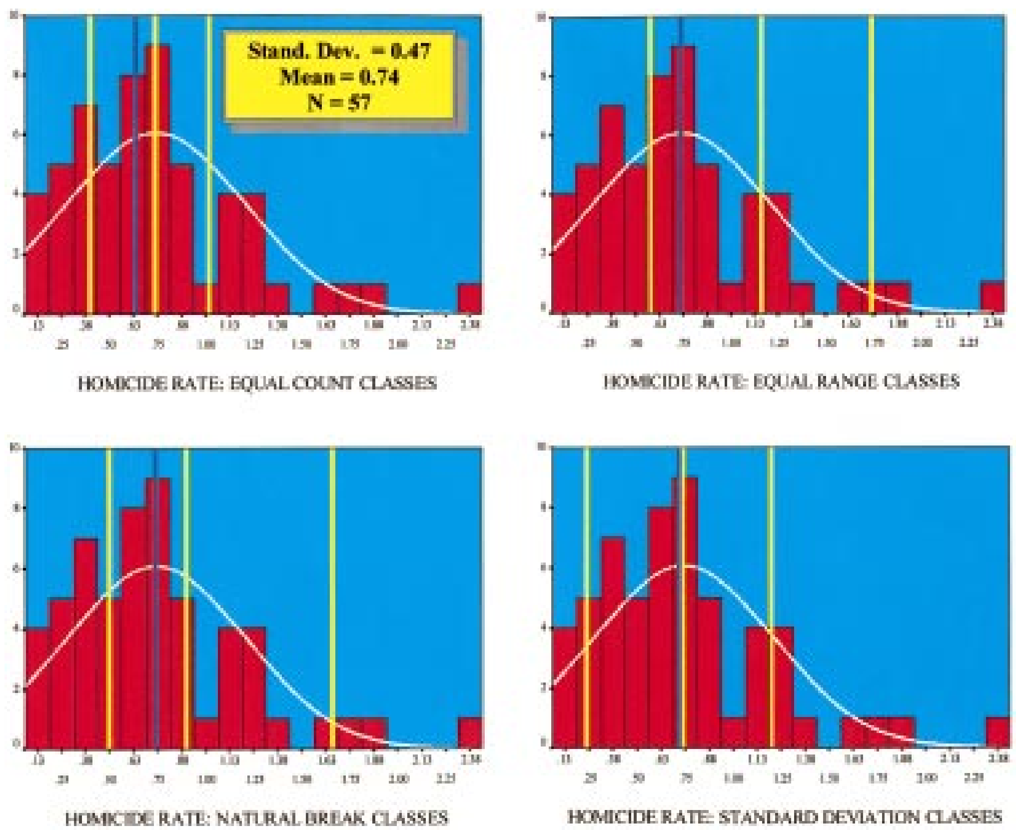



***Figure 2.16***

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

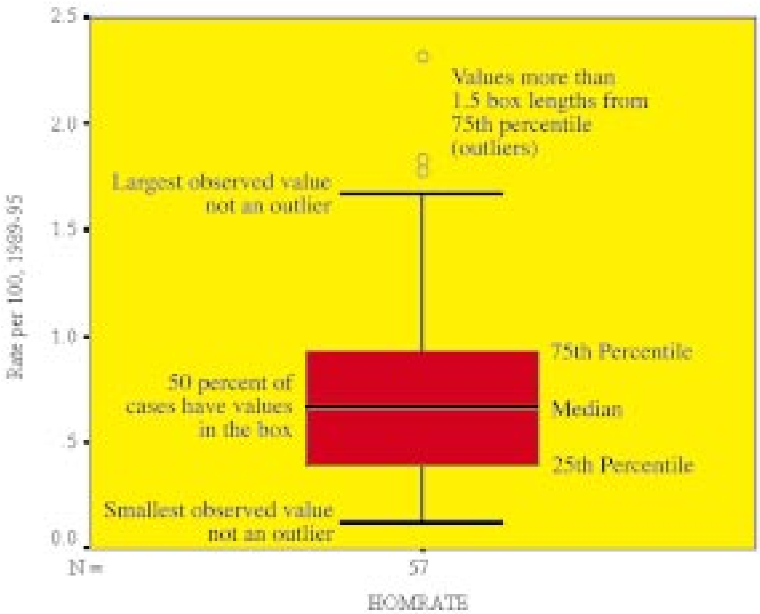



**Figure 2.17**

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 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.*

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*[11] 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

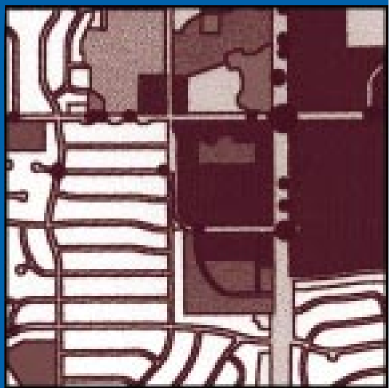
the choropleth map, see Tufte, 1990, pp. 40–41.

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.)

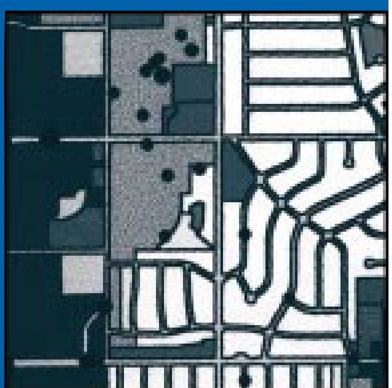
10. Take into account the size of the room and how far the back row of seats is from the image. Similar considerations apply if you have a poster-size map to be displayed to an audience.

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

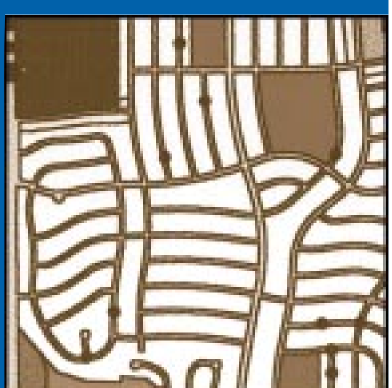


# Chapter 3:

## Maps That Speak to the Issues



This chapter discusses how map designs can address specific issues and audiences. The underlying assumption that "one map fits all" is inadequate because each audience has its own perspective on crime and how it can be prevented or controlled. Community leaders may have the latest notorious incident on their minds. Policymakers may be concerned about how to trim $1 million–$2 million from their budgets while making the community safer. Members of the court and corrections communities may be concerned with overloaded systems, overcrowding, and the ramifications of releasing offenders early. Investigators may need tools to help them organize place-related facts and processes. Police managers often worry about accountability, resource allocation, displacement problems, and the implications of demographic change. On the front lines where patrol and community officers operate, community information is a core resource rarely available in sufficient quantity or quality.



### Patrol officers

Officers who spend time on the street are entitled to the most up-to-date and comprehensive data related to their patrol areas. These data should be easily accessible and user friendly.

The most useful kind of information should focus on recent area history, with an emphasis on change. Effective policing emphasizes patterns, and mapping and understanding change are key to understanding these patterns. The most basic information shows what happened and where. For example, what has happened during the past two shifts? Are new hot spots emerging? Have significant developments occurred in outstanding cases? Is it necessary to communicate with specific neighborhood watch or citizen patrol representatives? Examples from Jacksonville, Florida, and San Diego, California, are shown in figures 3.1 and 3.2.

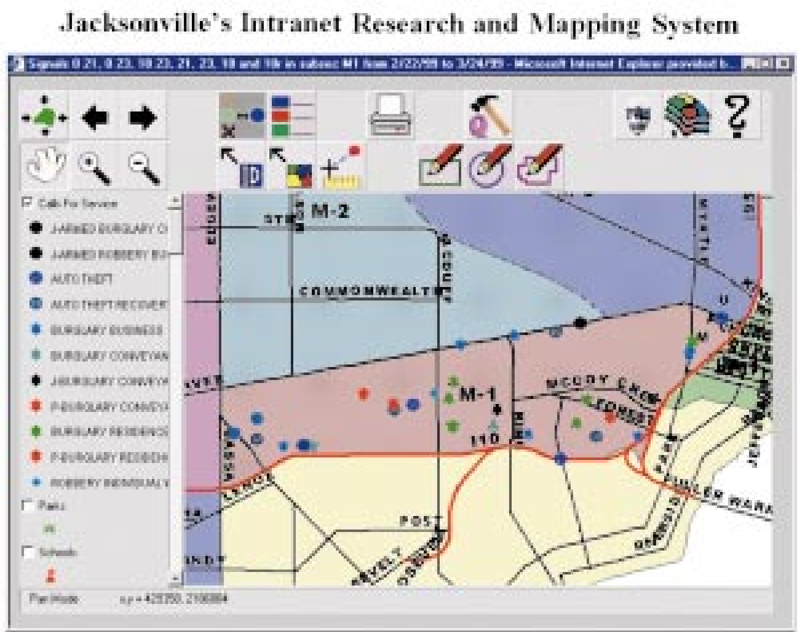



**Figure 3.1**

An intranet map showing calls for service classified by crime types, Jacksonville, Florida.

*Source: Jacksonville, Florida, Police Department. Reproduced by permission.*

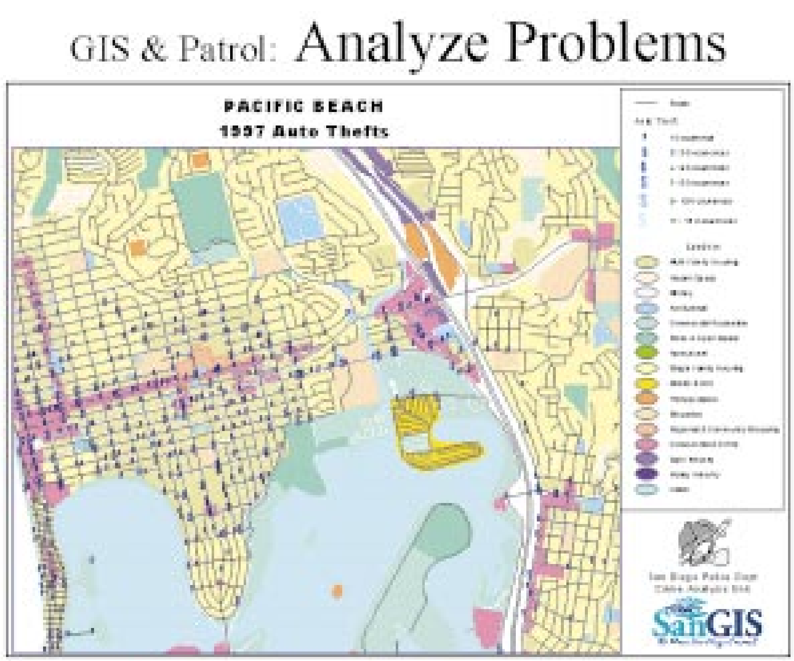



**Figure 3.2**

A map showing auto thefts, Pacific Beach area of San Diego, California.

*Source: Crime Analysis Unit of the San Diego, California, Police Department and SanGIS. Reproduced by permission.*

Quick mapping systems that support patrol functions have been developed by several police departments. These include Chicago's Information Collection for Automated Mapping (ICAM) program, which defaults to a map of reported offenses (based on the user's selection of a crime type) during the previous 10 days in the district. Figure 3.3 shows an example.

What are the basic elements of useful maps for patrol officers? Primarily, maps must be detailed and geographically legible. Generalization is acceptable on large city or county maps, but maps of individual beats or posts can include details such as street names, landmarks, and locations of significant events relevant to an officer's tasks. The ICAM model also incorporates some tabular data to give the map added depth. For example, a map of criminal damage to vehicles could display a table with the date, beat, time, address, make and model of the vehicle, and other details for each incident. A map of assaults could have embedded within it a table with similar detail plus data on the characteristics of the victim and suspect, weapon used, and number of assailants. Maps should be clear and unambiguous. Contrast should be strong because maps may be read under low light conditions and may need to be understood quickly.

Maps are reference documents, so map users do not memorize map detail any more than they would memorize the content of an encyclopedia. A well-used map will be referred to frequently, and this requires that the map be exceptionally legible. Crime analysts may consider establishing basic criteria for line weights, font and symbol styles and sizes, color, and shading. This should ensure that the maps convey their meanings clearly under all conditions. Maps lacking contrast or containing small lettering, symbols, or

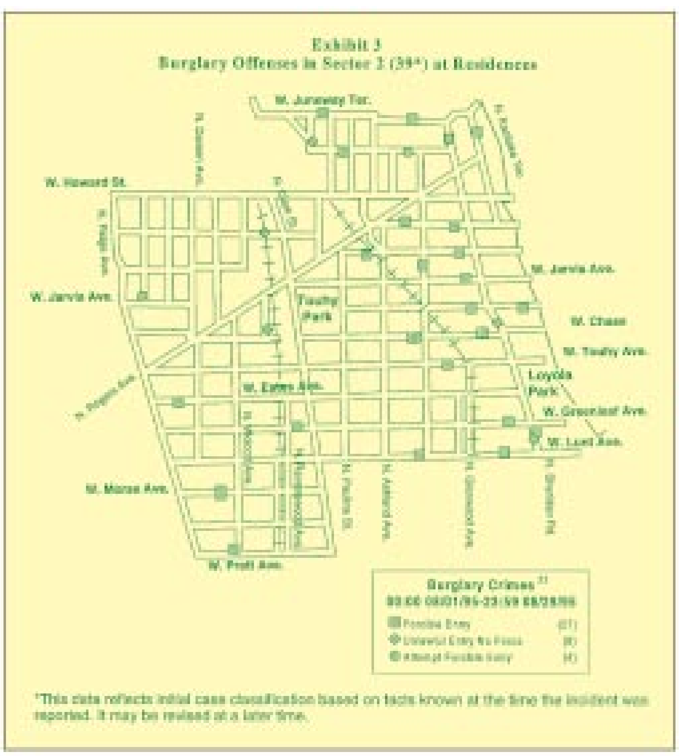



**Figure 3.3**

A map showing residential burglary offenses in Chicago's Sector 2.

*Source: Rich, 1996, p. 13.*

poorly defined lines will be relatively hard to read (figure 3.4).

## Investigators

The documented applications of mapping as a support tool for investigation suggest several generalizations applicable to the use of maps.

Maps:

- Bring together diverse pieces of information in a coherent way.
- Provide vivid visualizations of case-related data and descriptive patterns that may suggest answers to investigative questions.
- Provide opportunities for spatial analysis with selection and query tools. (See chapter 4.)
- Serve as tools to persuade managers to deploy resources in a specific manner.

A recurring theme is that maps often reveal a whole picture that is greater than the sum of its parts. This happens when many small and seemingly isolated and insignificant pieces of evidence take on critical importance when viewed as part of a pattern.

Without maps, data may be incomprehensible or available only in the form of a list. A list of suspects or pieces of physical evidence means little if key information is

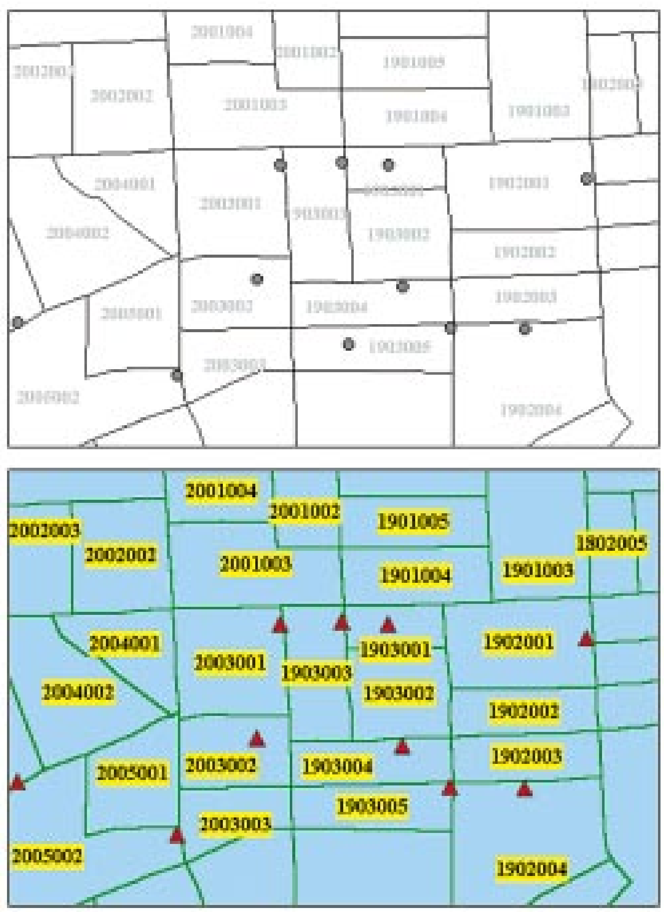



**Figure 3.4**

Contrasting maps, less legible (top) and more legible (bottom).

*Source: Keith Harries.*

seen best in graphic form. Even a list of addresses may be hopelessly confusing in a metropolitan area with thousands of streets.

These points are illustrated in several case studies outlined by La Vigne and Wartell (1998). In a McLean County, Illinois, case involving rural burglaries, for example, an inexpensive proprietary mapping program was used to plot incidents on a county map. Almost all incidents occurred close to major highways, suggesting the involvement of traveling criminal groups that specialized in burglaries. The burglaries also seemed to occur close to cemeteries, which were thought to be lookout places. Based on this information, more patrols were placed around cemeteries, leading to the arrest of persons belonging to a group called the Irish Travelers. Although there were no convictions, there was a sharp decline in burglaries in the region, suggesting that the group had been displaced (Wood, 1998).

In a Knoxville, Tennessee, rape case, ex-offenders living near a crime scene were mapped. Within 2 miles of the crime scene, there were 5 sex offenders, 15 parolees, and 2 juvenile habitual offenders. When additional offenses occurred, victims were able to identify the offender from the suspect group selected according to geographic proximity. The interpretation noted that “without the spatial analysis of the offender databases layered on top of the crime scene map, the offender information would not have been readily known” (Hubbs, 1998).

In Aurora, Colorado, the time and day of occurrence, location type, method of break-in, and property characteristics of several burglaries were used to determine that the burglaries were geographically clustered. The events had taken place in the afternoon in single-family dwellings, and similar entry points and crime scene behaviors (including damaging property in the home) were evident. This information was distributed to the police department’s burglary unit and patrol bureau, which immediately identified and eventually apprehended a suspect whose home address was at the center of the observed cluster (Brown et al., 1998).

Other relevant case studies involved preparing murder trial evidence in St. Petersburg, Florida (see chapter 5); employing an autodialing system in Baltimore County, Maryland (see chapter 5); predicting serial crime in Los Angeles, California; and mapping evidence left by a murderer in Lowell, Massachusetts (see La Vigne and Wartell, 1998, for details of these and other cases).

## Police managers

Police managers are confronted with many challenges. Not only must they be aware of crime problems, but they also must be able to address problems involving labor relations, public relations, and political influences. The following are typical issues affecting police managers, which can be addressed by using mapping as a management tool. The five issues are analyzing calls for service (CFS), hot spot mapping, crime displacement, the implications of demographic change, and accountability as exemplified by the CompStat process in New York.

### Management issue 1: Mapping calls for service to assist resource allocation

CFS are generally accepted as a crude index of the demand for police services. As such, they can be mapped. This process uses either point symbols (each symbol represents one or more calls) or choropleth form (calls are assigned to specific geographic or reporting areas). Although patrol officers find CFS maps help indicate "where the action is," maps with greater detail are more useful.

CFS maps are most useful as a tool to help managers allocate resources. In Baltimore County, Maryland, for example, descriptive data on the number of calls that various patrol units respond to are mapped (figure 3.5). This same police department then analyzes and "weights" the calls for service to designate or modify police "posts" or patrol areas. "Weight" in this context means that CFS involving more serious crimes are assigned higher values than CFS regarding less serious incidents. The weighted values are then totaled to indicate each post's workload. As needed, post boundaries are drawn (or redrawn) to equalize the workload (figure 3.6). This is done using a MapInfo® redistricting routine, which was originally intended to help redraw political districts following each census. The objective of political

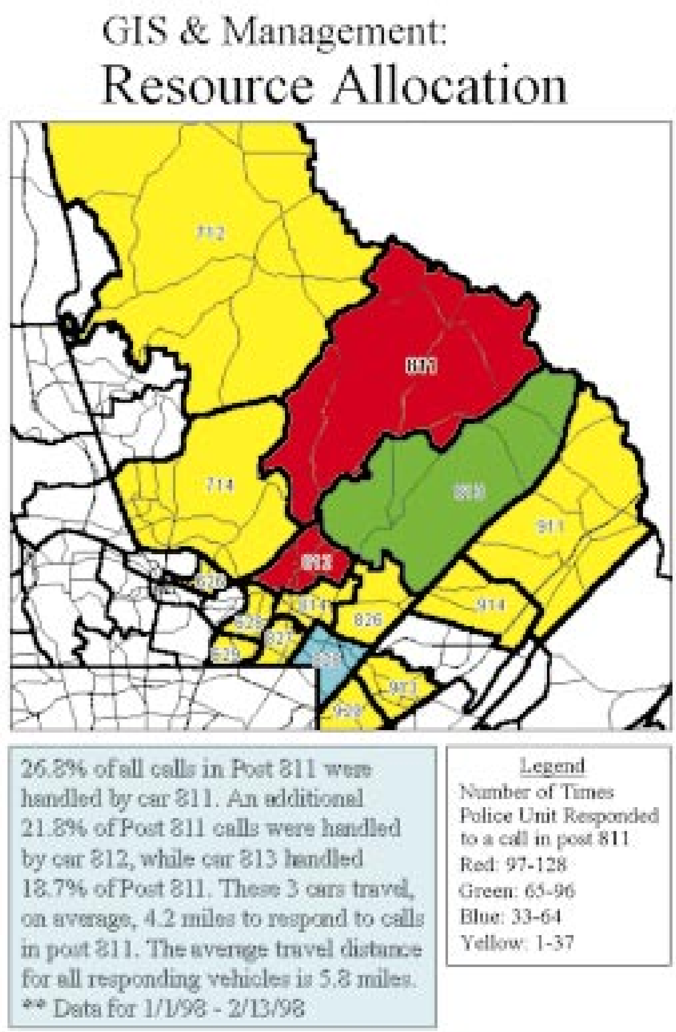



**Figure 3.5**

A map showing descriptive data on patrol responses to calls for service.

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

redistricting is to maintain an equal number of residents in each political area to maintain the "one person, one vote" principle—a process analogous to equalizing incidents or workload per officer in the police context (Canter, 1997). (See chapter 5 for another application of this method.)

Another example with implications for resource allocation is shown in figure 3.7,

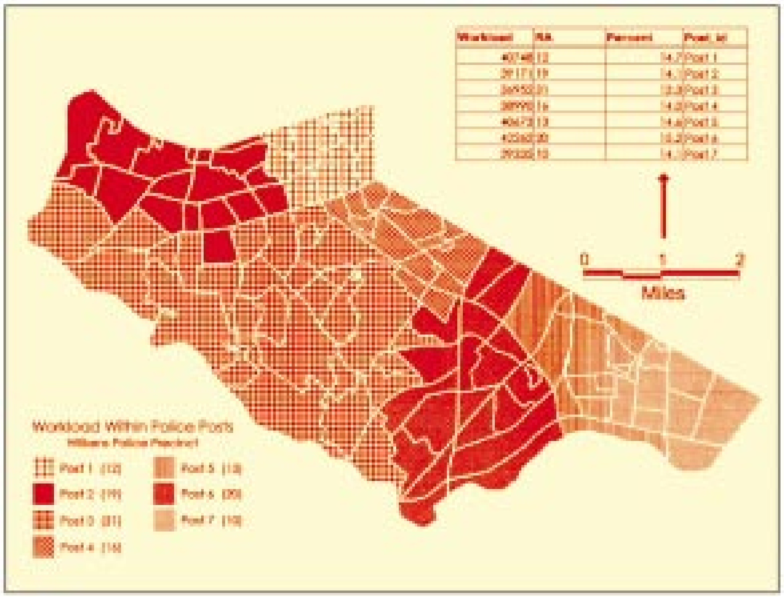



**Figure 3.6**

A map showing police posts based on workload assignments by reporting area.

*Source: Canter, 1997, figure 4, p. 173.*

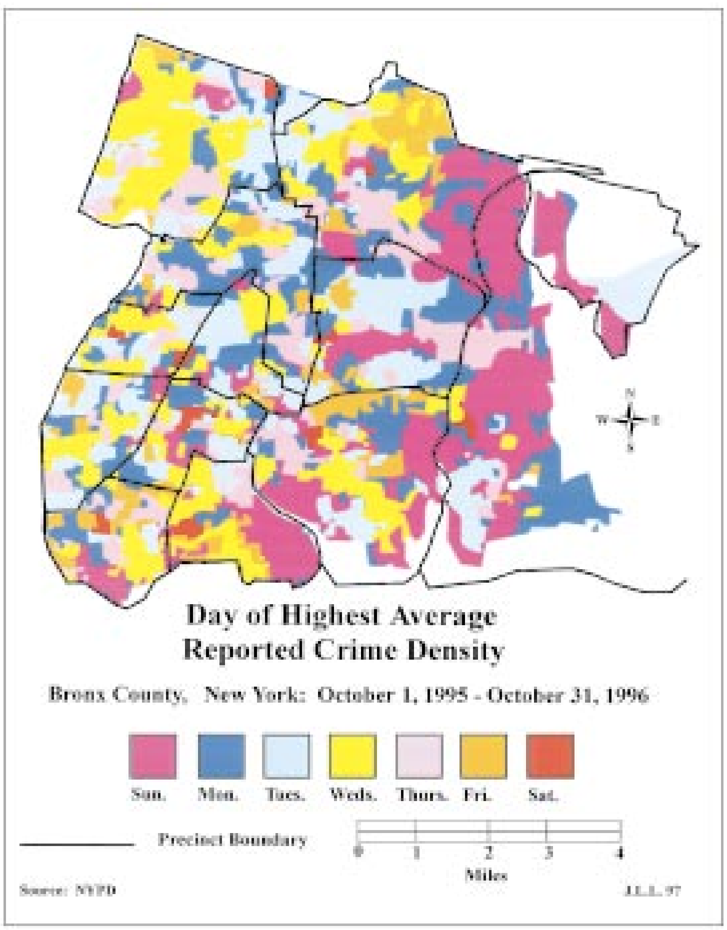



**Figure 3.7**

A map showing the day with the highest average reported crime density, Bronx County, New York, October 1, 1995, to October 31, 1996.

*Sources: Map by J. LeBeau, Southern Illinois University, with data from the New York City Police Department. Reproduced by permission.*

which illustrates the day of the highest average reported crime density. In this case, point data were aggregated into more than 950 census block groups, and the number of crimes per day, per square mile for each block group, was calculated.

### Management issue 2: An approach to hot spot mapping

Hot spots are discussed in more detail in chapter 4. Here, we describe an application designed to identify specific locations for increased law enforcement activity and to help law enforcement managers solve problems. This method, developed by Eck, Gersh, and Taylor (in press), is called *repeat address mapping* (RAM). It defines a hot spot as "a single place with many crimes." The term "many crimes" is defined using *minimum plotting density*—meaning simply that a minimum number of events must occur in a specific place for it to qualify as a hot spot.

The hot spot designation procedure is illustrated in figure 3.8. The steps include:

- Sort places according to the number of crimes so that the place with the most crimes is at the bottom of the list and the place with the fewest is at the top.
- Divide the list into 10 equal sections, with the top group containing the fewest crimes.

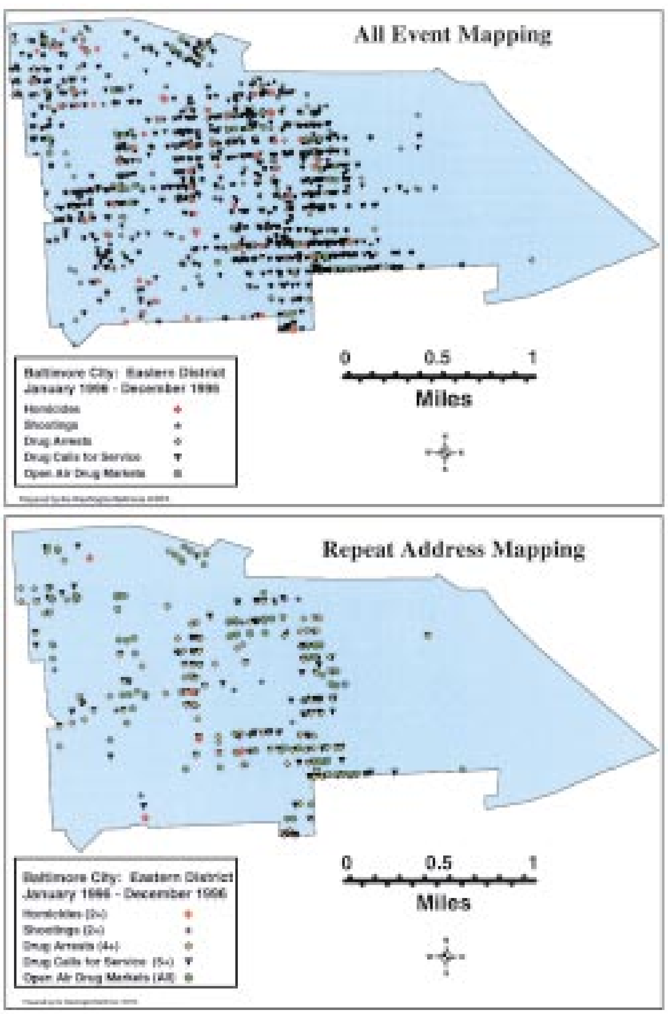



**Figure 3.8**

A map showing the RAM method applied to data for East Baltimore, Maryland. Note the distinctive difference between the pattern for "all event mapping" and the pattern for "repeat address mapping."

*Source: Eck, Gersh, and Taylor, in press. Reproduced by permission.*

- Designate addresses within the bottom group as hot spots.

## Management issue 3: Mapping displacement

In general terms, displacement occurs when criminal behavior is replaced by some other behavior or moved from one place to another. *Spatial displacement* occurs when offenders move from one area to another in response to a law enforcement effort. A fundamental problem in the analysis of displacement is the natural and inherent conflict between the local and general benefits of crime prevention. For example, a crime hot spot is identified and a prevention program is put in place. This has the effect of chasing offenders out of the area, only to move them across the city, county, or State line. Thus the local problem has been solved (at least temporarily), but the net general gain is zero—and could be negative if the offenders are displaced to an area that is more vulnerable because of weaker law enforcement. Taking this line of reasoning to its logical conclusion, it could be said that preventing crime in one place causes crime in another!

Barnes (1995) noted that the literature has identified six kinds of crime displacement:

- **Temporal.** Offenders perpetrate crimes at times seen as less risky.
- **Target.** Difficult targets are given up in favor of those easier to hit.
- **Spatial.** Offenders move from areas that may be targets of crime prevention programs to less protected areas.
- **Tactical.** Tactics are changed to get around security measures.
- **Perpetrator.** New offenders take the place of those who move, quit, or are apprehended.
- **Type of crime.** Offenders take up another type of crime if one type becomes too difficult to commit.

In theory, if perfect data were available, all six of these displacement types could be mapped. In practice, this is highly unlikely, and from the perspective of spatial analysis, spatial displacement is the prime candidate for mapping.

But mapping even spatial displacement alone is difficult due to measurement problems. Although it may seem simple enough to establish a law enforcement effort target area and a surrounding displacement area, measuring displacement there is, in reality, far more complex. The ability to measure displacement is also affected by the impact of the enforcement program, as well as the size of both the target area and the displacement zone and their existing crime levels.

For example, if the displacement area already has a high level of crime, the effects of the enforcement program could be indistinguishable from the normal variations in criminal incidents in the displacement zone. As shown in figure 3.9, the existing crime rate is a key factor in isolating crime displacement. Displacement would be difficult to identify in the top map. However, in an area with little existing crime, displacement may be obvious—or at least appear to be obvious (bottom map).

To suggest that spatial displacement analysis is too difficult to be viable is an exaggeration; managers and analysts should assess viability on a case-by-case basis. However, spatial displacement analysis is harder than one might think, and even a well-designed displacement study may need to hedge its conclusions (see Weisburd and Green, 1995; Reppetto, 1974; Hakim and Rengert, 1981; and Barr and Pease, 1990).

## Management issue 4: Demographic change and its implications for managers

A key fact affecting police department mapping is that some 26.3 million immigrants, about three times as many as in 1970, now live in the United States (Escobar, 1999). This 10 percent of the population is critically important to law enforcement, whose primary function requires interaction with the public. Although many communities may feel

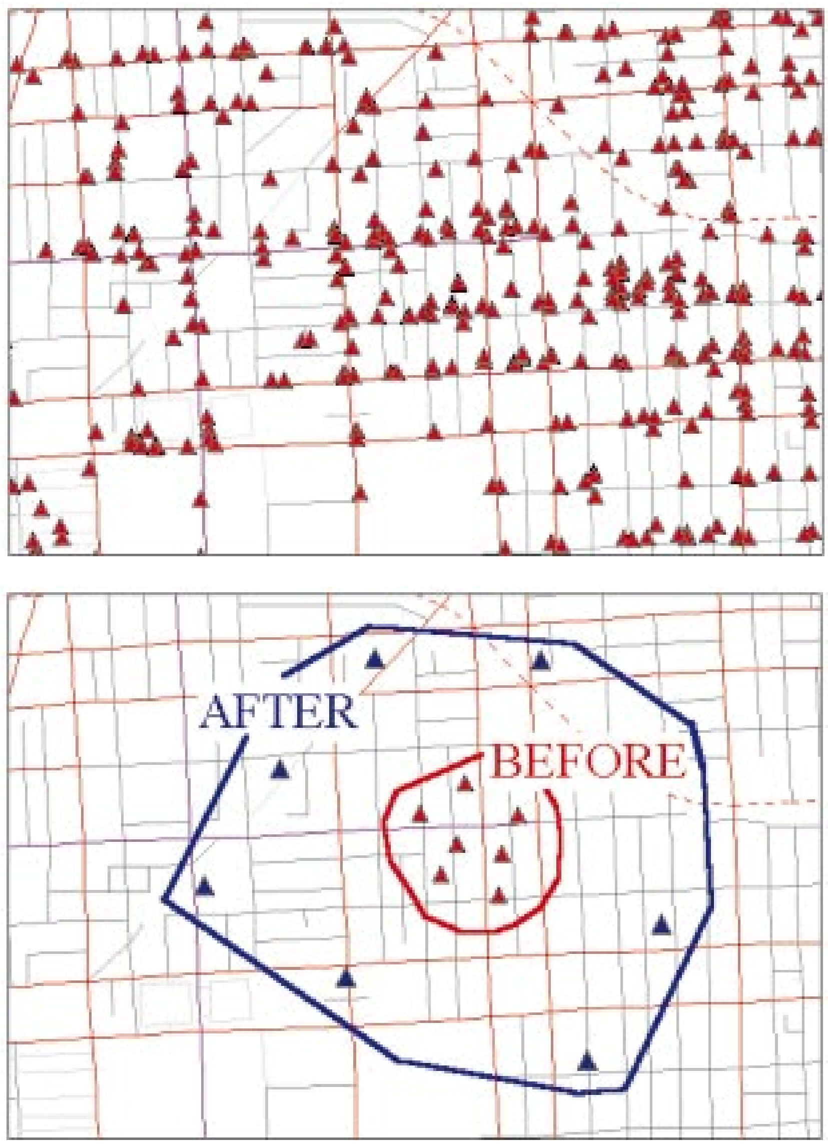



**Figure 3.9**

Maps illustrating displacement. The dense pattern in the top map makes it difficult to detect displacement. There is no such problem in the bottom map.

*Source: Keith Harries.*

little effect (particularly those that are more isolated and rural), major metropolitan areas with many immigrants have experienced profound social change.

It is in such places that community policing takes on special significance. Not only are "traditional" minorities (primarily African-Americans and Hispanics) voicing their opinions, but relatively new groups, such as Bosnians, Dominicans, Russians, Koreans, and Vietnamese, are becoming more visible and politically articulate. Matters are further complicated by the fact that a specific national group, such as the Vietnamese, may not necessarily constitute an ethnic group. Vietnam, for example, has 53 ethnic groups, leading to potential stresses along ethnic lines.

Each group's perceptions of what is legal or illegal may differ sharply from local norms. Opportunities for misunderstandings with law enforcement are rife, and community policing officers must understand the cultural values and practices of the groups they encounter. Language barriers mean:

- Citizen reports may be difficult or impossible to understand for officers who are unfamiliar with a language.
- Confusion and frustration over misunderstood reports may result in underreporting of crime because persons who assume they will not be understood may stop reporting crimes.
- It is unlikely that first-generation immigrants will become police officers.

What does this have to do with crime mapping? Because police agencies need to know what is going on demographically in their communities to react appropriately, mapping demographics and related factors may translate into better community relations. *The Washington Post* published the article "When Fighting Crime Isn't Enough: Fairfax, Montgomery [Counties] Seek Police Chiefs Adept at Community, Employee Relations" (Shear and Shaver, 1999). Surprisingly, perhaps, what was missing from the discussion about recruiting new chiefs was the crime issue. The debate was peppered with phrases such as "effective management," "comfortable with changing demographics," and "diversity." Traffic generated more interest than burglary!

A basic need is mapping where the minority and immigrant groups are located. Are they scattered throughout the community or clustered in distinct areas? What are their institutions and facilities (e.g., churches and temples, community centers, and schools)? What are the issues of concern to communities and what are their locational attributes? A map such as the one in figure 3.10 shows how census data can be used to locate ethnic groups and determine the overall degree of ethnic diversity. Based on 1990 census data, the figure illustrates the relative evenness in the proportion of five ethnic groups in census tracts. The index varies between 1.0 (equal numbers of all groups, maximum diversity) and 0.0 (only one group in the tract, minimum diversity). The ethnic diversity map could be viewed as a model for achieving the same ethnic distribution in the police departments serving various communities. A department does not match the community if it is less ethnically diverse than the area it serves.

Another possibility is to maintain a geographic inventory of minority and immigrant concerns so that managers can see what and where the issues are. Community leaders could be identified, perhaps by subareas of the larger ethnic community, to ensure that a contact person exists for each neighborhood. Mapping can also be used to show where second-generation minorities are reaching adulthood, enabling targeted police recruiting. The 2000 census will permit this type of analysis on the World Wide Web.

A major problem for demographic mapping is the lack of current population data. Until data from the 2000 census become available, alternative data sources are necessary. Analysts may have to improvise. Field mapping may need to be done and communities delineated on the basis of visual checks, perhaps with the aid of a global positioning system (GPS). Other possible data sources include those on school enrollments, utility hookups, and building permits and inspections. Although not yet fully operational, another promising resource is the American Community Survey (visit Web site *http://www.census.gov*).

### Management issue 5: Accountability and New York's ComStat process[1]

New York City's Computerized Statistics (ComStat) process was initiated in 1994 in the form of crime control strategy meetings. As a result of sharp declines in the city's crime, the system is now widely imitated. According to the police department, ComStat's objective is "to increase the flow of information between the agency's executives and the commanders

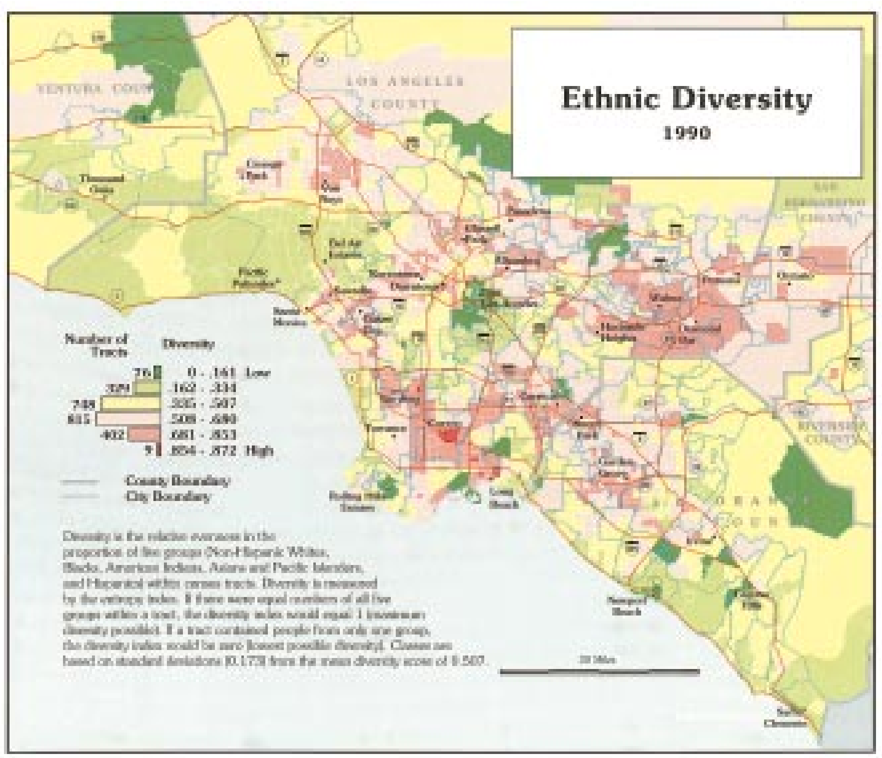



**Figure 3.10**

A map showing ethnic diversity in 1990, Los Angeles, California.

*Source: Allen and Turner, 1997. Reproduced by permission.*

of operational units, with particular emphasis on the flow of crime and quality-of-life enforcement information." Crime strategy meetings, held from 7 to10 a.m. twice a week, are part of an "interactive management strategy" intended to improve accountability "while providing local commanders with considerable discretion and the resources necessary to properly manage their commands." Precinct commanders present at the meetings twice a month.

The process format requires that precinct commanders appear before the ComStat meeting prepared to discuss crime and policing in their areas. A big-screen computer map shows the precinct under review. For example, a string of robberies with similar circumstances might lead to questions about known habits of robbery parolees living in the vicinity. As this conversation develops, a map showing relevant parolee addresses illustrates the discussion.

The crime reduction principles embodied in the ComStat process are:

- **Accurate and timely intelligence.** Information describing how and where crimes are committed, as well as who criminals are, must be available at all levels of policing.

- **Effective tactics.** Tactics are designed to respond directly to facts discovered during the intelligence gathering process. Tactics must be "comprehensive, flexible, and adaptable to the shifting crime trends we identify and monitor."

- **Rapid deployment of personnel and resources.** Some problems may involve only patrol personnel, but "the most effective plans require that personnel from several units and enforcement functions work together as a team."

- **Relentless followup and assessment.** To ensure that appropriate outcomes occur, rigorous followup is necessary.

Underpinning ComStat crime reduction efforts are eight explicit police strategies:

- Getting guns off the streets.

- Curbing youth violence in schools and on the streets.

- Driving drug dealers out of the city.

- Breaking the cycle of domestic violence.

- Reclaiming public spaces.

- Reducing automobile-related crime.

- Rooting out corruption and building organizational integrity in the New York City Police Department.

- Reclaiming the streets of New York.

How does crime mapping fit in? The police department explains it like this:

Among the command and control center's high-tech capabilities are computerized pin mapping and the capacity to display crime, arrest, and quality-of-life data in many formats, including comparative charts, graphs, and tables. By using MapInfo software and other computer technology, the ComStat database can be used to create a precinct map depicting almost any combination of crime and/or arrest locations, crime hot spots, and other relevant information. These visual presentations are a highly effective complement to the ComStat report, since they permit precinct commanders and executive staff members to instantly identify and explore trends, patterns, and possible solutions for crime and quality-of-life problems.

A problem often overlooked in other police departments—crime patterns that overlap precincts—is addressed through an expectation that precinct commanders cooperate with other commanders to address issues of mutual concern. Typical ComStat process maps are shown in figures 3.11–3.15.

## Maps in support of community oriented policing and problem oriented policing

Three broad categories of maps can be used in support of community oriented policing (COP) and problem oriented policing (POP)[2]:

- **Crime and offender information.** This includes information about the times, locations, and types of offenses, repeated offenses, methods of offenders, property taken, points of entry, linking evidence, types of vehicles

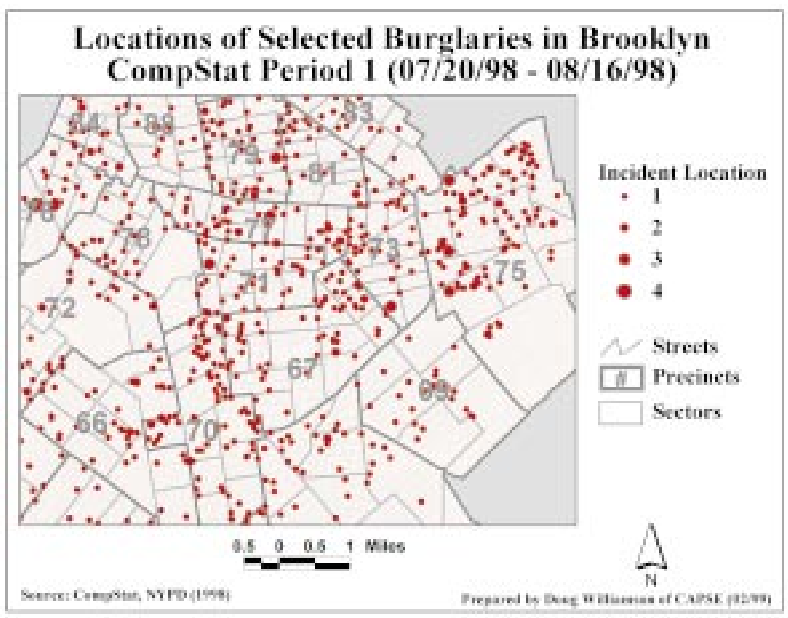



**Figure 3.11**

A CompStat map showing locations of selected burglaries in Brooklyn, New York.

*Source: D. Williamson, Center for Applied Studies of the Environment, Hunter College, New York, and New York City Police Department. Reproduced by permission.*

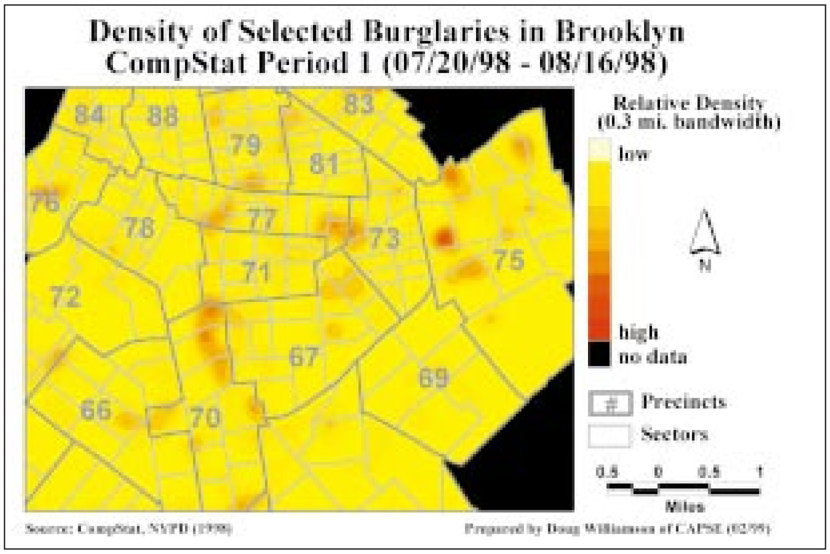



**Figure 3.12**

A CompStat map showing the density of selected burglaries in Brooklyn, New York.

*Source: D. Williamson, Center for Applied Studies of the Environment, Hunter College, New York, and New York City Police Department. Reproduced by permission.*

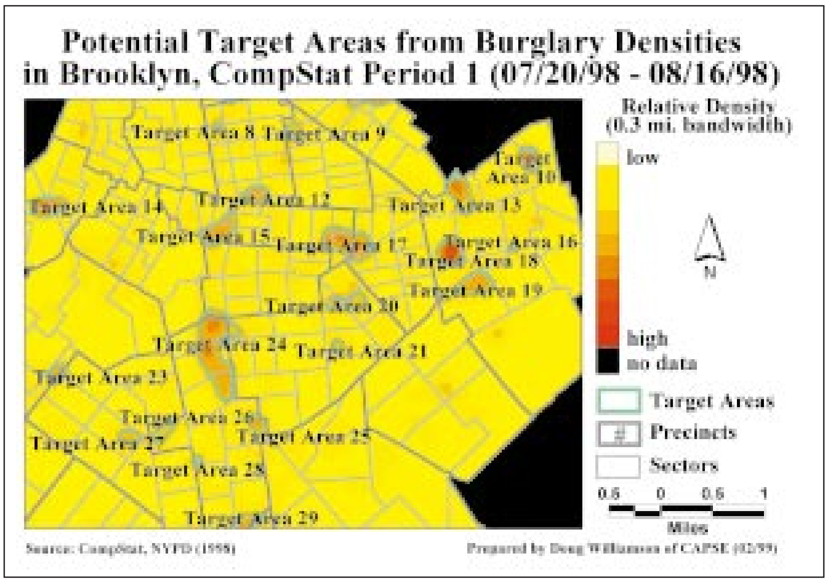



**Figure 3.13**

A CompStat map showing potential target areas from burglary densities in Brooklyn, New York.

*Source: D. Williamson, Center for Applied Studies of the Environment, Hunter College, New York, and New York City Police Department. Reproduced by permission.*

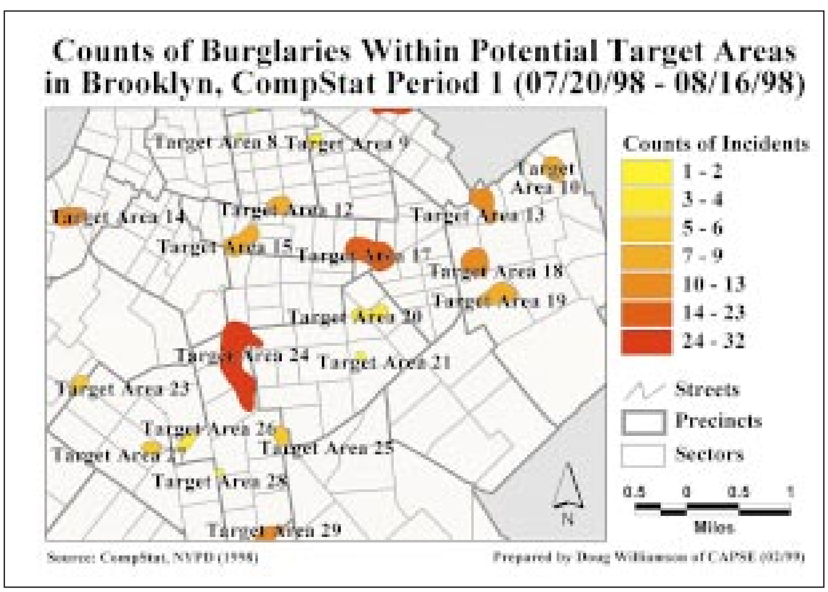



**Figure 3.14**

A CompStat map showing counts of burglaries within potential target areas in Brooklyn, New York.

*Source: D. Williamson, Center for Applied Studies of the Environment, Hunter College, New York, and New York City Police Department. Reproduced by permission.*

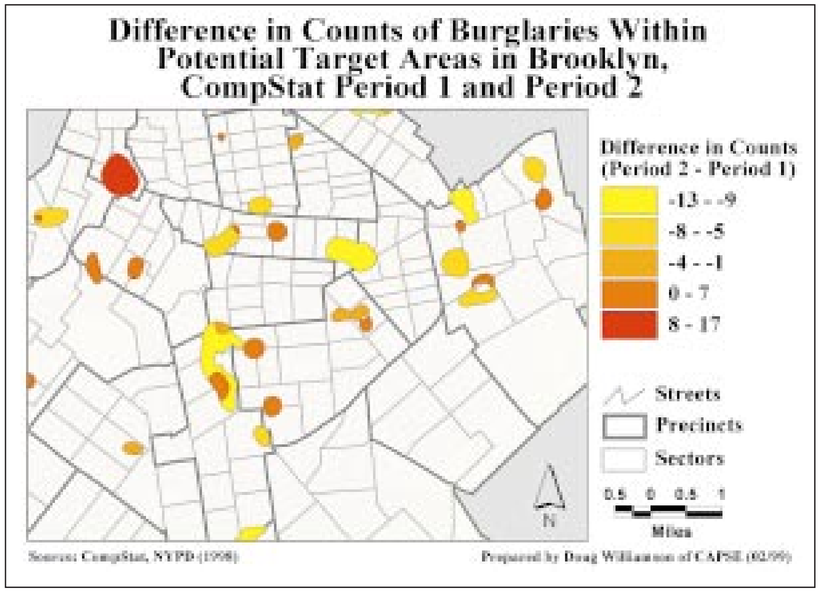



**Figure 3.15**

A CompStat map showing differences in counts of burglaries within potential target areas in Brooklyn, New York.

*Source: D. Williamson, Center for Applied Studies of the Environment, Hunter College, New York, and New York City Police Department. Reproduced by permission.*

used, and suspect information, such as personal appearance and case status, which is also an aspect of accountability (figure 3.16).

- **Community and government resources.** These include information about neighborhood watch groups, storefront stations (figure 3.17), parolees, probationers, tax assessment and zoning laws, owner occupancy, utility data, patrol beats, building footprints (planimetrics), alarm customers, alley lighting, playgrounds, walls as barriers, afterschool programs, high social stress areas such as low-income housing, liquor stores, and crime hot spots.

- **Demographics.** These include information about population change, ethnicity, race, socioeconomic status (SES), the percentage of female-headed households with children, the age of housing, and the school-age population.

Extremely broad-based geoarchives are very useful in COP and POP applications. Because it is impossible to predict what will be needed at any given moment, a reference-type archive is necessary. The ideal, noted in chapter 4, is an “enterprise” database that crosses departmental lines but remains accessible to all agencies.

In addition, there is need for versatility and flexibility in map preparation. For example, line maps of streets will probably need to be superimposed over aerial photos, which demands that their coordinate systems match (for more information, see chapter 4).

## Maps and community policing: The city of Redlands, California, approach

Under the leadership of Police Chief James R. Bueermann, the city of Redlands, California, has transformed its current means of addressing neighborhood quality of life by consolidating housing, recre-

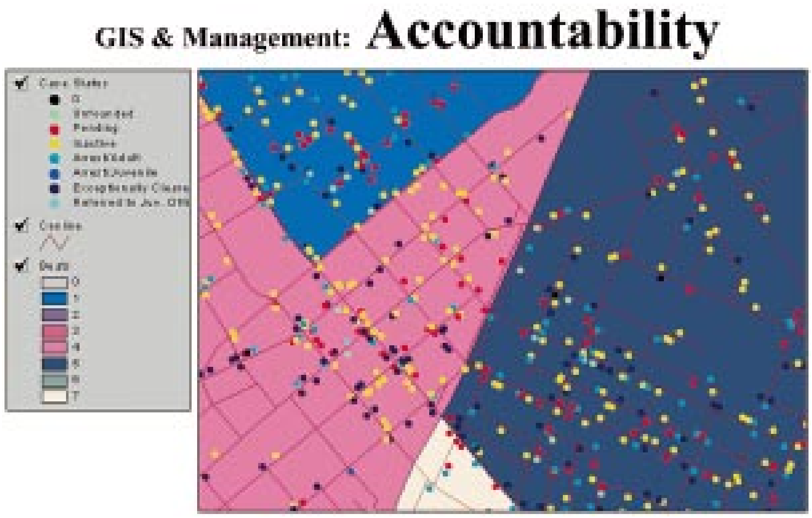



**Figure 3.16**

A case status map, Wilson, North Carolina.

*Source: Jeff Stith and Wilson, North Carolina, Police Department. Reproduced by permission.*

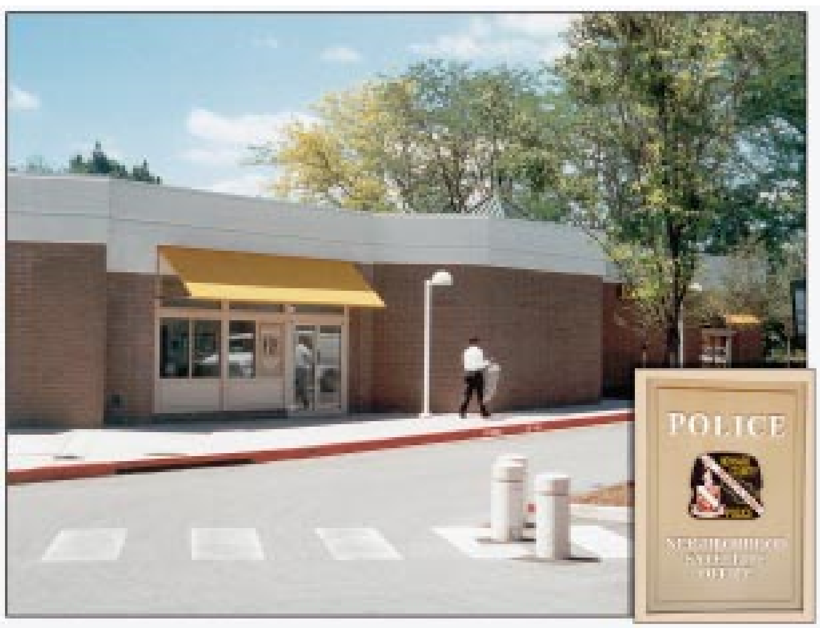



**Figure 3.17**

A photograph of a storefront police station, Long Reach Village Center, Columbia, Maryland. Geographic analysis can assist in the process of selecting an appropriate location for neighborhood facilities.

*Source: Keith Harries.*

ation, and senior services into the police department's Risk and Protective-Focused Prevention (RPFP) program—a problem-prevention model developed at the University of Washington. RPFP facilitates understanding of the causes and prevention of adolescent substance abuse, delinquency, violence, dropping out of school, and pregnancy. Further:

> By integrating the theoretical concepts of Risk Focused Policing with the cutting-edge technology of Geographic Information Systems (GIS), Redlands has been able to map community, family, and school and peer group risk and protective factors at the neighborhood level. This enables the police departments and the many community-based organizations that share access to this data to effectively focus their limited resources on the most problematic areas where the greatest

potential for change exists. [City of Redlands, 1999; see also Hawkins, 1995.]

The key is to mobilize collaborating institutions—schools, government, and community-based organizations—to reduce risk factors and foster “resilient youth.” The seven maps shown in figures 3.18–3.24 provide a sample of the kinds of maps prepared in support of risk focused policing in Redlands.

## Courts and corrections

As in other realms, law enforcement mapping can apply to any situation involving the display or analysis of spatial data. Courts and corrections are unusual in that many of their applications may involve large-scale representations of the type referred to as high-resolution geographic information systems and described in chapter 6. This type of display is also called forensic cartography in courtroom situations. Such large-scale maps are useful for illustrating the location of objects in relation to other objects in a building, a room, or a prison setting where incidents or gang activities have been problems.

Court and law enforcement mapping applications are in their infancy but will develop rapidly. A message on the crimemap listserv in 1999, for example, referred to GIS applications in the Wisconsin Department of Corrections. The message noted that four neighborhood offices had been selected for an enhanced supervision project and they routinely exchanged information with the Madison Police Department about where offenders were located. Other applications included using mapping to reduce the overlap of agents in a three-county region and for a graffiti eradication project (Koster, 1999). In

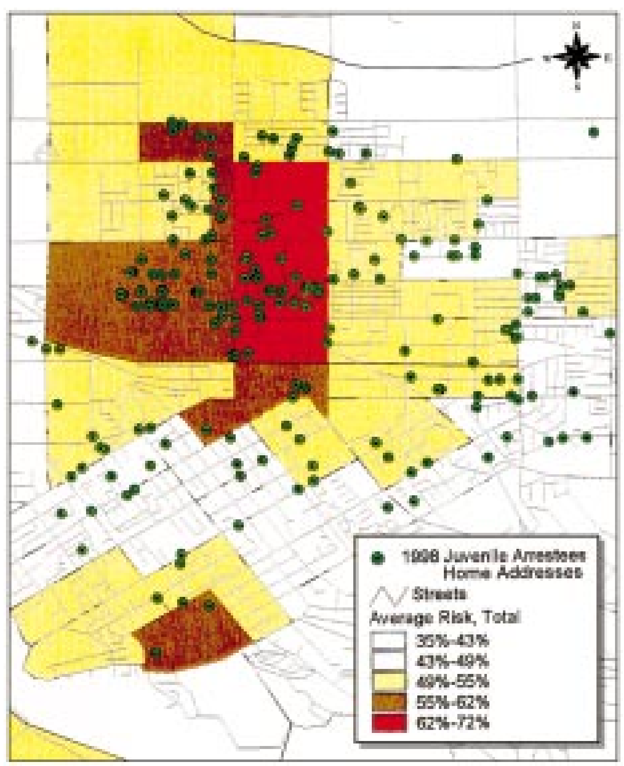



**Figure 3.18**

A juvenile arrestees' home addresses map superimposed on a total average risk map.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

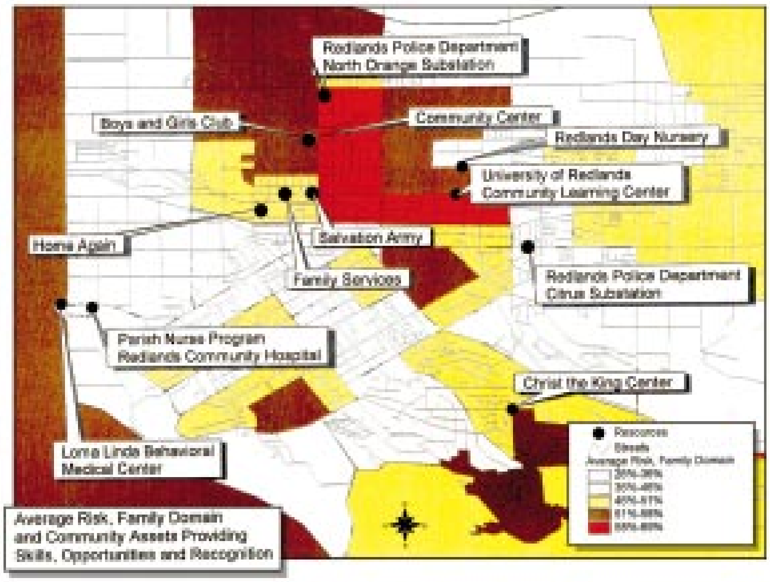



**Figure 3.19**

A map showing the average risk of family domain superimposed on a map of community assets providing skills, opportunities, and recognition.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

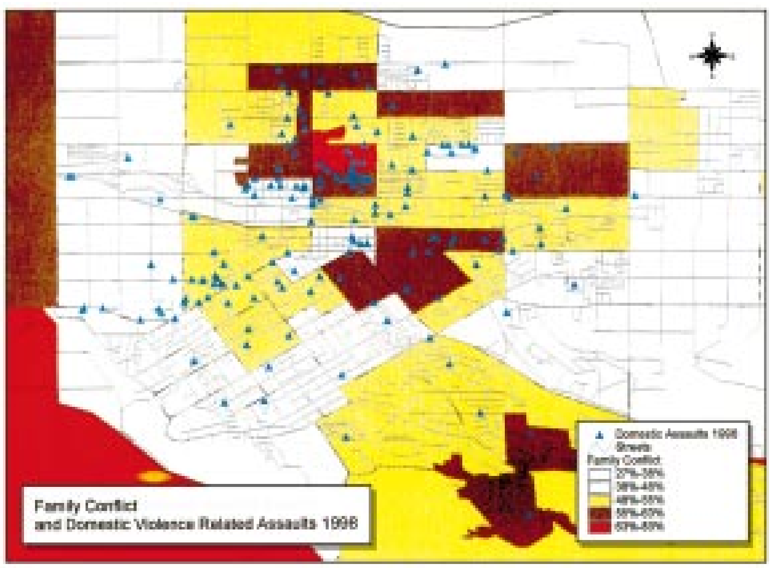



**Figure 3.20**

A domestic assaults map superimposed on a map showing the family conflict index.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

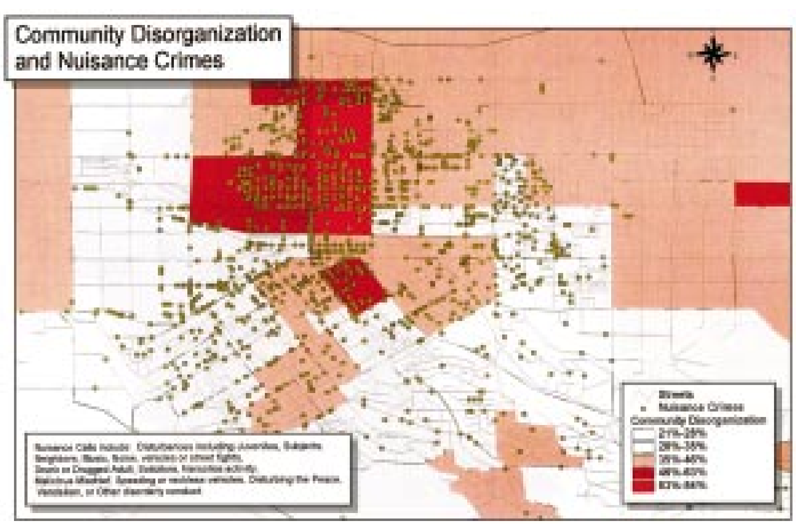



**Figure 3.21**

A nuisance crimes map superimposed on an index of community disorganization.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

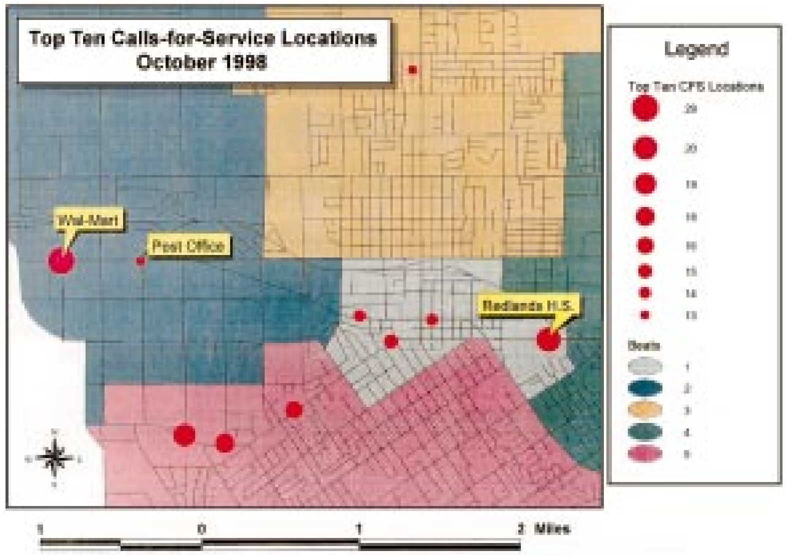



*Figure 3.22*

A map showing the location of the top 10 calls for service superimposed on a map of police beats.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

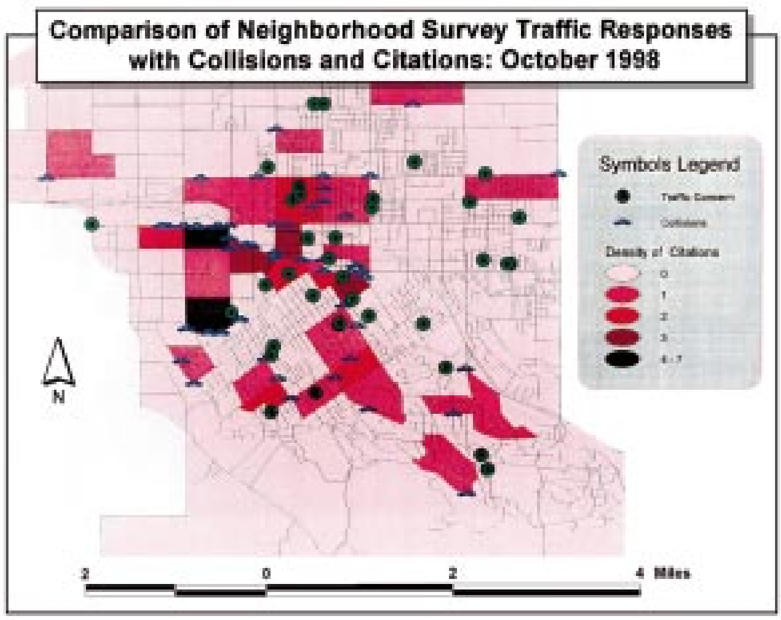



*Figure 3.23*

A comparison of neighborhood survey traffic responses with collisions and citations.

*Source: City of Redlands, California, 1999. Reproduced by permission.*


*Figure 3.24*

A map of where bats tested positive for rabies.

*Source: City of Redlands, California, 1999. Reproduced by permission.*

**To Massage or Not to Massage Data?**

*The risks of audience misunderstanding and confusion increase as you stray from raw data by, for example, calculating rates based on the population or other conditions. Saying more, better, has a tradeoff. Is it worth the price? You be the judge.*

addition to forensic and intrainstitutional investigative work, GIS has applications in resource allocation, offender tracking and monitoring, and facility location. Some of these are discussed in chapter 5.

## Policymakers: The medium and the message

A police department's in-house maps may take on a routine character, as the audience learns what to expect in map format and style. For an external audience, however, presentation needs to be handled differently. For example, how should data be massaged, if at all? Should data be presented as raw frequencies or in the form of a pin map, or should the numbers of incidents be converted into rates adjusted for population? Would other rates or ratios be more informative?

Ultimately, only the analysts and those doing the presenting can answer these questions. The analyst should put herself or himself in the position of the intended audience and ask specific questions. Are audience members likely to understand maps? Will they understand your maps? How can a point be communicated simply and directly? Is the map too complicated? Will this map serve its purpose?

These are extremely important considerations when addressing policymakers and community groups. Such groups are political by nature and will likely attempt to use information presented to them to their own advantage. When information is complex, the room for political maneuvering increases, and the underlying "truth" is more likely to become a casualty. This does not mean that sophisticated mapmaking is taboo. Rather, it suggests that external audiences may need to be educated about the types of maps they can expect to see and the pros and cons of each.

The need for education about map types is only one possible complication. In addition to being confused by different modes of data presentation, external audiences may have little or no appreciation for spatial analysis. This dictates simplicity, at least in the initial stages of using maps to publicly present crime data. Care must be taken to provide a consistent style and format, which includes the consistent use of scale. A minor problem may be perceived as worse than it is if it is presented in large type or vivid colors (figure 3.25).

As noted, another issue to be considered is management of the presentation. How will the map(s) be presented? Using hard copy? As a presentation? (If a presentation, will it use computer software, an overhead projector, slides, or what?) By fax? In a report? (If a report, will it be printed in color or monochrome?) As an e-mail attachment? As noted in chapter 2, each presentation mode requires different design considerations, including color and scale. The difference between what works in a fax presentation and what works in large-format, color hardcopy is extreme. The latter can accommodate detail and color; the former demands expression in plain, bold, and simple terms.

## Community organizations

Similar considerations apply to presentations aimed at community organizations. Again, the design and mode of presentation considerations need to be taken into account. For example, community maps could be produced for the following audiences and events:

- Neighborhood watch groups.

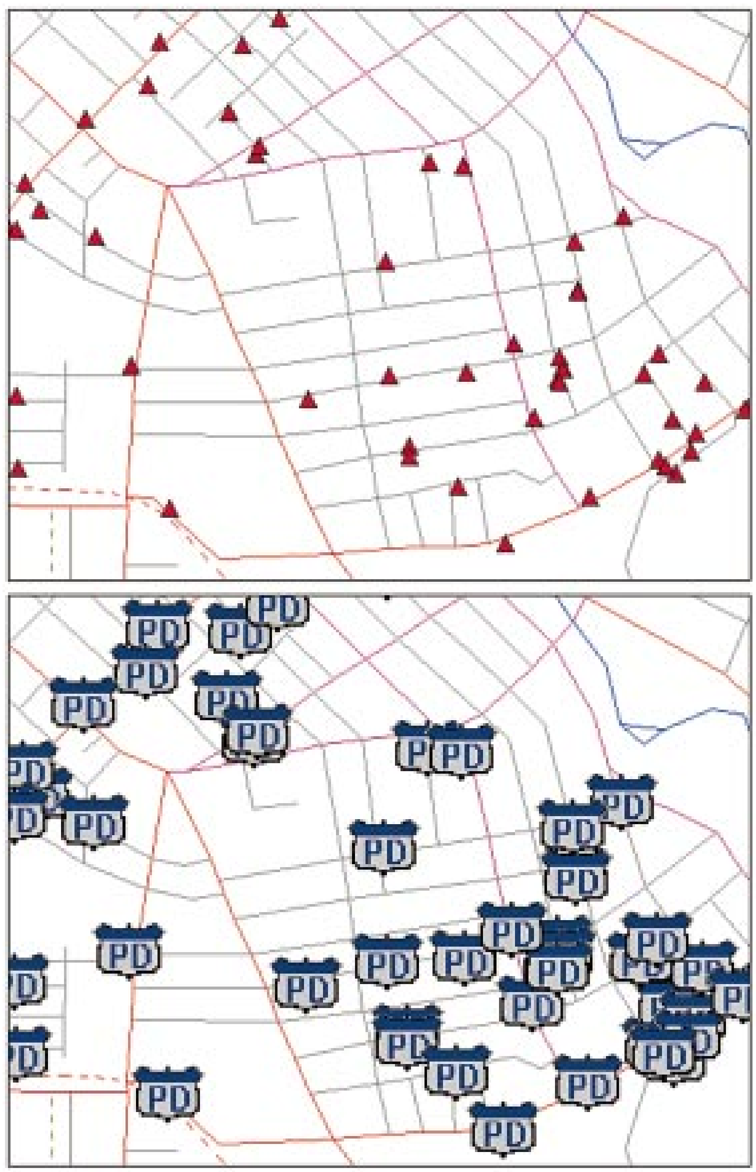


**Figure 3.25**

Two presentations of the same data that may lead to different perceptions, i.e., a "lesser" problem (top) or a "greater" problem (bottom).

*Source: Keith Harries.*

- Neighborhood patrol groups.
- Public meetings to address specific problems (reactive).
- Public presentations to promote goodwill between the police department and the community (proactive).

In each case, the nature of the audience influences map design, content, and use. For example, neighborhood watch and neighborhood patrol maps may be used in the field. Therefore, their design must be suited to less-than-ideal reading conditions. Public presentations should accommodate the audience's level of sophistication, which is often a reflection of their age and education. If complex street patterns or topography make the mapped area confusing, the analyst may use more icons on maps to "pictorialize" the maps. However, great care is needed to avoid patronizing audiences or giving the impression that the police department is putting something over on them by using complicated maps. Figure 3.26 shows a map of community resources that can be used as a basis for the formation of constructive alliances.

## Conclusion

If geographic information is useful in a law enforcement context, ways can often be found to present that information in a map. Geographic crime data alone are not enough to create a meaningful map, as they must be paired with a base map and other data to make the map interesting. Every day, however, the demand for "geographically enabled" data grows as businesses, governments, and organizations begin to appreciate the value of maps and spatial analyses.


**Figure 3.26**

Community organizations in Detroit mapped as part of an effort to reduce Devil's Night arson.

*Source: Martin, Barnes, and Britt, 1998. Reproduced by permission.*

## Summary

Chapter 3 has explained:

- How maps can be designed to address specific issues and the needs of special audiences, such as patrol officers, investigators, and police managers.
- How maps can be used in support of COP and POP.
- The importance of the medium and the message in communicating with policymakers.
- How maps can be used in courts and corrections.

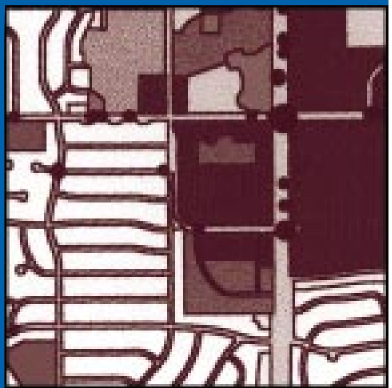
### What's Next in Chapter 4?

- *The role of GIS in crime mapping.*
- *How GIS is used in law enforcement agencies.*
- *How GIS affects what we can do and how we do it.*
- *Vector and raster formats.*
- *Geocoding.*
- *Filtering data.*
- *Measurement using maps.*
- *Constructing derivative measures.*
- *Hot spots.*
- *Buffering.*
- *How large databases can be used in mapping and analysis.*
- *Data warehousing and data mining.*
- *Factors demanding caution in the mapping process.*

## Notes

1. This section draws extensively on an Office of Management, Analysis and Planning (nd) document cited in the references; also see Dussault, 1999.

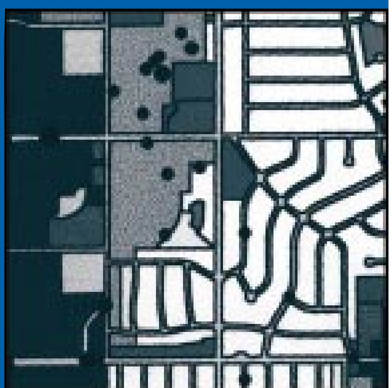
2. I am indebted to Sgt. Jeff Dean (San Diego, California, Police Department) and Dr. Richard Lumb (Director, Strategic Planning and Analysis, Charlotte-Mecklenburg, North Carolina, Police Department) for the elements contained in this list. Any misinterpretations are the author's.



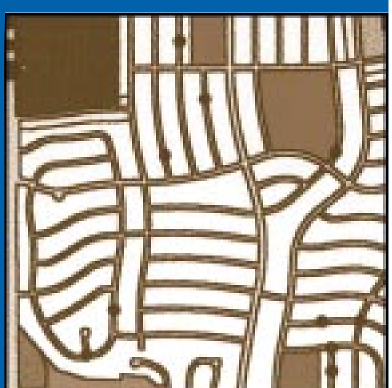
# Chapter 4:

## Mapping Crime and Geographic Information Systems

### The GIS revolution

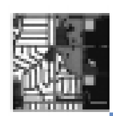


Although it is tempting to think of geographic information systems (GIS) as a thoroughly contemporary technology, its conceptual roots reach far back. A GIS is based on drawing different spatial distributions of data on paper (or other suitable media) and overlaying them on one another to find interrelated points. Foresman (1998) notes evidence that this model was used at the Angkor Wat temple complex (in today's Cambodia) in the 11th century. Modern geographic information systems can be linked to developments in the 1960s, including land use analysis in the United Kingdom by Coppock (1962), development of the Canadian GIS by Tomlinson (1967), and publication of McHarg's *Design with Nature* (1969).



Early GIS efforts were restricted by the limitations of older computer systems lacking memory and speed, such as the 512k memory of the IBM 360/65, a computer widely used in the 1960s and 1970s (Tomlinson, 1998). This limited the size of data sets and made it difficult to simultaneously manipulate multiple observations or large numbers of variables.

These constraints limited the attractiveness of GIS technology to law enforcement agencies. Weisburd and McEwen (1997) noted that police departments typically lacked the computer resources and the base



### What Is a GIS?

*A GIS is a computerized mapping system that permits information layering to produce detailed descriptions of conditions and analyses of relationships among variables.*

*Strictly speaking, any system that permits the representation and analysis of geographic information is a geographic information system. The acronym GIS is understood to refer to computer-based software, generally in the form of a few popular proprietary software packages. Although a prominent component of a GIS, proprietary software does not define a GIS.*

*Even the acronym "GIS" is the subject of debate, with some arguing that the "s" stands for "system(s)," while others object that this is too narrow, and the "s" should stand for "science."*

maps necessary to support a GIS operation. Labor, startup, and operational costs, such as coding incident addresses for the computer, were prohibitive, and the field lacked user-friendly software.

The earliest applications of crime mapping appeared in the mid-1960s, according to Weisburd and McEwen, who cited the work of Pauly, McEwen, and Finch (1967) and Carnaghi and McEwen (1970). Most early crime maps were produced using the SYMAP program developed at Harvard University. Input required punched cards, and output was produced on a line printer that limited detail to the size of the printer typeface. Shading of choropleth maps was accomplished by overstriking printer characters so that they darkened (figure 4.1). All maps produced this way were black and white. Line symbol mapping (of auto thefts, for example) was done on a plotter (figure 4.2). (See Weisburd and McEwen, 1997, for additional information.) Later, the SYMVU variant of SYMAP used line renditions on a plotter to produce three-dimensional visualizations, like that shown in figure 1.13. Pioneering work done in St. Louis by the police department involved the establishment of a Resource Allocation Research Unit with the objective of improving the efficiency of patrol operations. The unit recognized that fixed boundaries would have to be established for crime mapping purposes. This was done using so-called Pauly Areas, named for (then) Sgt. Glenn A. Pauly, who designated mapping areas similar in size to census block groups. Thomas McEwen then devised a system for geocoding by relating street segments to Pauly Areas. This was the first time in an operational setting that computerized visualization of crime data was recognized as a management tool.

GIS applications in policing took off in the late 1980s and early 1990s as desktop computing became cheaper and software

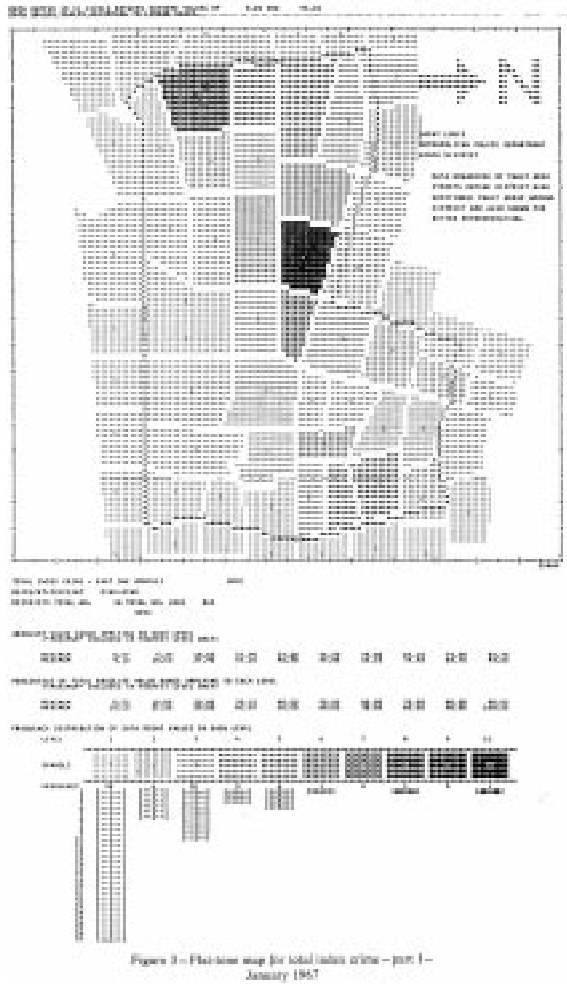



**Figure 4.1**

A "Flat-tone" map of total index crime, St. Louis—Part I—January 1967.

*Source: Pauly, McEwen, and Finch, 1967, p. 744. Reproduced by permission.*

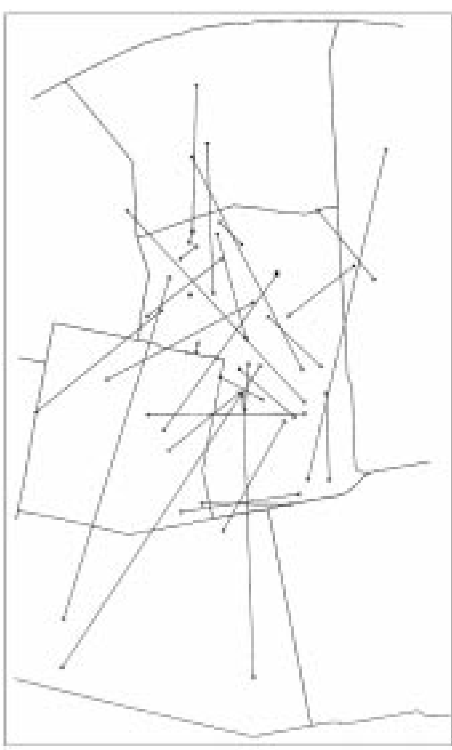


**Figure 4.2**

A map showing auto thefts in the Ninth District, St. Louis, January 1967.

*Source: Carnaghi and McEwen, 1970, p. 401. Reproduced by permission.*

became more accessible and user friendly. To date, large departments have been more likely to adopt the innovation; however, almost any police agency that wants a GIS can have one. Foresman (1998, figure 1.2, p.11) recognized five ages of GIS development.

The *Pioneer Age*, which lasted from the mid-1950s to the early 1970s, was characterized by primitive hardware and software. The *Research and Development Age* lasted into the 1980s and overlapped the *Implementation and Vendor Age*, which in turn lasted into the 1990s, when the *Client Applications Age* began. The *Local and Global Network Age* followed.

Crime mapping came of age in the Implementation and Vendor period, when computing costs began to fall and software became more immediately useful. Over the past decade we have also seen more examples of police departments commissioning customized versions of software to meet their individual needs.

A survey of police departments conducted in 1997–98 (Mamalian and La Vigne et al., 1999) showed that only 13 percent of 2,004 responding departments used computer mapping. Slightly more than one-third of large departments (those with more than 100 officers) did so, but only 3 percent of small units did. On average, departments had used computer mapping for 3.3 years. Crime analysts were the primary users of mapping, with relatively few patrol officers involved. The types of data most likely to be mapped were:

- Arrests and incidents, including Uniform Crime Reports Parts I and II crimes.
- Calls for service.
- Vehicle recoveries.

The most frequent applications were:

- Automated pin mapping (point data).
- Cluster or hot spot analysis.
- Archiving data.

## The GIS perspective

### Software

Other information gleaned from the computer mapping survey showed that 88 percent of respondents used off-the-shelf GIS software, such as MapInfo® (about 50 percent), ArcView® (about 40 percent), ArcInfo® (about 20 percent), and others (about 25 percent). Some departments used more than one package. Approximately 38 percent of departments that used mapping had done some kind of customizing, and 16 percent were using global positioning system (GPS) technology.

It would be expected that GIS computer mapping would follow the classic bell curve of innovation adoption (figure 4.3). In the lower left are the early adopters, followed by the early majority, the late majority, and the laggards. A wider bell means a longer process, or greater reluctance to adopt. GIS adoption will likely be a rapid process because the technology is simultaneously becoming cheaper and more powerful.

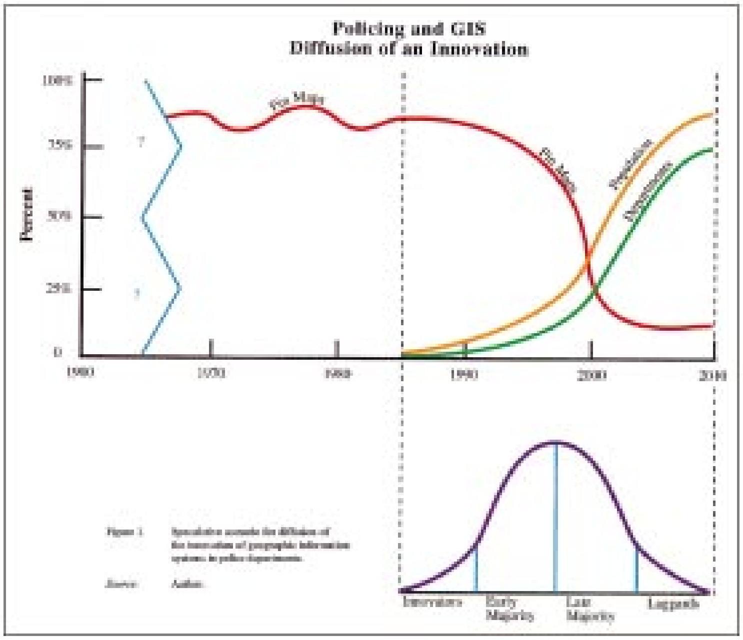



**Figure 4.3**

Hypothetical bell curves for GIS adoption in police departments.

*Source: Keith Harries.*

## Vector? Raster? Say what?

You will probably hear the terms *vector* and *raster* in mapping conversations. How much do you need to know about them? Enough to understand the jargon and enough to make informed choices about formats.

Raster maps store data in the form of a matrix, or grid. A raster map represents information by assigning each pixel, or picture element, a data value and shading it accordingly. The size of a raster data matrix can be determined by multiplying the number of rows by the number of columns in the display. For example, if the display settings on the computer read 640 by 480 pixels, the matrix has a total of 307,200 pixels—each of which would have a data value on a raster-based map.

Vector-based maps are built from digitized points that may be joined to form lines, or vectors, and polygons, or closed shapes. (Digitizing means recording the exact coordinates of each point along x-y axes.) You will sometimes see the term topology used in connection with vector format, and this refers to the study of geometric forms. This type of analysis is integral to GIS but is largely transparent to users.

Each format has advantages and draw-backs. For example, lines in raster dis-plays may appear jagged if resolution is not high enough. Rescanning an image at a finer resolution greatly increases file size. For example, if the 640- by 480-pixel screen is doubled to 1,280 by 960 pixels, the number of pixels increases four times from 307,200 to 1,228,800 pixels. However, raster processing is quicker.

Vector files are good at showing lines but are labor intensive due to the need to clean and edit vector data (Faust, 1998). Applications that use the vector format include emergency personnel routing and determining whether a suspect could have traveled a particular route in a given amount of time. Most databases in urban areas use vector format; examples include street centerlines, precinct boundaries, and census geography. Vector files are not very good for managing continuous distributions, such as temperature or land elevation.

Although crime is not continuously distributed (crimes occur at separate points in geographic space), we can estimate values between known points to construct a continuous surface representation. The triangulated irregular network (TIN) data structure is one frequently used way of doing this. In it, points are connected to form triangles, the attributes of which become the basis for surface construction.

Summing up raster-vector differences, Clarke (1997) cited Bosworth's analogy about the work of composers Mozart and Beethoven. Raster is Mozart (dainty little steps), and vector is Beethoven (big jumps from place to place). Another way of characterizing the difference is to say, "vector systems produce pretty maps, while raster systems are more amenable to geostatistical analysis" (LeBeau, 1995). However, an alternative view argues that whether a vector or raster format is most useful depends on the type of analysis and what it will be used for. For example, crime densities are often calculated using the raster format, even when the point data for crime locations are in vector format. The vector data simply will be converted to the raster format.

It bears repeating that the analyst should know what format is used, why it is used, and the limitations and possibilities of each. A frequently encountered problem involves conversion to another format. Conversion from vector to raster is the simplest. Going from raster to vector, however, means that each line must be converted on a pixel-by-pixel basis and a vector equivalent produced. This is much more time consuming than vector to raster. Users may also convert from one software system to the other (Clarke, 1997).

Because photographic and satellite images are raster products, there is no choice between formats unless conversion is undertaken. As imagery of both types is used more frequently in crime mapping, we will see mixing of vector and raster technologies. For example, a large-scale aerial photo (raster) might be used as an underlay for point crime data (vector) and patrol area line files (vector). In most cases, the crime analyst will not be aware that different data formats are being used because the importation and manipulation will be seamless (figure 4.4). Although photos and satellite images are in raster format, they can be used to digitize data into vector format. Specific features on an aerial photo, such as the footprints of buildings or physical barriers between neighborhoods, are linear features amenable to vector representation. Aerial photos are often the source of other important base data, such as street centerlines, with data being digitally traced from the photo into a vector system.

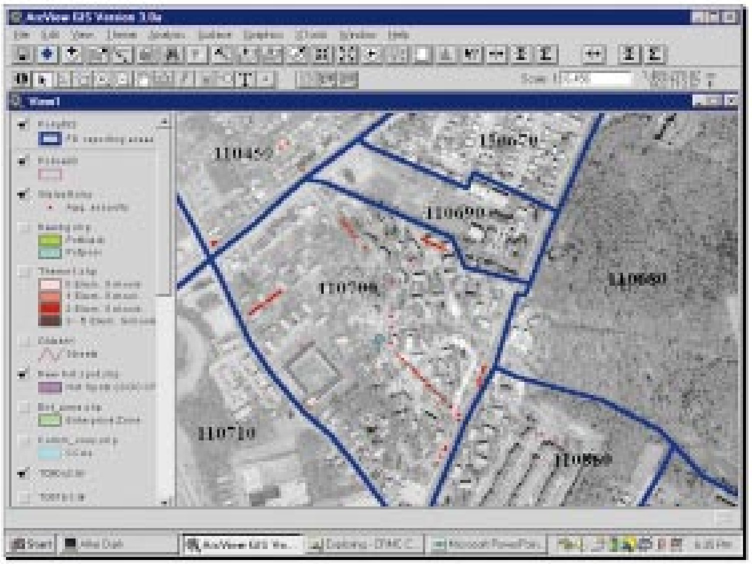


*Figure 4.4*

A map showing a vector format superimposed over a raster format. ArcView®, Baltimore County, Maryland. The heavy blue lines are police reporting areas (vector), triangles are aggravated assaults (vector), and the underlay is orthophotography (raster).

*Sources: Reporting area polygons and assault data: Baltimore County Police Department. Orthophotography: Baltimore County, Maryland, GIS Unit, March 1995, pixel size: 1 inch, compilation scale 1 inch=200 feet. Reproduced by permission.*

## Spatially enabling the data: What is geocoding?

If we break the word *geocoding* into its components, it means coding the Earth—providing geographic reference information that can be used for computer mapping. The history of geocoding is tied to efforts at the U.S. Census Bureau to find ways of mapping data gathered across the country, address by address. In the 1960 Census of Population and Housing, questionnaires were mailed to respondents and picked up from each household by enumerators. In 1970, the plan was to use the mail for both sending and returning surveys—hence references to that census as mail out/mail back. This demanded geocoding capability and, subsequently, the development of an address coding guide (ACG). According to Cooke (1998), the Data Access and Use Labs created to accomplish this were responsible for creating today's demographic analysis industry.

The first geocoding efforts permitted only street addresses to be digitized (admatch), but the capability to show blocks and census tracts was soon added. This demanded that block faces be recognized, and this was done by digitizing the nodes representing intersections. This, in turn, meant that intersections had to be numbered and address ranges had to be reconciled to the correct block faces. The shape of the lines on the map had to be precisely determined and annotated, creating the map's topology. The name given to this new block mapping process was *dual independent map encoding* (DIME) and, when combined with the address matching process, it was referred to as ACG/DIME. By 1980, ACG/DIME had become *geographic base file* (GBF)/DIME. This was followed by a call for a nationwide, seamless, digital map, to be called TIGER, short for topologically integrated geographic encoding and referencing. Census Bureau geographer Robert Marx and his team implemented TIGER for the 1990 Census (Cooke, 1998; Marx, 1986).

TIGER files contain address ranges rather than individual addresses. An address range refers to the first and last possible structure numbers along a block face, even though the physical structures may not exist (figure 4.5). For each chain of addresses between the start node and end node, there are two address ranges, one for odd numbers on the left, the other for even numbers on the right. For a complete explanation, see U.S. Census Bureau (1997).

Geocoding is vitally important for crime mapping since it is the most commonly used way of getting crime or crime-related data into a GIS. Crime records almost always have street addresses or other locational attributes, and this information enables the link between the database and the map.

How does the computer map in a GIS know where the data points should be put? It reads the x-y coordinates representing their locations. When crime locations are geocoded, the address is represented by x-y coordinates, usually either in latitude and longitude decimal degrees or in State-plane x-y coordinates identified by feet or meter measurements from a specific origin. The big headache in working with address data is that those data are often ambiguous and may be erroneously entered in field settings. Common field errors include:

- Giving a street the wrong directional identifier, such as using east instead of west or north instead of south.
- Giving a street the wrong suffix or street type (e.g., "avenue" instead of "boulevard"); providing no suffix when there should be one.
- Using an abbreviation the streets database may not recognize (e.g., St., Ave., Av., or Blvd.).
- Misspelling the street name.
- Providing an out-of-range, or impossible, address. For example, a street is numbered 100 to 30000, but an extra zero is added, accidentally producing the out-of-range number 300000.
- Omitting the address altogether.

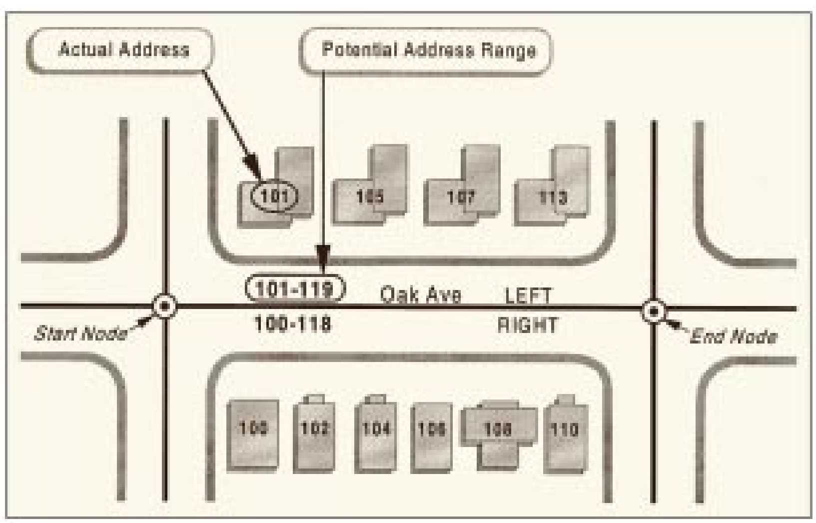



**Figure 4.5**

A map showing TIGER/Line® address range basics.

*Source: U.S. Census Bureau, 1997, figure 3–1, pp. 3–9.*

As you initially attempt automatic geocoding, street addresses are compared against the existing street file database, and coordinates are assigned to the "hits." This process is sometimes called *batch matching*. The process is a one-time affair, done automatically. Then, it becomes necessary to deal with the "misses," those addresses that did not geocode automatically.

Handling misses is done manually. The bad address is displayed with the closest possible matches the database includes. Analysts use these options to select the most likely match. This involves some guesswork and risks geocoding errors. For example, if the address entered is 6256 Pershing Street, and the only reference to Pershing in the database is to Pershing Avenue, then assigning the geocode to "avenue" is not likely to be an error. On the other hand, if the database also contains Pershing Boulevard, Pershing Circle, and other Pershing suffixes, assigning "avenue" could be wrong. This shows how important it is to have standards for entering addresses into a file, whether the system deals with records or computer-assisted dispatching (CAD).

Not all records in large data sets are likely to be successfully geocoded. The title of a section in a chapter in the *MapInfo Professional User's Guide* (MapInfo Corporation, 1995), "Troubleshooting: Approaching the 100% Hit Rate," hints at this. Some records may not be salvageable for a variety of reasons, including ambiguity in an address that cannot be resolved. Two other issues deserve mention, as well. One is that street addresses are estimated along block faces and may not represent true block face locations. (For more on this, consult technical documentation.) Second, address matching can be done for locations other than street addresses, such as street centerlines, land parcels, or buildings, depending on the availability of each element in a spatially enabled format.

Surprisingly, there is no minimum standard for geocoding. Maps can be produced and distributed based on a 25-percent *hit rate*. Readers may have no idea that a map represents only a small fraction of all cases. Worse, the missing cases may not be randomly distributed, thus possibly concealing a critical part of the database. For example, in the geocoding process, a person or persons may be inept or may decide to distort the data. If this error originates in the field, it will probably have a geographic bias based on the location of the person making errors. Analysts may consider reporting the hit rate for geocoding to better inform map readers.

Although most map users may not understand the hit rate, a technical footnote reading, "X percent of cases were omitted due to technical problems, but, the police department considers the pattern shown to be representative of the total cases under consideration," may clarify the information. (Seek legal advice for actual wording.)

Given that there is no minimum standard, the issue becomes: What hit rate is acceptable? This is a subjective decision, but a 60-percent hit rate is unacceptable and may lead to false assumptions. Hit rates this low should raise questions about a crime analysis unit's level of readiness because low hit rates indicate that the base maps in use and/or incoming data are seriously deficient.

A distinction needs to be made between the hit rate and another geocoding measure, the *match score*. The latter is a score derived from matches on each component of the address. If all components of an address are correct—street name, direction, street type—the address will receive a perfect score. Missing or incorrect parts reduce the score. This differs from the hit rate, which is the percentage of all addresses that are capable of being geocoded in either batch or manual mode. Therefore, the hit rate and match score can be used to set acceptable geocoding standards. However, setting the acceptable threshold of either rate too high or too low may result in too few records making the cut or, in the worst case scenario, incidents being given wrong addresses, thus placing crimes on the map where they did not happen.

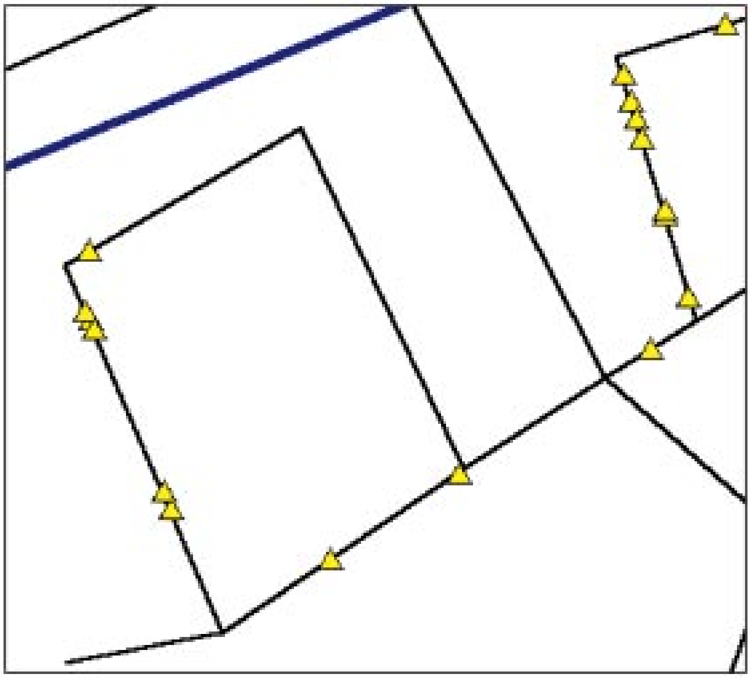
Like some other aspects of computer mapping, geocoding can be quite involved and demand considerable practice and expertise before you can regard yourself as an expert. The technical procedures used to fix geocoding problems are beyond this document's scope. Readers are referred to the user's guides, online help, and reference guides that accompany software or that are available on a proprietary basis. Asking more experienced GIS users for advice, perhaps in other departments of local government (management information systems, planning, engineering, and so forth), is another possibility. For additional information, see Block (1995).

## Data selecting, filtering, and mapping according to useful criteria

The great power of GIS lies in its analytical capability, in addition to its capacity to quickly create maps of large, complex data sets. This analytical power takes more forms than can be described here, but a few examples offer the reader the general idea. (For an excellent overview, see McEwen and Taxman, 1995.) Since procedures vary according to the GIS software used, we offer a broad sketch of some possible analytical approaches. Specific details can be found in user's guides, reference manuals, tutorials, and listservs such as *crimemap@aspensys.com*, where many analysts pose questions and get useful answers on a variety of crime mapping topics, including how-to GIS questions.

## Selecting and displaying specific information

Perhaps the most basic analytical task in using geographic information systems is the process of selecting and displaying scientific information. As shown in figure 4.6, when objects, in this case aggravated assault cases, are selected or "highlighted" on the map with the select tool, their corresponding database records are highlighted in color or with a symbol located next to the record. If the analyst wants to bring together the selected records at the top of the table for easier recognition and manipulation, they can be "promoted" (in ArcView, for example) using the appropriate button.



Attributes of Stplaslt.shp

| Beat | Ucr_code | Date_rptd | Date_occrd | Time_occrd | Dis | Vic_cn | Veh_cn | Rd |
|---|---|---|---|---|---|---|---|---|
| 0570 | 0450 | 19961210 | 19961210 | 2043 | 20 | 1 | 0 | 2 |
| 0570 | 0450 | 19961207 | 19961207 | 0140 | 10 | 1 | 0 | |
| 0570 | 0450 | 19961207 | 19961207 | 0140 | 10 | 1 | 0 | |
| 0570 | 0450 | 19961207 | 19961207 | 0140 | 10 | 1 | 0 | 1 |
| 0570 | 0420 | 19961206 | 19961206 | 1455 | 20 | 1 | 1 | 1 |
| 0570 | 0450 | 19961204 | 19961204 | 1924 | 20 | 2 | 0 | 1 |
| 0570 | 0450 | 19961122 | 19961122 | 1400 | 30 | 1 | 0 | |
| 0570 | 0450 | 19961115 | 19961115 | 1730 | 20 | 1 | 0 | 3 |
| 0570 | 0430 | 19961107 | 19961107 | 1730 | 20 | 1 | 0 | 1 |
| 0570 | 0450 | 19961107 | 19961107 | 1730 | 20 | 1 | 0 | 1 |
| 0570 | 0450 | 19961103 | 19961103 | 1135 | 20 | 2 | 0 | 1 |
| 0570 | 0450 | 19961031 | 19961028 | 0220 | 20 | 1 | 0 | 3 |
| 0570 | 0450 | 19961027 | 19961027 | 1545 | 30 | 2 | 0 | |
| 0570 | 0410 | 19961005 | 19961005 | 1822 | 10 | 1 | 0 | |
| 0570 | 0450 | 19960924 | 19960924 | 1602 | 10 | 2 | 0 | |
| 0570 | 0450 | 19960910 | 19960910 | 1215 | 10 | 1 | 0 | 1 |
| 0570 | 0450 | 19960828 | 19960828 | 1540 | 60 | 1 | 0 | |

**Figure 4.6**

A map and table frames from ArcView® showing the relationship between objects selected on the map and their highlighted records in the table.

*Source: Keith Harries.*

## Mapping time

A more sophisticated process for selecting information uses various criteria and is referred to as "filtering" or "querying." Sometimes, you will see Structured Query Language (SQL), which is a specialized programming tool for asking questions of databases. If the conditions you set are satisfied, then certain cases are included or retained in a new data set, as a subset of the main data. The new file can then be saved, mapped, or manipulated in any way. For example, the condition "Time is greater than or equal to 1500 hours and time is less than or equal to 2300 hours" (written in computerese as *time>=1500 & time <=2300*) would select all cases in the 8-hour shift between 3 and 11 p.m.

Many variations are possible on the "mapping time" theme. In figure 4.7, maps of domestic disputes in Charlotte-Mecklenburg, North Carolina, show change over a decade. The units of analysis were the central points, or *centroids* (see the section "Centroid display" later in this chapter) of 537 response areas. Idrisi software (see appendix) was used to generate the two surfaces based on the square roots[1] of the data values for each response area, resulting in a clear picture of substantial growth over the time period. In 1984, domestic disputes occurred mainly in the north and west, as shown in green. By 1993, calls had increased in number and geographic coverage, particularly on the east side and in the southwest.

Time geography is viewed through a different lens as shown in figure 4.8. Using methods similar to those used to produce figure 4.7, seven daily maps were constructed, followed by an eighth map to denote the day of the week with the highest frequency of calls for each of the 537 response areas. Maps such as those in figures 4.7 and 4.8 could be used to allocate resources and to coordinate domestic violence prevention efforts.

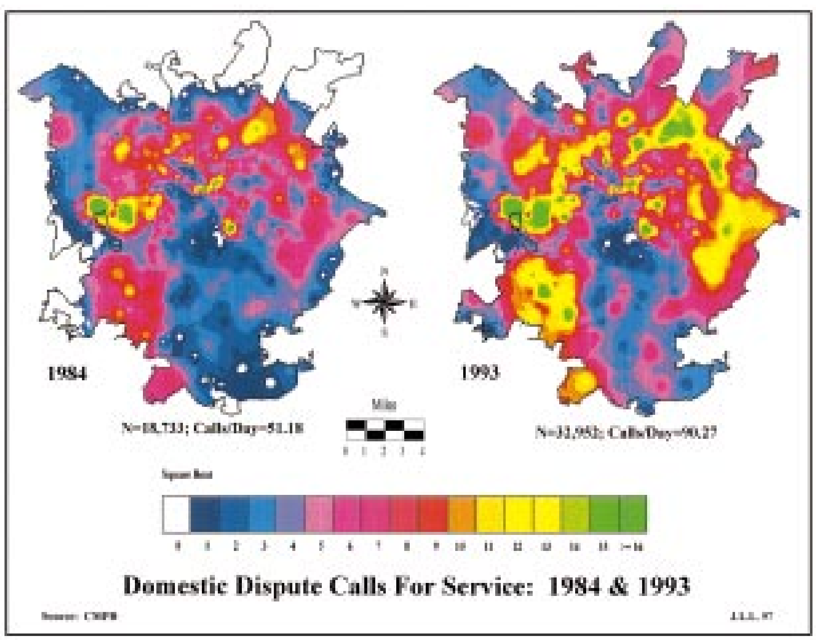
## Mapping space

Because crimes usually affect some neighborhoods more than others, maps may focus on certain beats, posts, patrol areas, communities, census tracts, neighborhoods, or other units. What is the geography of crimes in terms of council districts? Could this information be used by the police department to anticipate political firestorms? Attention may not be confined to such official areas, but may involve informal or ad hoc areas, such as a 500-yard radius around a drug market, bus stop, or automatic teller machine, for temporary investigative purposes. Provided that the boundary files for the official areas are in the computer, queries can be addressed to them. For example, you could compute the rate of vandalism incidents per 1,000 housing units, per unit of

**Figure 4.7**

Maps showing domestic dispute calls for service, 1984 and 1993, Charlotte-Mecklenburg, North Carolina.

*Source: Map by J. LeBeau, Southern Illinois University, with data from the Charlotte-Mecklenburg, North Carolina, Police Department. Reproduced by permission.*



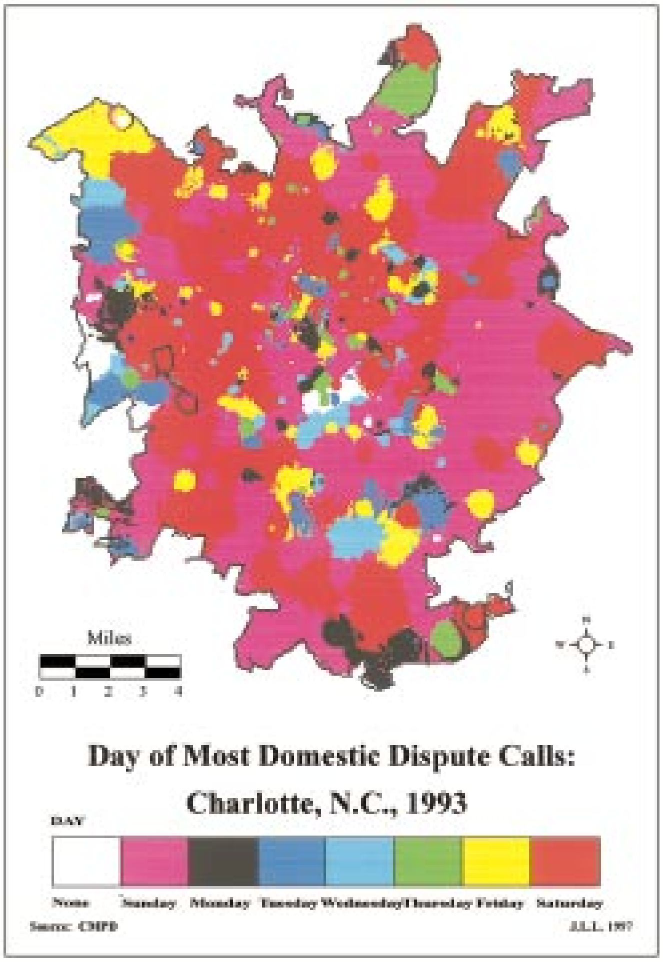



*Figure 4.8*

A map showing the day of the week with the most domestic dispute calls for service, Charlotte-Mecklenburg, North Carolina, 1993.

*Source: Map by J. LeBeau, Southern Illinois University, with data from the Charlotte-Mecklenburg, North Carolina, Police Department. Reproduced by permission.*

the general population, or per unit of the male youth population. A few alternative base maps are shown in figure 4.9.

## Mapping incident types and modus operandi

Conditions, or filters, can be used to refine searches at any level the analyst chooses. For example, the most obvious filter would isolate all crimes of a specific type. However, filtering can isolate crimes by time of day, by neighborhood, and by modus operandi (MO). Conditions can be set to specify all the desired criteria, possibly resulting in the isolation of a cluster of incidents that could be linked to the same perpetrator. In figure 4.10, for example, rape has been selected. These incidents are shown without identifying victims by using a large symbol to make the location of each somewhat vague. The analyst must trade some precision to accommodate the overriding need to protect victims.

## Mapping attributes of victims and suspects

Mapping by characteristics of victims, suspects, or both can also be useful and is easily accomplished. For example, where have females been assaulted? Is there evidence that a cluster of burglaries has occurred at homes occupied by elderly persons?

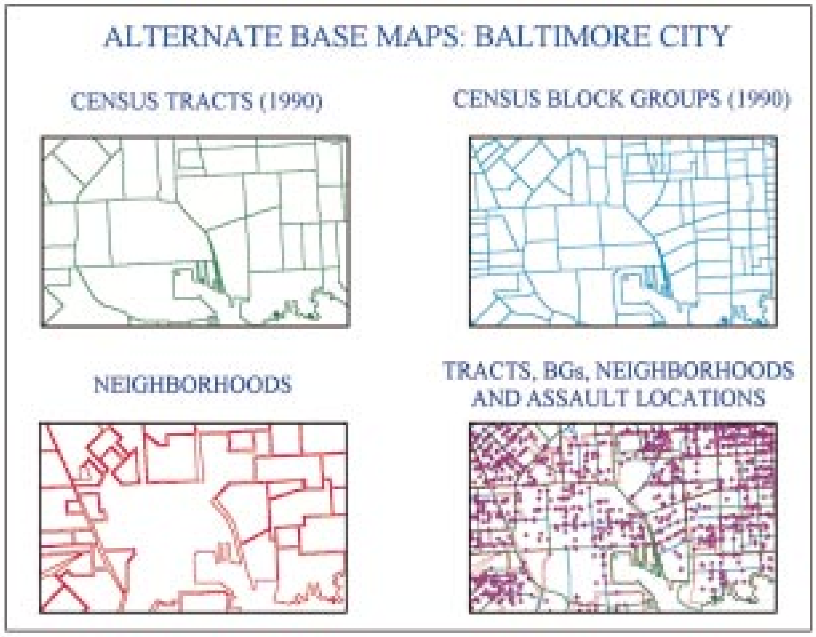



**Figure 4.9**

Some alternate base maps for use in crime mapping.

*Source: Keith Harries.*

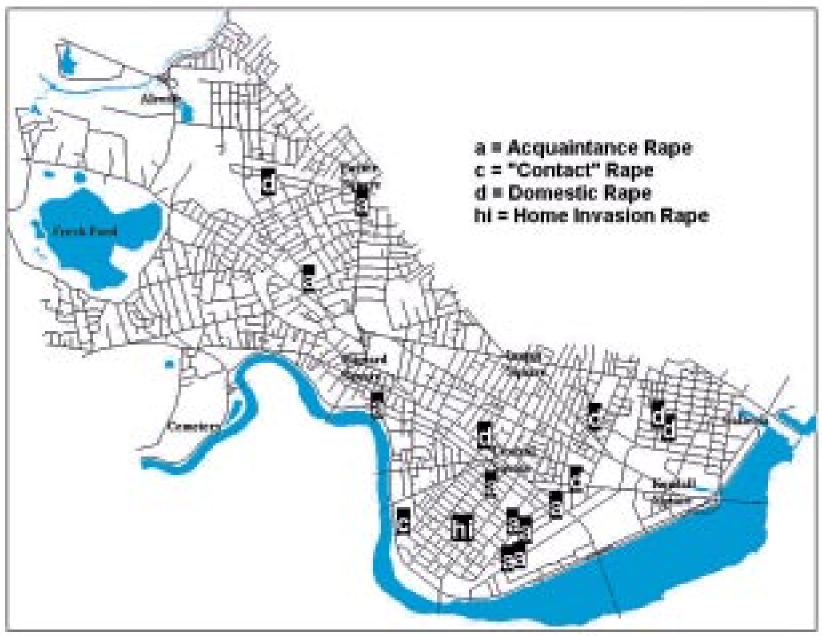



**Figure 4.10**

A map showing the distribution of rape in the city of Cambridge, Massachusetts. Large symbols were used to avoid presenting the specific locations of the victims.

*Source: Cambridge, Massachusetts, Police Department. Reproduced by permission.*

## Mapping other recorded characteristics

Possibilities for filtering are unlimited. You can set as many time, space, victim, suspect, MO, or other filters as you wish, given data availability. For example, where are the armed robberies occurring? What is the pattern of robberies at gunpoint within a 1-mile radius of drug markets? Where are juvenile offenders victimizing elderly persons at gunpoint during hours of darkness? Are spousal assaults randomly distributed, or are they clustered?

The only limitation is the availability of geocoded or geocodable information in the database. A potentially useful map might reflect the relationship between persons on probation or parole and the types of crimes they have committed. For example, a rash of robberies occurs in a neighborhood: Where are the robbery probationers and parolees in that area? Do the MOs match up?

## Using GIS to measure from maps: Aggregating data

Why measure? In the most general sense, measurement is the foundation of scientific analysis, and it lies behind any quantitative analytical statement. For example, what is the crime rate? To answer this we have to know the base of the rate. Do we want it per 1,000 persons, per reporting area, or per patrol district? To calculate this rate we must know how many crime incidents have occurred, and, if we are calculating a population-based rate, how many persons there are per unit area. This value, the base of our rate, is also known as the denominator, because it is the bottom of the fraction used to calculate the rate. Therefore:

$$\text{density} = \frac{\text{number of incidents per area}}{\text{population per area}}$$

Here, "number of incidents per area" is the numerator (top of the fraction) and "population per area" is the denominator. If there are 428 incidents and the population expressed in thousands is 3.7, the rate is 428/3.7, or 115.68 per 1,000 persons. We can check that the calculation is correct by multiplying the rate by the population to reproduce the original incident count:

$$115.68 \times 3.7 = 428.$$

A GIS program would do these calculations for you, but analysts need to know how to provide appropriate instructions before anything useful can be produced.

An application of density analysis is shown in figures 4.11, 4.12, and 4.13. First, the density of burglar alarm calls was mapped using 48,622 locations for alarm calls in 1990 in Charlotte-Mecklenburg, North Carolina. Using the ArcView Spatial Analyst extension, a grid was used to generate the surface shown in figure 4.11. Peaks occurred near the central business district, along major transportation arteries, and in the industrial northwest area. A similar map (see figure 4.12) was prepared to show the density of the 10,288 burglaries reported in 1990, focusing on both the central business district and a radial, highway-oriented distribution. In the final phase, the burglary density surface was subtracted from the alarm density surface, and a query tool was used to select parts of the surface where burglary density exceeded alarm call density (see figure 4.13). This map directs the analyst to areas where displacement may be occurring and suggests areas for possible interventions. Such interventions could include additional alarm installations or other target-hardening measures (see figures 3.11–3.15).

The various types of measurement now available in GIS programs are too numerous to describe. However, a few types of measurement will be outlined to provide a sense of what can be done.

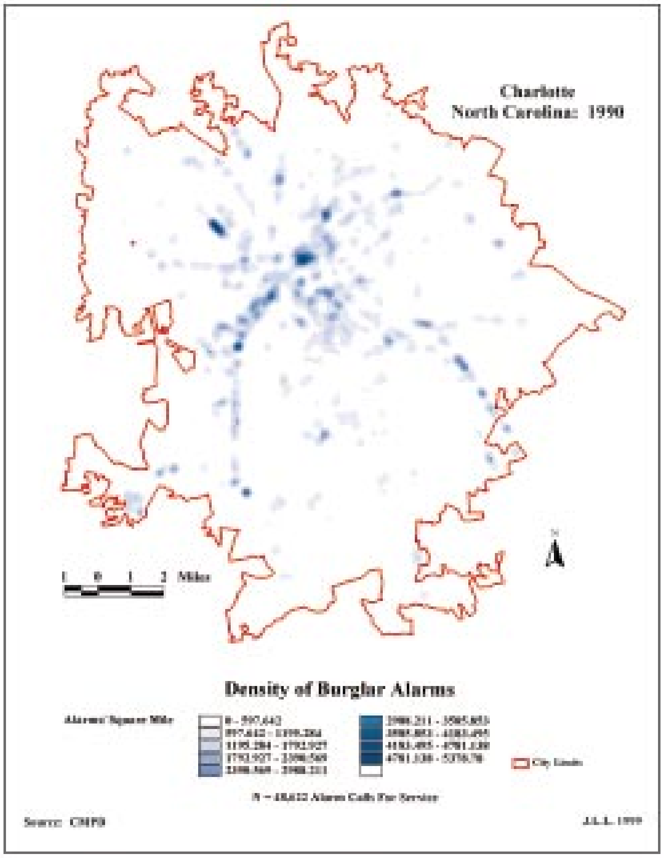



**Figure 4.11**

A map showing the density of burglar alarm calls, Charlotte-Mecklenberg, North Carolina, 1990.

*Source: Map by J. LeBeau, Southern Illinois University, with data from the Charlotte-Mecklenburg, North Carolina, Police Department. Reproduced by permission.*

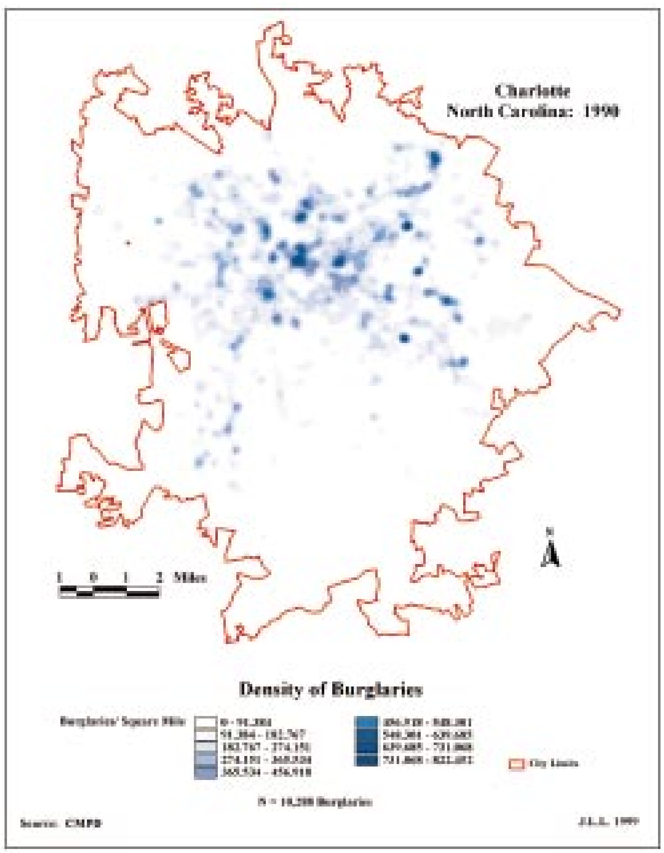



**Figure 4.12**

A map showing the density of burglaries, Charlotte-Mecklenberg, North Carolina, 1990.

*Source: Map by J. LeBeau, Southern Illinois University, with data from the Charlotte-Mecklenburg, North Carolina, Police Department. Reproduced by permission.*

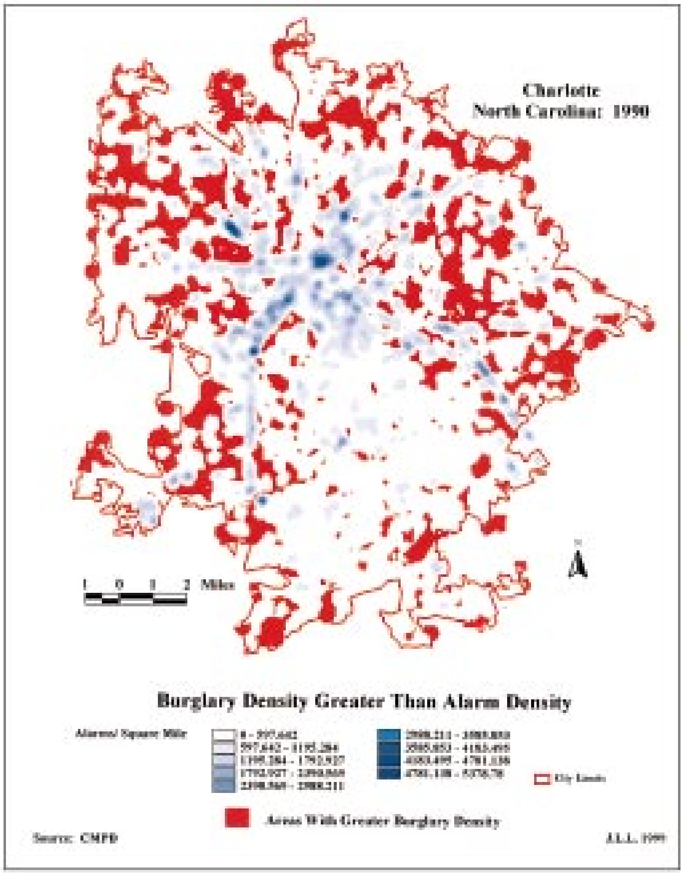



*Figure 4.13*

A map showing areas with burglary density greater than alarm call density, Charlotte-Mecklenberg, North Carolina, 1990.

*Source: Map by J. LeBeau, Southern Illinois University, with data from the Charlotte-Mecklenburg, North Carolina, Police Department. Reproduced by permission.*

## Count incidents in areas

Although the primary need for counting will be to total crime incidents, counting other objects or events could be useful, too. It may be helpful, for example, to know how many and what types of alcoholic beverage licenses (beer, liquor, restaurant, liquor store, and so forth) are in specific areas. The information could serve as a gross index of alcohol availability, although it would not necessarily indicate where or how much alcohol is consumed or by whom. Or perhaps the local building inspection agency supplies a list of addresses of code violations. These could be mapped and sorted by any relevant areas, such as neighborhood association jurisdictions or police operations areas.

GIS software makes such identification easy. Users may find it helpful to write down the operation they want to do to clarify the steps—especially if they anticipate several steps of filtering, measuring, or other manipulations. In fact, this exercise is helpful for any kind of analysis. For example, you might want to count incidents of spousal abuse within patrol districts, which in some programs might be expressed in SQL something like this:

```
count spousal abuse.object
within patrol district.object
```

This tells the program to evaluate each spousal abuse incident (“object”) and determine in which patrol district it occurred. Additional instructions may ask the program to group incidents by patrol district by listing in a new table or file each patrol district identification number and the number of spousal abuse incidents that occurred there.

### Measure areas and distances

Area measurements are especially useful for determining how many crimes occur per unit area. This is not to be confused with crime measurements by population size or density. Generally, though not necessarily, crime densities will reflect population densities because population density is an expression of crime potential. More people means more potential victims and offenders.

Distance measurements are also simple. They require the use of ruler or tape software tools and, as with area measurements, the units can easily be changed.

### Measure inclusion and overlap

Areas of interest in policing do not always fit together neatly. Police districts, precincts, patrol areas, and so forth, may not match school districts, council districts, census tracts, neighborhoods, community conservation districts, and officially designated hot spots. GIS tools allow users to measure overlaps between areas or small enclaves in large areas because any incidents found in a specific area can be electronically identified. All the crimes (or drug markets, liquor licenses, parolee addresses, injury accidents, and so forth) in a specific area can be selected and separated as a new data set for special analysis. How are drug arrests divided among council districts or neighborhood association areas? One GIS package, for example, includes the following functions: *contains, contains entire, within, entirely within, intersects*. These capabilities are typical of this type of analytical function.

### Centroid display

A *centroid* is an area's center defined as the halfway point on its east-west and north-south boundaries. However, the centroid will not always be inside the area. For example, an area may be L-shaped, in which case the centroid theoretically would fall outside the area. A centroid is generally used as the point where labels will be located by default and where statistical symbols will be placed.

Centroids can approximate the geographic midpoints of areas, which may in turn (theoretically) approximate the most accessible points in the areas. Normally, centroids are hidden, but they can be displayed on request. If you have area objects without centroids, the centroid (x,y) function can be used to generate them. Centroids are used infrequently in crime analysis and are typically used as surrogates for other conditions, such as accessibility.

For surface-fitting purposes, the data values that apply to tracts, block groups, or blocks could be assigned to their centroids, thus reducing areas to points for computational convenience. Given the common use of grid-based, surface-fitting algorithms, however, this type of centroid application is unlikely.

## Derivative measures: How to create new indicators

*Derivative measures* are new variables created by manipulating information in one or more databases. The rate calculations discussed in the section "Using GIS to measure from maps" are a simple form of derivative measures that divide a crime count by a population measurement to produce a population-based rate. Generally, if you can express a sought-after relationship using ordinary mathematical logic, then it can be calculated in a GIS. There you will typically find an array of *operators* (+, -, =, *, "like," "contains," "and," "or," "not," and so forth), *aggregates* (average, count, minimum, maximum, sum, and so forth), and *functions* (area, centroid, distance, perimeter, day, year, and so forth). These provide substantial versatility in general analysis or in creating derived measures.

### Getting a bit more fancy

The complexity of potential derivative measures is unlimited. For example, you might want to create a quality-of-life measure for community areas that goes beyond mapping income or real estate values. This index could include such variables as crime rate, education levels, dropout rate, drug addiction measures, and incivility reports. Provided the underlying data can be geocoded, or joined to a geocoded table, they can be mapped. Then most, if not all, mathematical manipulations can be done in the GIS.

### Apples and oranges

How do you combine variables measured in different units, such as dollars, years, or population? The quickest approach is to combine data in the GIS using overlays and then to use "logical operators" such as "greater than" or "less than" to reselect groups using your criteria. A more indepth process, but one that leads to greater familiarity with the data, involves converting the data values into ranks (*ordinal scale* measurement) before making any calculations. Although you will lose the *ratio level* measurement this way, you gain the overwhelming advantage of being able to work with any units of measurement. Another advantage of this process is that conversion to ranks smooths the effects of poorly measured data by intentionally making them less precise. The conversion eliminates some of the "phony" precision of data that are inherently subject to error.

A problem that can generally be overcome is that GIS software is typically weak in statistical (as compared with purely mathematical) tools and may not be able to convert data to an ordinal scale.[2] This could be done by using a statistical software package such as S+, SAS, or SPSS. Or if the number of measures and areas is not too large, the work could be done manually. Then ranks are summed to generate the index, after taking care to organize ranks so the lower numbers always represent either the best or the worst, but not a mix of both. The resulting numbers will indicate a cumulative rank, or relative status, that can be mapped (figure 4.14). Crime data can then be overlaid on the index map to show a possible relationship with, for example, social dysfunction. For

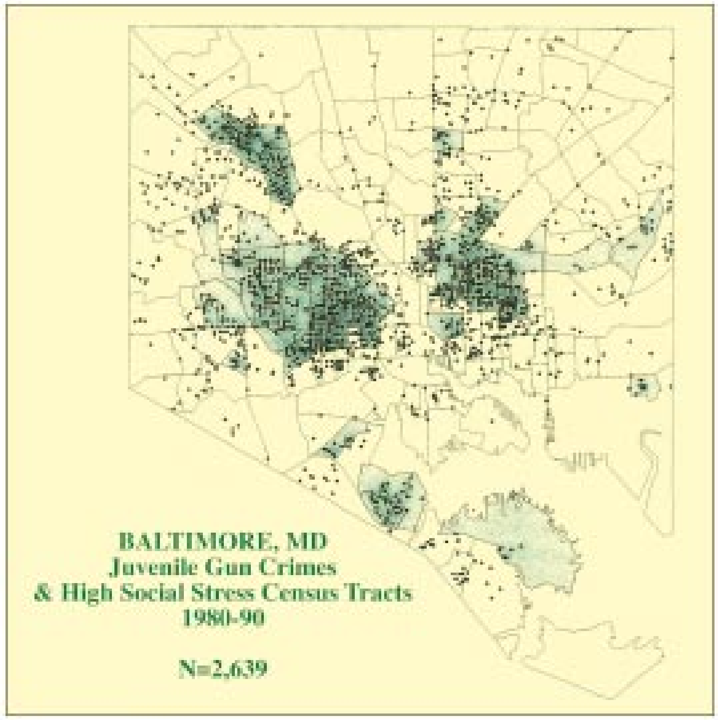



**Figure 4.14**

A map based on an Urban Pathology Index.

*Source: Harries and Powell, 1994, figure 2, p. 54. Adapted by permission.*

additional explanation, see Harries and Powell (1994).

## GIS as a tool for data integration and exploration

A GIS is an ideal tool for bringing together various databases that share common geography. This function will become more useful as the importance of data integration is increasingly recognized. Not only is there a need for more data integration, but there is also a need for recognition that most data used in policing about land use, street centerlines, liquor establishments, bus routes, schools, subway stops, and so forth are likely to come from sources outside the police department. Finding these types of data and adapting them for crime analysis often take considerable initiative and may also demand attention to data quality. This raises the issue of *metadata*. This term refers to data about data. Metadata provide information about the databases that you use. (See "Minimum for Federal Geographic Data Committee-Compliant Metadata.") Metadata standards are developed under the auspices of the Federal Geographic Data Committee (FGDC), a unit that coordinates development of the National Spatial Data Infrastructure (NSDI). (See the appendix for additional resources.)

All data with common geography can be overlaid. These layers may be manipulated—moved up or down, added or removed (permanently or temporarily), or made to become visible or invisible only when the map is shown at a specified scale. As noted on page 92, "What Is a GIS?," a fundamental concept in GIS is *layering*. The various forms of this process can provide a GIS with much of its power and flexibility.

### Minimum for Federal Geographic Data Committee-Compliant Metadata

- **Identification_Information:**
  - Citation:
    - Citation_Information:
      - Originator: This is the originator
      - Publication_Date: 000000
      - Title: This is the title
  - Description:
    - Abstract:
      - A concise abstract of the data
    - Purpose:
      - (Types of projects that use the data, models, general use, illustrations, specific type of analysis, and so forth. Be specific if the data are geared toward a narrow set of applications.)
  - Time_Period_of_Content:
    - Time_Period_Information:
      - Single_Date/Time:
        - Calendar_Date: 000000
    - Currentness_Reference: Publication date of sources
  - Status:
    - Progress: Complete
    - Maintenance_and_Update_Frequency: Unknown
  - Spatial_Domain:
    - Bounding_Coordinates:
      - West_Bounding_Coordinate: -109.9959
      - East_Bounding_Coordinate: -108.0022
      - North_Bounding_Coordinate: 37.0671
      - South_Bounding_Coordinate: 35.9330
  - Keywords:
    - Theme:
      - Theme_Keyword_Thesaurus: none
      - Theme_Keyword: None
  - Access_Constraints: none
  - Use_Constraints:
    - Limitations of data for use at certain scales and date ranges and for use with other data
- **Metadata_Reference_Information:**
  - Metadata_Date: 19950628
  - Metadata_Contact:
    - Contact_Information:
      - Contact_Organization_Primary:
        - Contact_Organization: Bureau of Land Management
      - Contact_Address:
        - Address_Type: mailing address
        - Address: PO Box 0047 DWO
        - City: Denver
        - State_or_Province: CO
        - Postal_Code: 80225-0047
      - Contact_Voice_Telephone: 555-5555
  - Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
  - Metadata_Standard_Version: 19940608

Source: http://www.blm.gov/gis/meta/minimum.html

Combining data in geographic space provides opportunities for data exploration and analysis that are lacking when geographic data are missing. An analyst may want to see how robbery locations relate to the locations of convenience stores. Although this information may be in different databases, it can be brought together in GIS and the locations subjected to the necessary analysis. For example, buffer zones could be constructed at a specified distance around each convenience store, and the number of robberies in each zone counted. Then the percentage of robberies proximal to stores could be calculated to provide an indication of the importance of this type of store as a robbery target. The possibilities offered by this type of *spatial analysis* are virtually unlimited. They include hot spot analysis, stolen auto recovery directions and distances, delineations of gang turfs, calculations of area-specific rates, the construction of crime or other "surfaces," network analyses, boundary determinations, and others mentioned elsewhere.

## Hot spots

### Definition in geographic space

The term *hot spot* has become part of the crime analysis lexicon and has received a lot of attention. What are hot spots? How do we recognize them?

A hot spot is a condition indicating some form of clustering in a spatial distribution. However, not all clusters are hot spots because the environments that help generate crime—the places where people are—also tend to be clusters. So any definition of hot spots has to be qualified. Sherman (1995) defined hot spots "as small places in which the occurrence of crime is so frequent that it is highly predictable, at least over a 1-year period." According to Sherman, crime is approximately six times more concentrated among places than it is among individuals, hence the importance of asking "wheredunit" as well as "whodunit." (See the appendix for hot spot-related resources.)

A great deal of confusion surrounds the hot spot issue, including the distinction between *spaces* and *places*. Block and Block (1995) pointed out that a place could be a point (such as a building or a classroom) or an area (such as a census tract or a metropolitan region). However, the former generally are regarded as places, and the latter, with their greater area, are spaces.

Sherman's definition notwithstanding, there is currently no widely accepted definition of a hot spot. Indeed, a rigid, absolute definition may not be possible. Except for programs with procedures that self-define hot spots, such as the Spatial and Temporal Analysis of Crime (STAC) program (Block, 1995), jurisdiction-specific procedures to define hot spots may make the most sense because they will fit local conditions. In Baltimore County, Maryland, for example, hot spots are identified according to three criteria: frequency, geography, and time. At least two crimes of the same type must be present. The area is small, and the timeframe is a 1- to 2-week period. Hot spots are monitored by analysts until they become inactive (Canter, 1997).

In many cases, analysts may not be able to define hot spots but may know one when they see it. This makes comparisons difficult both within and between jurisdictions.[3] Furthermore, meaningful time-based analyses are problematic, because hot spot definition criteria may not be used consistently over time.

Wide interjurisdictional and intrajurisdictional variations in environments also make the application of absolute definition criteria tricky. For example, the size and shape of city blocks vary widely. West of the Appalachian Mountains, city layouts are usually dictated by the rectangular land survey system, and blocks tend to be fairly regular and rectangular. In the east, where metes-and-bounds surveys prevailed, blocks are more likely to be irregular in shape and size. Densities also vary greatly. Can the same definition criteria be applied in low-density areas as in high-density areas? Crime-prone populations are found in both environments. Can hot spots exist in very low-density suburbs? Residents would probably think so.

## Hot spots and scale

Are hot spots purely a function of scale? Some argue that any set of points in geographic space can be made into a hot spot if the scale is modified enough. At extremely small scale,[4] all the crime incidents in an entire metropolitan area appear to be a hot spot (figure 4.15, upper left). As scale increases, points become more dispersed (figure 4.15, upper right and lower left) until, at the largest scale, individual points can be isolated (figure 4.15, lower right). The level of resolution in the absence of absolute criteria makes it possible to manipulate the presence or absence of hot spots. However, absolute criteria are difficult to apply in urban environments (Brantingham and Brantingham, 1995).

Generally, the hot spot concept is applied to street crime rather than white-collar crime, organized crime, or terrorist crime. That a few white-collar crimes might overwhelm street crime in their economic impact tends to be ignored. This may be

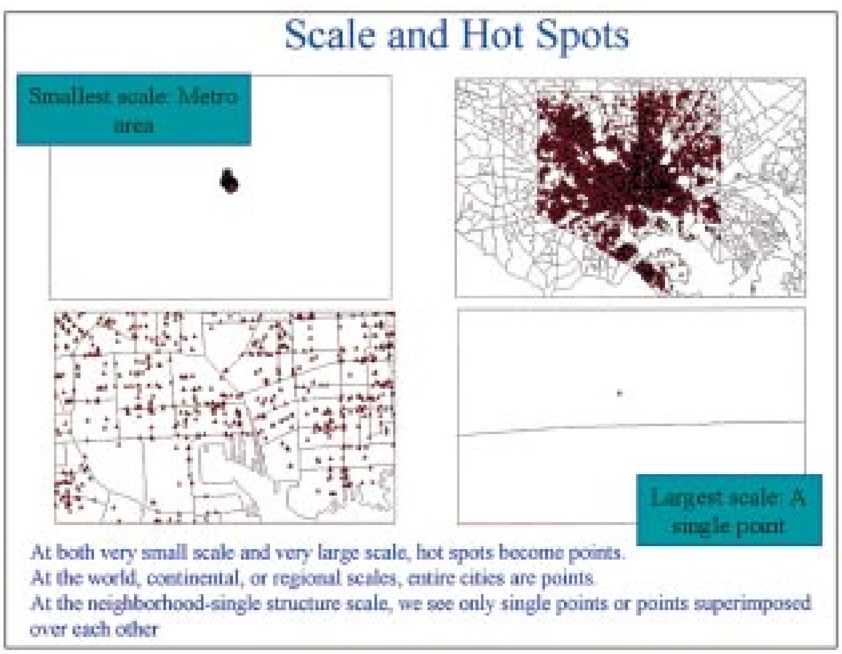



**Figure 4.15**

An illustration of the scale-dependency of hot spots.

*Source: Keith Harries.*

because white-collar crime does not cause the same kind of community fear and anxiety as street crime. Similarly, if a city experienced several terrorist bombings or school shootings within 1 year, it is considered a hot spot that defies the normal hot spot definition. There is a qualitative aspect to hot spots; they refer only to limited crime types.

### *Hot spots in time*

Just as hot spots can be described geographically, they can also be defined using time-related criteria. An important question is: How long is a hot spot "hot"? The answer requires defining an incident accrual rate within the spot, based on units of time. Related decisions are needed to determine whether the hot spot's "temperature" is measured according to all confirmed crimes, all calls for service, specific crimes, or other conditions. In a GIS framework, hot spots (and/or incidents within hot spots) can be color coded or otherwise symbolized according to their age.

An approach to monitoring hot spots over time is shown in figure 4.16. This map shows Devil's Night arson hot spots in Detroit in 1994 and 1997, using the STAC program developed by the Illinois Criminal Justice Information Authority. Although not a mapping program itself, STAC can be used with most popular GIS packages. (For additional details on STAC, see the appendix and figure 4.20.)

### *Definition and measurement*

What is a hot spot? Perceptions and definitions vary widely. Some analysts may see a hot spot as any cluster that looks interesting. Others define hot spots using rigid, detailed criteria. A study by Buerger, Cohn, and Petrosino (1995) found that the latter group initially used the following relatively formal criteria:

- Not more than one standard linear street block (one side of the street only).

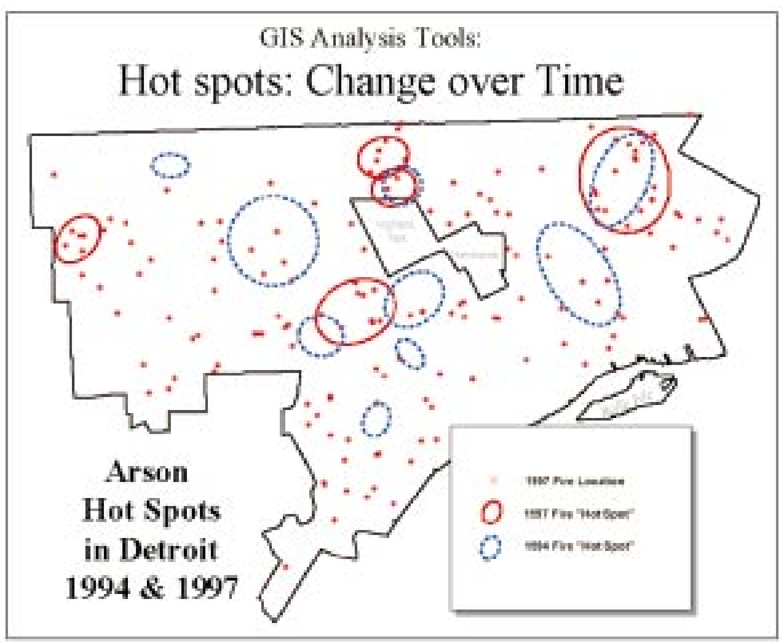



**Figure 4.16**

A map showing hot spot changes over time: Detroit, 1994 and 1997.

*Source: Martin, Barnes, and Britt, 1998, figure 3, p.10. Reproduced by permission.*

- Not more than half a block from an intersection.

- No closer to another hot spot than one block.

The Buerger group further identified three principal definition-related issues:

- **Public space.** Hot spots were initially limited to one side of the street, raising the question of how *street curtilage* (public space in front of private properties) would be treated. Common sense dictated that if a patrol car was across the street, technically outside the hot spot, it should be considered in the hot spot, so the definition was modified to include both sides of the street.

- **Intersections.** Ambiguities surrounded the definition of an intersection. The term eventually came to include not only the street, but also adjacent sidewalks and buildings. Even when a hot spot did not technically include all four corners of an intersection, it was found that the best viewpoint for seeing around a corner might be on the other side of the street, outside the hot spot. Thus, all four corners of intersections came to be included in hot spots.

- **One-block exceptions.** Irregular blocks with large open spaces contained some hot spots, making exceptions to the one-block rule.

In practice, hot spots are defined in numerous ways, some with rigid criteria, like those above, and others with a more flexible approach. None is right or wrong. Both approaches have pros and cons, and an informal cost-benefit analysis can determine the ideal criteria in individual locations. The sharply defined criteria may omit many commonsense exceptions (but allow greater comparability in space and time); softer rules permit easy adaptation to local variation (but make comparisons difficult).

## Hot spot mapping

A detailed presentation of hot spot mapping methods is beyond the scope of this guide. However, an investigation sponsored by the Crime Mapping Research Center at the National Institute of Justice in 1998 can offer some tips. This assessment found that most hot spot analysis methods fall into one of five categories: *visual interpretation*, *choropleth mapping*, *grid cell analysis*, *cluster analysis*, and *spatial autocorrelation* (Jefferis, 1999; see also Canter, 1995).

- **Visual interpretation.** The survey showed that, of the police departments that do computer mapping, 77 percent conducted hot spot analyses. Of these, 86 percent identified hot spots visually, and 25 percent used a program to perform this task (Mamalian and La Vigne et al., 1999). The problems presented by the visual approach include overlapping points, points stacked on top of one another, making it impossible to see how many incidents are represented[5] (that is, only one appears at any given location). Most serious, perhaps, is that readers' interpretations of point data vary, resulting in different interpretations of the same patterns.

- **Choropleth mapping.** Areas are shaded according to their data values, by either rate or frequency. The caveats mentioned in chapter 2 still apply—class interval selection methods will affect the appearance and interpretation of the map (see figures 2.15 and 2.16), as will color choices, shading levels, and size variation among the polygons. The latter elements tend to draw attention to the largest areas, particularly when they have higher data values.

- **Grid cell analysis.** A grid is superimposed over a map. Points within cells, or within a designated radius from the centers of the cells, are assigned to the cells. The size of cells is variable and affects the outcome of the analysis. Small cells present higher resolution, at the cost of more computer resources. With larger cells, resolution suffers, but computation is easier. What is the advantage of grid cell analysis over a pin map? First, adding points to the grid solves the problem of "stacked" data points, which occurs when multiple incidents occur at the same location or nearby locations. Second, the points are transformed into a smooth surface, generalizing the data. (For related methods, see the appendix: ArcView Spatial Analyst Extension, Idrisi, Vertical Mapper, the U.S. Department of Justice Criminal Division Hot Spot Slider.) Several examples of grid cell analysis have been illustrated in figures 4.11, 4.12, and 4.13. Another map of this type is shown in figure 4.17, which depicts hot spots in the United Kingdom city of Nottingham and police perceptions of hot spots. This map was produced using the custom program known as SPAM (Spatial Pattern Analysis Machine), which links to MapInfo for the finished map (see appendix). Variations of surface mapping include three-dimensional renditions, as noted in chapter 1. One key to readers' perception of three-dimensional maps is the degree of vertical exaggeration in the map. In the examples shown in figures 4.18 and 4.19 of Salinas, California, quite different types of data (firearm crimes and gangs) are shown in three dimensions.

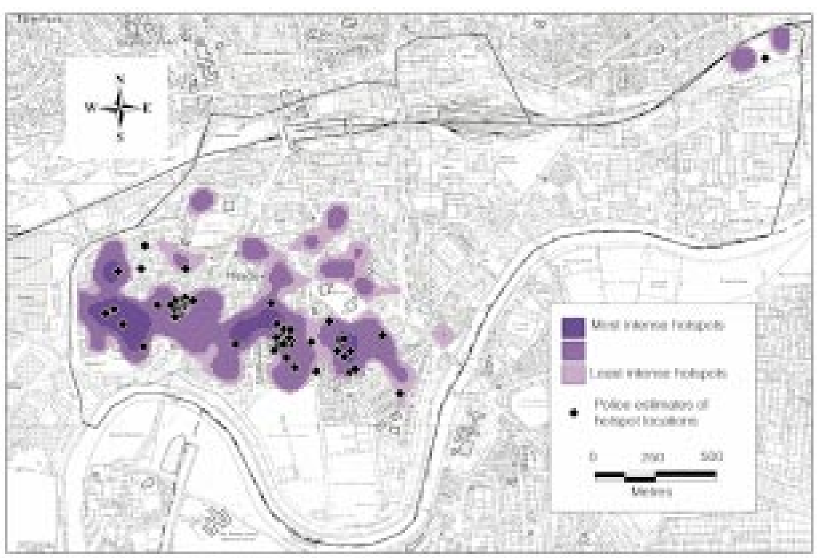


**Figure 4.17**

A map showing domestic burglary hot spots and police perception in the Meadows area of Nottingham, United Kingdom.

*Source: Ratcliffe and McCullagh, 1998, figure 1, p. 48. Reproduced by permission.*

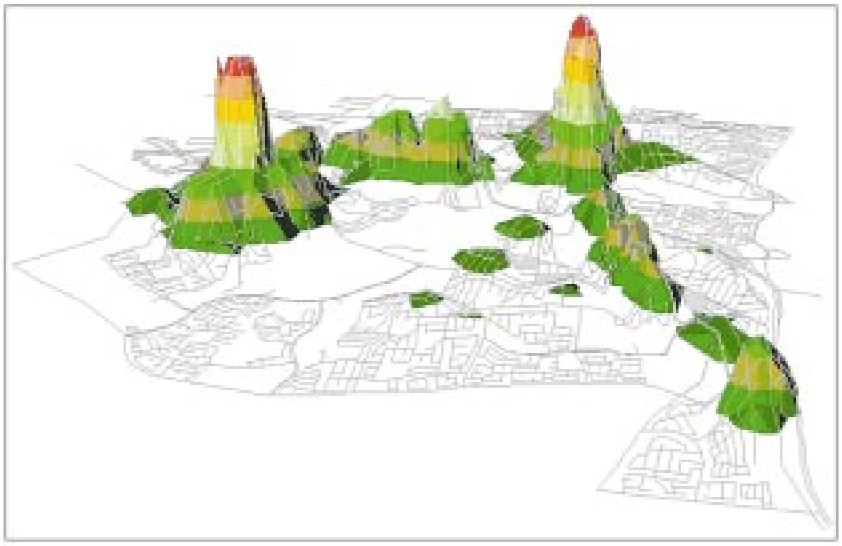


**Figure 4.18**

A map showing firearm incidents in Salinas, California.

*Source: Salinas, California, Police Department. Reproduced by permission.*

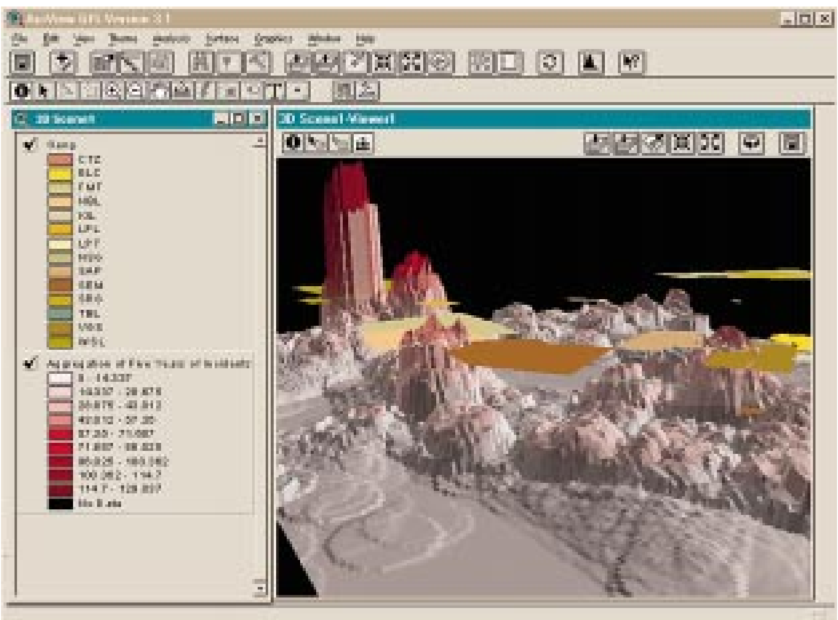


**Figure 4.19**

A 5-year analysis of incident data with an overlay of identified gang turfs in Salinas, California.

*Source: Salinas, California, Police Department. Reproduced by permission.*

- **Cluster analysis.** Cluster analysis methods depend on the proximity of incident points. Typically, an arbitrary starting point ("seed") is established. This seed point could be the center of the map. The program then finds the data point statistically farthest from there and makes that point the second seed, thus dividing the data points into two groups. Then distances from each seed to other points are repeatedly calculated, and clusters based on new seeds are developed so that the sums of within-cluster distances are minimized. (For related methods, see the appendix: STAC, SaTScan, SpaceStat, and Geographic Analysis Machine (GAM.) Figure 4.20 illustrates hot spots derived from the STAC method, which performs the functions of radial search and identification of events concentrated in a given area (Levine, 1996).

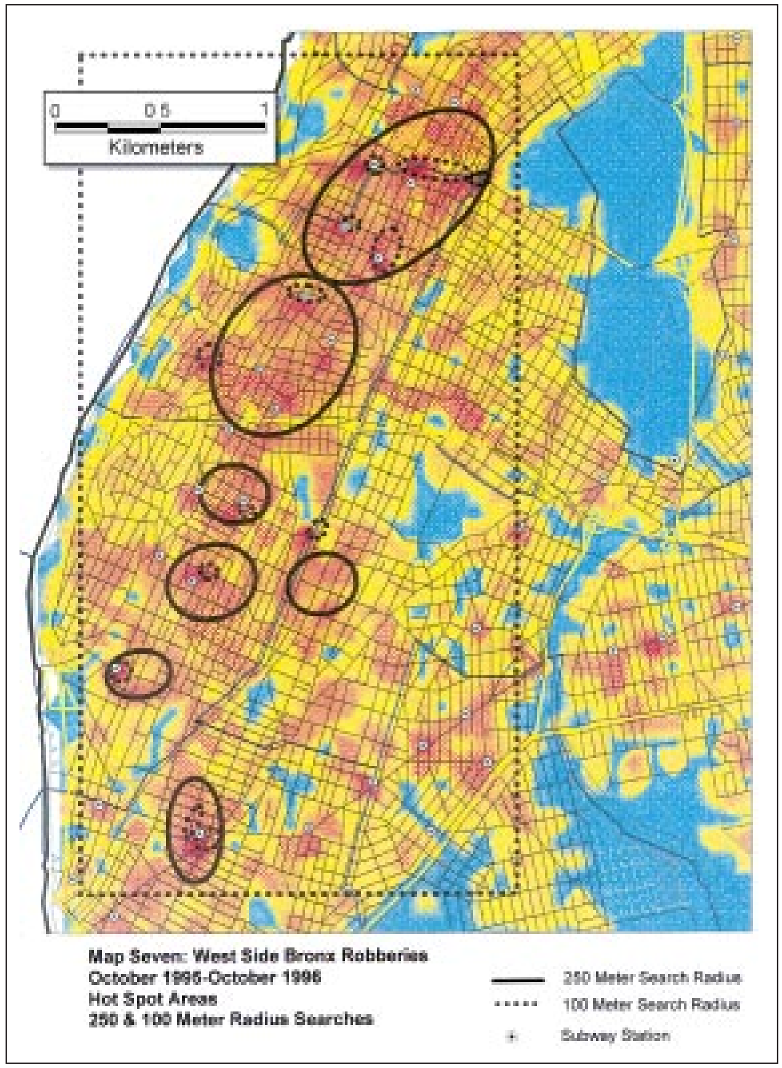



**Figure 4.20**

A map showing robbery hot spots, using STAC, West Bronx, New York.

*Source: Block and Block, 1997, figure 7. Reproduced by permission.*

- **Spatial autocorrelation.** This concept relies on the idea that events that happen in different locations may be related. In a crime hot spot, for example, underlying social and environmental processes generate crimes in a small area. Multiple events, such as the presence of drug markets, may have similar causes. This means that statistical measures of this condition, known as autocorrelation, can serve as hot spot indicators (Roncek and Montgomery, 1995).

All methods of hot spot mapping should produce similar maps if there are underlying and recognizable point clusters. Something is wrong if a method produces clusters where visual inspection indicates there are none. However, analysis should recognize that some methods involve user-defined search criteria, and variations in those criteria, such as differences in cell sizes or search radii, can affect outcomes.

## Buffering: Meaning and applications

A *buffer* is a zone around an object, such as a school or intersection, that has some investigative or analytical significance. For example, drug-free school zones may be defined using a 1,000-yard radius. Such buffers can be drawn around schools and overlaid on large-scale aerial photographs so that field officers can easily recognize the zone's boundaries, even without demarcating signs. Hardcopy maps can be given to patrol officers as an aid in recognizing the zones. Buffering tools in GIS programs make this a relatively simple task (figure 4.21).

Techniques for selecting objects can be used to identify certain types of events. For example, what are the characteristics of calls for service within 1 mile of high schools? Calls for service can be identified and separated into a new data set if they are within the 1-mile buffer.

Buffers are shown as circles if the location buffered is a point or street address, but buffers do not have to be circles. For large

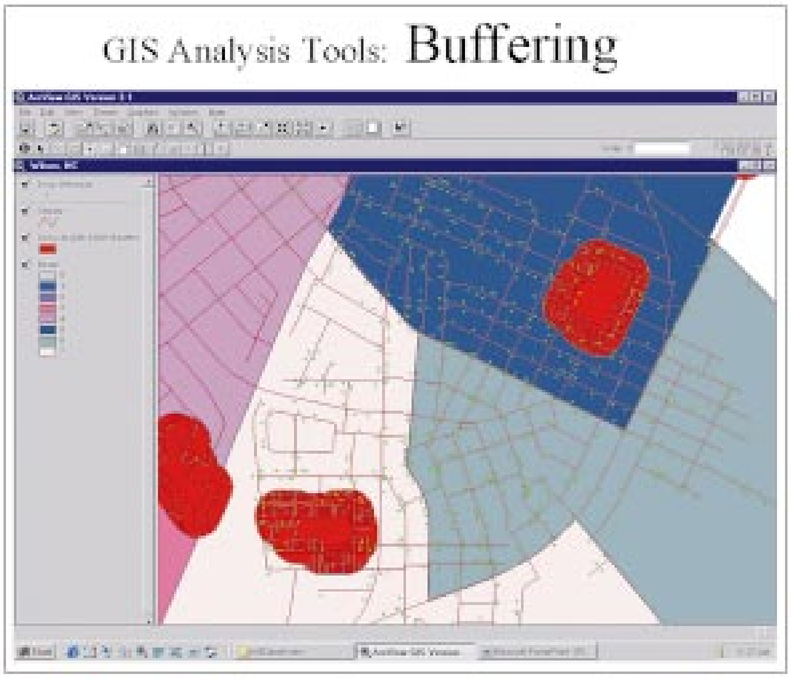



***Figure 4.21***

An example of buffering used in conjunction with the mapping of related data. Red areas represent 1,000-foot drug-free school zone buffers around schools, large polygons represent police beats, and point data represent drug offenses.

*Sources: J. Stith and the Wilson, North Carolina, Police Department. Reproduced by permission.*

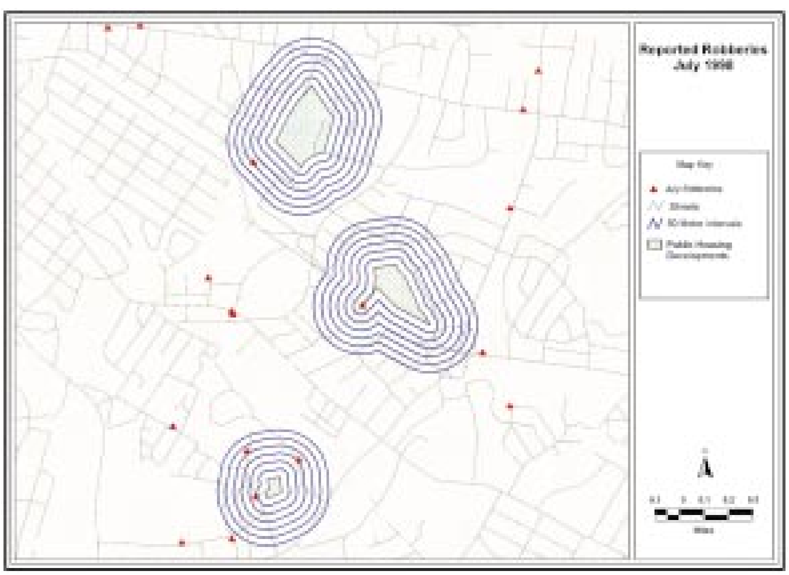



***Figure 4.22***

A map showing polygon buffers around public housing in Baltimore, Maryland.

*Source: Hyatt and Holzman, 1999. Reproduced by permission.*

polygons like school campuses, parks, apartment complexes, or industrial plants, buffers can mirror the shape of the polygon. In figure 4.22, public housing properties were buffered to evaluate the relationship between public housing and the surrounding neighborhood. The underlying question was whether crime in public housing was committed mostly by residents or by persons from the surrounding community. Analysis of incidents in the buffer zones can help determine the answer, using data on the residential addresses of victims and offenders. The same areas could be represented either by a circle buffer (if it is represented as a point or address) or as a polygon buffer (if the area is mapped to match its actual footprint).

In a community policing example, questions may arise about the quality of street or neighborhood lighting. Analysts can consult with city engineers to learn about the illuminated radius of various streetlights and their coordinates in the community. Then, using the buffer tool in GIS, circles of the appropriate radii can be drawn around each light location to create a basis for assessing community concerns about lighting quality (figure 4.23).

Also in the context of community policing, an extremely disruptive phenomenon is house fires. This is especially true in older neighborhoods with substandard row houses, where the likelihood of fire spreading from one home to adjacent houses is great. In one study, buffers were drawn around residences where fire-related injuries occurred in the previous 2 years. This, along with census data indicating risk, helped establish zones that were appropriate for the distribution of smoke alarms. (This may seem like a fire department function, but economic and social disruptions can contribute to conditions in which crime flourishes, making both fire and police functions relevant, as with arson cases. This helps demonstrate

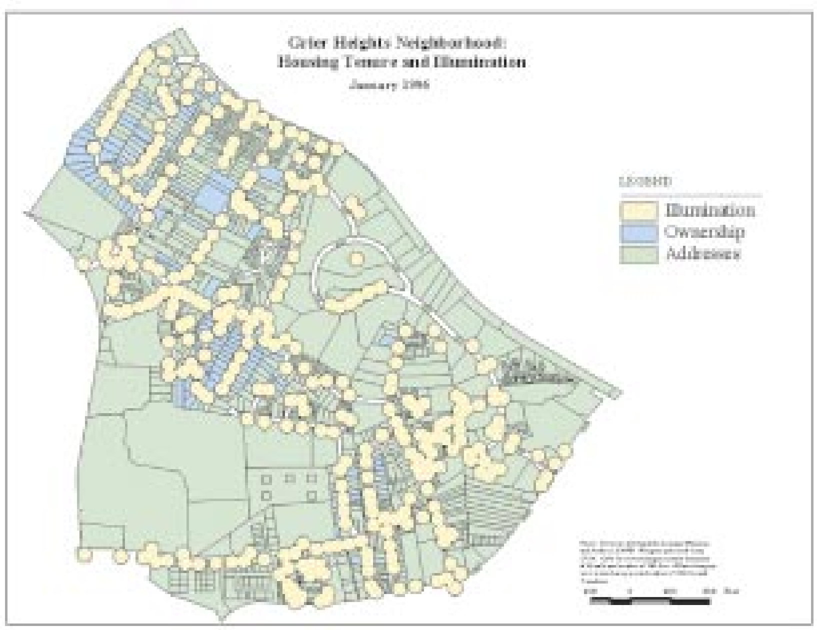



**Figure 4.23**

The Grier Heights neighborhood in Charlotte, North Carolina, showing street light buffers and housing tenure in 1996.

*Source: E. Groff and Charlotte-Mecklenberg Police Department. Reproduced by permission.*

the breadth of data that crime analysts need access to.)

In Tornado Alley, the high-frequency tornado region in the Plains States, a community safety concern is the audibility of warning sirens. Because the decibel output of sirens is known and varies with weather conditions, a GIS can be used to map the audible zone of each siren. Areas where sirens cannot be heard can be targeted by public safety agencies for special action during tornado warnings. This type of map could also serve as a blueprint for locating new sirens.

## Data, data, everywhere: What's an analyst to do?

### Mapping outside data

Although most data used in crime analysis are generated and used within one department, the need to integrate information from other agencies is becoming more important. Unfortunately, outside data are often in an incompatible format. What do you do when you get a *delimited* or *fixed field ASCII* file, for example? Table 4.1, "Census data in ASCII," shows data almost exactly as they are presented on the U.S. Census Bureau Web site, with only slight editing to adjust the spacing. The Federal Information Processing Standard (FIPS) codes attached to all census geographic areas[6] make up the first two columns. Starting in the left-hand column, the State of Missouri FIPS code is 29. In the next column, the city of St. Louis FIPS code is 510. Next are the tract numbers, literal tract numbers, tract populations (P00010001), tract median family incomes in 1989 (P107A001), and tract per capita incomes in 1989 (P114A001).

Most GIS software can handle data compiled in a variety of formats, although some variations may generate headaches. MapInfo will open the following formats: dBase, Lotus®, Microsoft Excel®, delimited ASCII, some raster files (.tif, .pcx, and so forth.), AutoCAD® (.dxf), and others, using either the *Open* or *Import* command. ArcView expects tabular data to be in dBase (.dbf), Info, or delimited text (.txt) format. One solution to the somewhat limited data conversion repertoires of some GIS programs is to launder files through a more versatile spreadsheet program and then transfer them to the GIS in a more compatible format.

To do this, the user imports the foreign data spreadsheet into Lotus, Microsoft Excel, or Microsoft Access®, and then exports it in a GIS-compatible format. This way, a fixed-field ASCII file can be converted into a delimited ASCII or dBase format. This is done by parsing the fixed-field file in the conversion program, and then outputting it in a delimited format. Parsing is a process of instructing the program how to read the fixed-field data by identifying the variables in each field and dragging field delimiters to appropriate locations. For example, the analyst instructs the program that the case number is in columns 1–10, the address is in columns 11–30, and so forth. Delimited means that each data field is separated from the next by a character such as a comma or a tab. With delimiters, it does not matter if data values have different widths, as in the sequence 3.5, 14.276. When the program recognizes the delimiter as a cue, it moves to the next value.

You may receive data that consist of x-y coordinates, without the points themselves. In such situations, the coordinates are used to generate the points in the GIS, using a Create Points command that allows users to select a preferred symbol and an appropriate projection. (For information

**Table 4.1. Census Data in ASCII Tab-Delimited Format as Acquired Directly From U.S. Census Bureau Web Site**

*(http://www.census.gov)*

*See text for explanation*

*(Selected census tracts for St. Louis, MO)*

| FIPS. ST | FIPS. CO. | FIPS. TRACT90 | STUB.GEO | P0010001 | P107A001 | P114A001 |
|---|---|---|---|---|---|---|
| 29 | 510 | 1011 | Tract 1011 | 000002867 | 000032281 | 14262 |
| 29 | 510 | 1012 | Tract 1012 | 000003287 | 000041559 | 15743 |
| 29 | 510 | 1013 | Tract 1013 | 000004446 | 000036234 | 15401 |
| 29 | 510 | 1014 | Tract 1014 | 000003075 | 000028322 | 11859 |
| 29 | 510 | 1015 | Tract 1015 | 000003763 | 000021519 | 9787 |
| 29 | 510 | 1018 | Tract 1018 | 000003773 | 000025197 | 9027 |
| 29 | 510 | 101899 | Tract 1018.99 | 000000028 | 000000000 | 13929 |
| 29 | 510 | 1021 | Tract 1021 | 000002820 | 000032625 | 15883 |
| 29 | 510 | 1022 | Tract 1022 | 000006608 | 000040897 | 17131 |
| 29 | 510 | 1023 | Tract 1023 | 000001834 | 000031157 | 14262 |
| 29 | 510 | 1024 | Tract 1024 | 000002550 | 000034545 | 13226 |
| 29 | 510 | 1025 | Tract 1025 | 000002253 | 000034911 | 13158 |
| 29 | 510 | 1031 | Tract 1031 | 000003429 | 000039677 | 19250 |
| 29 | 510 | 1034 | Tract 1034 | 000002200 | 000037222 | 13316 |
| 29 | 510 | 1036 | Tract 1036 | 000001617 | 000033105 | 13240 |
| 29 | 510 | 1037 | Tract 1037 | 000002883 | 000035461 | 14024 |
| 29 | 510 | 1038 | Tract 1038 | 000004213 | 000039194 | 15466 |
| 29 | 510 | 1039 | Tract 1039 | 000001229 | 000028375 | 11771 |
| 29 | 510 | 1041 | Tract 1041 | 000003153 | 000030313 | 12649 |
| 29 | 510 | 1042 | Tract 1042 | 000004076 | 000030660 | 14218 |

about map projections, see chapter 1.) After the points are generated, they can be imported as a new layer on the map. Data generated in the field, perhaps from patrol cars using global positioning system technology, can be treated in the same manner.

Any database with an address or geographic reference included can be mapped, provided the corresponding digital base map is available. For example, you may want to map census tract data. The census data are available, but the map of tracts is not. In this case, the map is readily available to download off the Web, but non-census tract maps must be acquired elsewhere.

## Data warehousing and data mining

Police departments generate volumes of information. A single call for service ultimately results in its own pile of paper, and computer files tracking all calls for service grow rapidly. *Data warehousing* and *data mining* provide sophisticated ways of storing and accessing information.

A data warehouse is a megadatabase that stores data in a single place instead of storing them in project files or throughout the local government or government agency. Government agencies have been slow to do this because agency politics tend to create an attitude oriented more toward defending departmental turf than toward sharing data. A data warehouse could assist with crime analysis efforts, which often demand data from diverse sources, such as the health, housing, traffic, fire protection, liquor licensing, and planning agencies.

Law enforcement is primarily a local government activity, which often leaves police agencies at the mercy of data managers overseeing city or county information technology functions. Ideally, data warehouses consolidate all jurisdictional databases and permit use of data from any agency according to quality control standards. Data mining, as the label suggests, involves digging nuggets of information out of vast amounts of data with specialized tools. These tools are typically called exploratory data analysis (EDA), which, in the context of mapping, can become exploratory *spatial* data analysis (ESDA) tools. An IBM software engineer (Owen, 1998) identified these as the factors that brought data mining to the attention of the business community:

- The value of large databases in providing new insights is recognized.
- Records can be consolidated with a specific audience or objective in mind.
- Cost reductions are achieved with large-scale database operations.
- Analysis is being *demassified* (futurist Alvin Toffler's term) meaning that the information revolution permits the creation of specialized custom maps for specific audiences.

Chapter 2 discussed hypothesis testing. That discussion now comes full circle because data warehousing and data mining make hypothesis testing even more practical. Queries can be addressed to large arrays of data, increasing the reliability of responses. However, this is truer for historical questions than for current data.

## Cautions

Although GIS makes mapmaking relatively easy, it is not necessarily easy to make good maps. The fundamental problem is that fancy fonts, tables, maps, or diagrams can dress up almost any data. However, just because data look good does not mean they are.

As a rule of thumb, do not blindly accept the default settings in GIS programs. Defaults apply to such steps as the selection of class intervals in choropleth maps (see "Classifying map information" in chapter 2), as well as the colors, symbol types, and sizes.

> ***Rule of Thumb***
>
> *Default settings in GIS programs should not be accepted blindly.*

Boilerplate maps, produced regularly to show specific needs such as weekly precinct or division crime patterns, can be fine tuned so they consistently convey the intended message. Problems are more likely to arise with specialized maps. A checklist may be a useful reminder of the most important map elements and criteria:

- **Need.** Is a map needed for this message or analysis? Could the job be done as well or better with another approach, such as a table, a narrative, a chart, or conversation?

- **Data source.** Are the data reliable? If there are questions about data quality, how can the audience be alerted? (By using a map subtitle or map footnote?) Are data so poor that mapping and analysis should not be done? Who decides if this is the case?

- **Scale.** Is the appropriate area shown? Can the map be enlarged without compromising the message?

- **Scope.** Is the map trying to show too much? Too little? Can more context be added to better inform the reader?

- **Symbols.** Would icons convey the message more convincingly than abstract default symbols? Note that some icons are awkward shapes and may have a minimum size, below which they become meaningless.

- **Color.** Misused color detracts from an otherwise excellent map. Excessive use of bright colors may hurt the eye and repel the reader. Illogical color gradations may be confusing. Think in terms of drawing the eye to important areas (normally higher data values) by using more intense color tones. Think about how the map will be used. Color may be irrelevant if the map is to be distributed by fax or printed in a document that will not be reproduced in color. In such cases, color can be counterproductive. Even black-and-white (gray-scale) shades should be chosen carefully if the document is to be faxed. Gray-scales should not be too subtle (variations will be lost), and cross-hatched shading should be coarse (lines relatively far apart) or they will not hold up through the fax process.

- **Lettering.** Are the default font style and size appropriate? Consider, for example, whether the user may decide to make the map into an overhead transparency. Will the lettering be legible in that medium?

- **Methodology.** What opportunities does your software offer? (Hot spot identification? Buffers? Filtering?) Have those opportunities been taken advantage of? Or have unnecessarily glitzy methods only created confusion?

- **Privacy.** Will this map reveal information about individuals who may be subject to privacy restrictions? Most data are in the public domain, including arrest records and court documents. Exceptions to this include the practice of protecting the identities of rape or sexual assault victims, and the identities of juveniles.

## Summary

Chapter 4 has explained:

- The impact GIS has had on crime mapping.

- How GIS is used in law enforcement agencies.

- How GIS affects what we can do and how we do it.

- The difference between vector and raster formats.

- What geocoding is.

- How we can filter data and make useful maps according to specific criteria.

- How GIS can be used to measure information on maps.

- The meaning of derivative measures and how they are created and used.

- What hot spots are and how they are defined, measured, and mapped.

- What buffering is in the context of GIS.

- How large databases can help with mapping and analysis.

- What data warehousing and data mining are.

- Some factors that demand the exercise of caution in the mapping process.

## Notes

1. Data transformations using square roots or logarithms smooth data and reduce problems associated with having both very large and very small values in a distribution The effect may change the distribution to a more normal, or bell-shaped, curve.

2. The need for more integration of statistical tools is gradually receiving more recognition, and the problem should diminish over time. For example, a new package known as Regional Crime Analysis GIS (RCAGIS) developed for the Baltimore-Washington, D.C., region has an embedded statistical package, CRIMESTAT. Also, the S+ package by MathSoft® (*http://www.mathsoft.com/splus/*) interfaces with ArcView.

3. Hot spots may be split by jurisdiction boundaries in such a way that they fail to meet hot spot criteria on either side of the line.

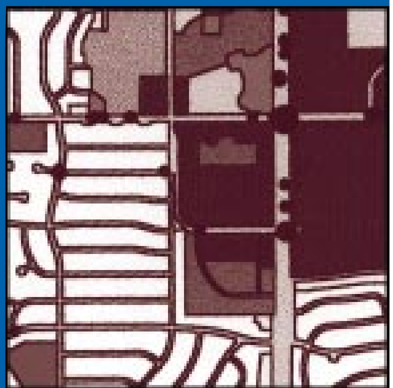
4. Reminder: Small-scale maps show large areas, large-scale maps show small areas.

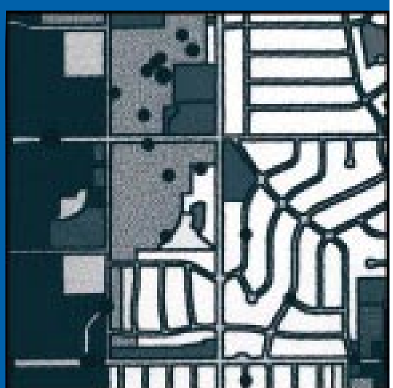
5. This problem of overlapping points can be fixed with software manipulation.

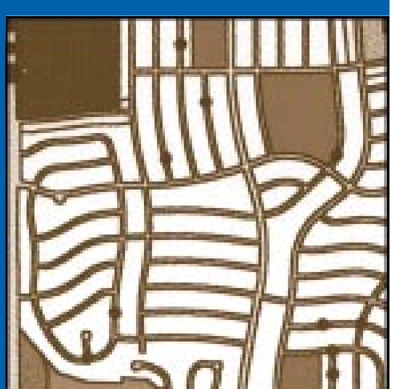
6. Regions of all nations have FIPS codes. Greater London, U.K., for example, is UK17. For details, see: *http://webcentral.bts.gov:80/itt/T%26T/resource/fipscode.pdf*.

### *What's Next in Chapter 5?*

- *Current events in crime mapping.*
- *How to apply analytical crime mapping.*
- *Criminal intelligence.*
- *Crime prevention.*
- *Courts and corrections.*
- *Public information.*
- *Resource allocation and planning.*
- *Census geography and analysis.*
- *Crime mapping applications and improved effectiveness.*







# Chapter 5:

## Synthesis and Applications

This chapter brings together concepts discussed previously and gives an overview of crime mapping applications in selected areas of criminal justice.

### Synthesis 2000

What are the most obvious characteristics of crime mapping at the beginning of the new millennium? Several come to mind:

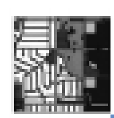
**Technology imbalance**—most police departments, except large ones (more than 100 sworn officers), do *not* use crime mapping technology.

**Urban, suburban, and rural differences**—in terms of crime analysis and mapping, the perspectives and needs of urban, suburban, and rural police departments greatly differ.

**Incomplete geocoding**—efforts to geocode rural addresses are under way.

**Geographic information system (GIS) functions**—GIS is used for *descriptive*, *analytical*, and *interactive* purposes.

**GIS mapping**—GIS is used to represent information in the form of *points*, *areas (polygons)*, and *lines*.



**Decreasing costs**—more capabilities become available as the cost of mapping technology declines.

**Crossjurisdiction alliances**—these relationships recognize that criminal behavior pays little heed to departmental boundaries.

**Theory and practice**—the link remains weak.

**Data sharing**—collaboration among State and local agencies is becoming more common.

**Context**—the "backdrop" is increasingly being recognized as critical to understanding crime patterns and crime prevention.

**Privacy issues**—these issues become more urgent as the ability of law enforcement agencies (and others) to link information to addresses and individuals increases.

**Public access**—access to geographic information increases with the use of the Web and systems such as ICAM (Information Collection for Automated Mapping) in Chicago.

Let's consider each point in turn.

**Technology imbalance.** Why are most police departments not using computerized crime mapping? (Only 13 percent reported using the technology in the 1997–98 survey by Mamalian and La Vigne et al., 1999.) Part of the answer lies in the very different needs and capabilities of urban, suburban, and rural law enforcement agencies. The needs and resources of large urban departments make computer crime mapping practical. Crime rates, particularly in so-called inner cities with larger police departments, are generally higher than in suburban or rural areas. A larger police force also means that tasks can be more specialized and that the probability of having a staff dedicated to crime analysis is greater. The political map is extremely fragmented in some areas, such as Los Angeles and Chicago, with numerous small, incorporated communities outside the central city. While the total population in such metropolitan areas may be large and the crime problems significant, political fragmentation decreases the likelihood that police departments are, individually, able to deploy specialized crime analysis units.

**Urban, suburban, and rural differences.** Reasons for variations in the use of automated mapping go beyond the size of police departments and questions of labor force specialization. Urban, suburban, and rural environments differ fundamentally in a number of ways that relate to the distribution of crime (Mazerolle, Bellucci, and Gajewski, 1997). Among the obvious differences are those relating to population density, racial and ethnic diversity, social cohesion, and economic health. Higher population density means more potential for crime in a given area. This does not necessarily mean higher crime rates, however. A rural county may have a higher population-based crime rate compared with a city, but the city has more crimes due to its having a larger population.

Urban law enforcement differs markedly from that in rural areas, where communities and residences may be widely separated.

Rural policing may be just as fragmented as urban policing. Each small town may have its own police department with a handful of officers, while the surrounding area may be the responsibility of the sheriff or State police. (To add to the confusion, in large cities sheriffs are not necessarily involved in street-level criminal law enforcement but may act as officers of the court, dealing with court orders, evictions, repossessions, and, perhaps, jail administration.)

Paradoxically, perhaps, response times to calls for service (CFS) for the responsible agency in a low-density rural area may be much longer than from its neighbor, depending on the locations of police facilities. Concepts like *patrol* that are the bedrock of urban and suburban law enforcement mean little in an environment like that illustrated in figure 5.1. *Response time*, too, must be thought about differently. It is easy to overlook law enforcement environments that are nonmetropolitan, since the problems that attract most attention are in urban locations, as are the media. Furthermore, the literature on GIS in policing is almost exclusively dedicated to urban case studies. Because the application of GIS to low-density suburbs and rural environments is a new frontier and has been extremely limited, hard questions need to be asked: Does rural law enforcement really need computer mapping? Can GIS improve rural policing?

**Incomplete geocoding.** Historically, geocoding efforts have had a distinctly urban bias, for obvious reasons. The majority of people lived in the cities, and the census enshrined urban geocoding by linking early address matching initiatives to the areas that we know today as Metropolitan Areas. Rural areas were essentially impossible to geocode because their rural route and post office (P.O.) box addresses inhibited the construction of links to the locations of housing units or businesses. Preparations for Census 2000 include an aggressive effort to geocode rural addresses. In some cases, 911 street addresses are already available (typically


*Figure 5.1.*

A photograph of a low-density environment in the Oklahoma panhandle. In this rectangular land survey grid area, directions refer to miles and compass directions. Privacy has a different meaning than in high-density urban areas. On a map representing this low-density area, a dot could easily be linked to a specific household, in sharp contrast to high-density urban environments.

*Source: Keith Harries.*

in the rural parts of metropolitan counties). In other cases, field workers go out and record the locations of structures and reconcile them to their rural route or P.O. box number, if possible. This effort is essentially a cooperative venture among local governments, the U.S. Census Bureau and the U.S. Postal Service.[1]

**GIS functions.** The uses of GIS in policing can be characterized as descriptive, analytical, and interactive. Descriptive maps can be equated with traditional cartography in that they tend to be a static picture of information, albeit a very useful one, as exemplified by the styles shown in figures 5.2, 5.3, and 5.4. Descriptive is not a pejorative term—it is the foundation of scientific investigation. Accurate description is an extremely valuable commodity easily capable of providing answers to questions. Accurate and timely description is the foundation on which GIS rests. Analytical maps go a step further and consider relationships among map elements or use methods based on spatial statistics software, such as STAC (Spatial and Temporal Analysis of Crime) or the ArcView® Spatial Analyst. In interactive mapping, the analyst enters and changes map parameters "on the fly," perhaps testing theories about fluctuating drug-market boundaries, studying the displacement effects of a crackdown, or examining how buffering features may affect outcomes. (For examples of analytical maps, see figures 5.7 and 5.9. For an example of what was originally an interactive animated map, see figure 6.8.)

**GIS mapping.** The predominant applications of GIS have involved the representation of point, area (polygon), and line data for reasons that have been outlined previously. However, as databases become more integrated and newer technologies

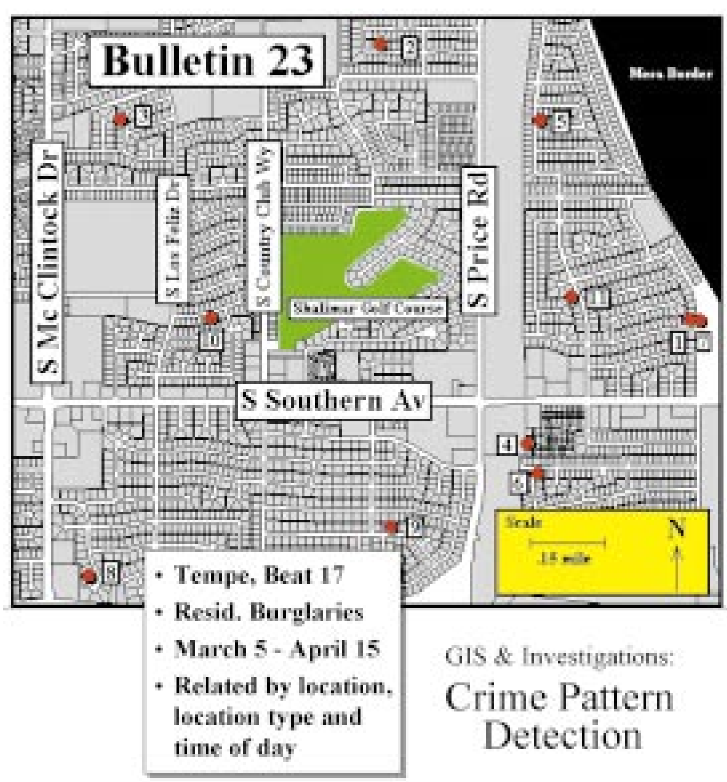



**Figure 5.2**

A map showing a burglary pattern for a specific time period in a specific neighborhood in Tempe, Arizona.

*Source: Rachel Boba and the Tempe, Arizona, Police Department. Reproduced by permission.*

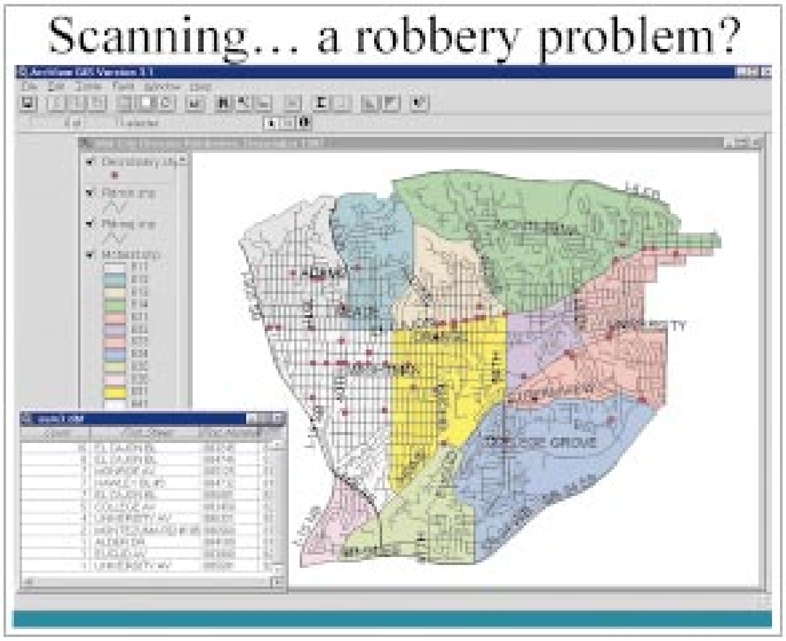



**Figure 5.3**

A map showing a scan of the robbery problem in specific neighborhoods in San Diego, California.

*Source: Julie Wartell and the San Diego, California, Police Department. Reproduced by permission.*

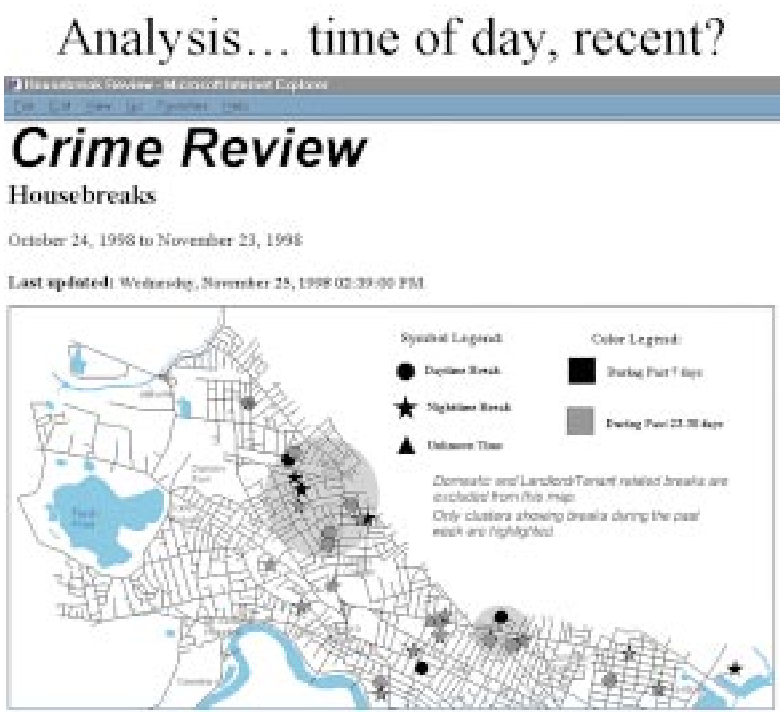



**Figure 5.4**

A map representing the regular crime review process in Cambridge, Massachusetts, with housebreaks classified according to various time criteria.

*Source: Cambridge, Massachusetts, Police Department. Reproduced by permission.*

like global positioning systems (GPS) become more commonplace, we might expect the "traditional trio" of point, area, and line to be supplemented by an ever-richer array of raster data in the form of digital orthophotography and other photographic images. The wide availability of orthophotography (often commissioned by local governments) combined with the advent of inexpensive digital cameras and (still somewhat expensive) digital video recorders presages the fuller integration of all georeferenced "visual" data. Most likely, traditional point, area, and line maps will begin to be embedded with useful raster elements, so that the user will have the choice of seeing a map or bringing up an orthophoto and/or a ground-level photo of the location of interest. (See chapter 6 for more on orthophotography applications.)

Other nontraditional applications include, for example, public safety events, in which police, fire, and other agencies are brought together in a common effort to alleviate a natural disaster. A map constructed for this purpose (figure 5.5) details data that provided general locations of police and fire units during a catastrophic flood in Dallas, Texas.

**Ever-decreasing costs.** Decreasing costs have brought mapping technology within the reach of agencies that would not otherwise have been able to acquire it. In the early days of the Information Age, equipment and software often cost more than the operator; now that situation is reversed. But the impact of less expensive technology goes deeper. Not only can agencies put computers on their workers' desks, but those computers are increasingly powerful and thus provide additional opportunities that slower or memory-challenged devices could not have accommodated. For example, very large raster files, unmanageable until recently, no longer pose as much of an access problem as they once did.

**Crossjurisdiction alliances.** The belief that "all politics are local" has inhibited collaboration between police agencies. The mantra has been that local problems should be solved locally, although the use of State or Federal dollars was acceptable provided not too many strings were attached. Unfortunately, offenders have not subscribed to the notion that they should recognize city, county, and State lines.

The following inconsistencies among law enforcement agencies have acted to make political boundaries "law enforcement opaque" rather than transparent or invisible, as criminals perceive them:

- Different radio frequencies.

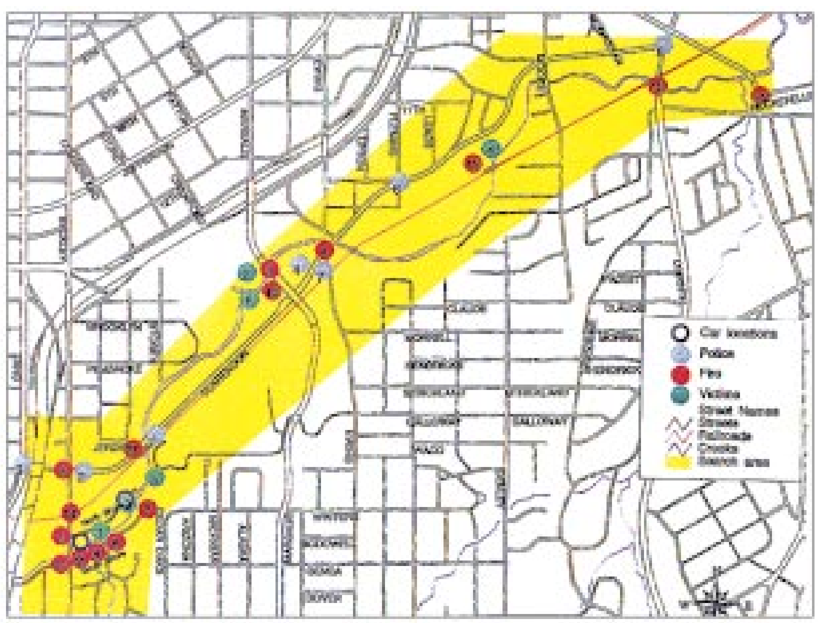


**Figure 5.5**

A map showing locational information relating to a flood in Dallas, Texas.

*Source: Mark Stallo and the Dallas, Texas, Police Department. Reproduced by permission.*

- Different protocols for hot pursuits.
- Agencies competing with one another in hot pursuits and investigations.
- Lack of information sharing and coordination between administrative units and/or agencies (referred to as "linkage blindness" by Rossmo, 1995).

Mapping has helped break down such barriers due to its power to provide visual evidence that criminal groups or individuals move across boundaries at will, sometimes intelligently exploiting the lack of communication between agencies. The increased interlinking of databases needs to be coupled with jurisdictional interlinking so that the official view of crime more closely corresponds to regional reality. Politically bounded areas, whether cities, counties, or States, rarely conform to social areas. Until policing areas more closely conform to or recognize social areas, crime analysis and prevention will be stymied to some degree. Crime mapping has tended to focus on technical issues, but the bigger picture—Are we mapping and analyzing the most appropriate areas?—also deserves attention. Crime can be a *regional* phenomenon. Regional problems call for regional solutions.

**Theory and practice.** Crime mapping is typically based on experience and observation, with a weak or nonexistent theoretical foundation. Empirical and theoretical perspectives battle each other in the here-and-now world of law enforcement. When tangible flesh-and-blood problems need to be taken care of immediately, theory is at best abstract, at worst completely irrelevant. But theory does have a place as a conceptual backdrop—a reference base that can provide consistency to our analyses and tactical responses. Eck (1997) pointed out that as the theoretical content of maps increases, it becomes easier to make sense of the data (see also Eck and Weisburd, 1995). In other words, if a map shows only crime locations, indepth explanation of pattern is next to impossible. But if other elements of context are included, such as the socioeconomic environment or locations of drug markets or of abandoned housing, (any elements that theory would lead us to expect to be linked to the crime pattern in some way), then understanding is likely to be enriched. For example, a CFS map, such as in figure 5.6, may be substantially more meaningful when the CFS are displayed along with housing code violations. "Negative" information showing where the anticipated link between conditions fails to apply may be just as useful as "positive" information showing where the link does apply.

**Data sharing.** Local and State governments are finding that data gathered by one agency might be valuable to others. This is not surprising, given the baffling complexity of social problems, including crime. Social scientists have long recognized that social systems are in some ways like natural ecosystems: change something and everything else changes to some degree. Land use patterns and changes, demographics, transportation system configurations, the weather, and the strength of social controls embedded in the culture—these and many more factors influence patterns of crime. It makes sense to give crime analysts access to the rich variety of data they need to help them answer the widely varied questions that come their way.

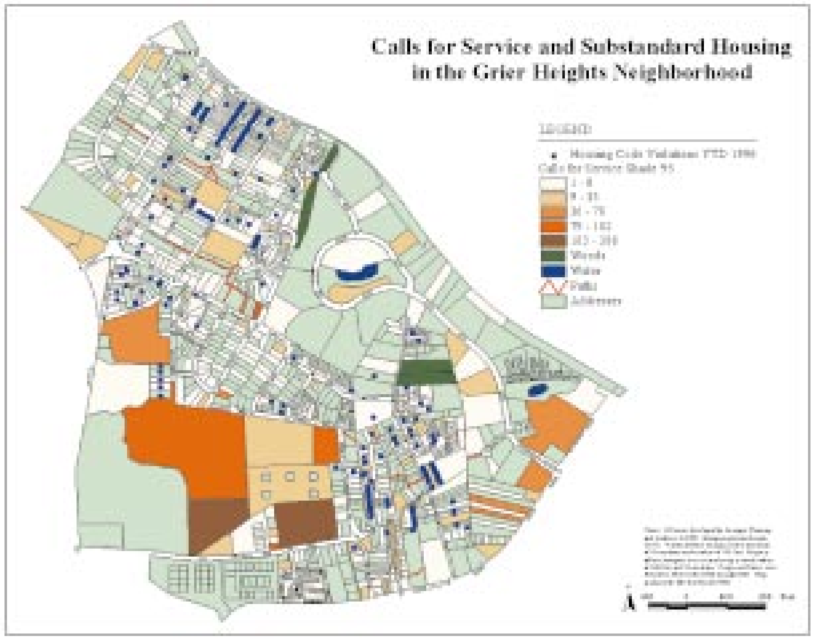



*Figure 5.6*

A map showing substandard housing and calls for service in the Grier Heights neighborhood, Charlotte-Mecklenberg, North Carolina.

*Source: Elizabeth Groff and Charlotte-Mecklenberg, North Carolina, Police Department. Reproduced by permission.*

Gradually, and inconsistently in terms of geography, "community" approaches to problem solving dictating collaboration and data sharing among agencies are gaining popularity.

**Context.** A relatively recent trend in crime analysis emerging from the community policing movement has been the increasing tendency to see crime "in context" rather than as a self-contained phenomenon with self-contained solutions. A broad view is needed, one that incorporates understanding of social background and crime patterns. Complete preoccupation with patterns and their immediate causes is a kind of professional shortsightedness that may miss fundamental causal processes (see Sherman et al., 1998, for more on the broad view of crime prevention). Crime analysis that ignores this wider perspective, or backdrop, runs the risk of ignoring important connections to community-based processes. This again reinforces the importance of making a variety of data available to police officers and crime analysts alike.

**Privacy issues.** Privacy questions are touched on elsewhere in this guide, but they also deserve a mention in any discussion of synthesis. In marked contrast to the cultures of many other developed nations, U.S. culture is quite resistant to government intrusion, even when that intrusion seems to be well intentioned and in the apparent best interest of the majority. Along with this goes a degree of mistrust of law enforcement, a posture reinforced by high-profile events such as the Rodney King affair in Los Angeles, the Abner Louima incident in New York City, and the Branch Davidian standoff in Waco, Texas. Fears of privacy violations by law enforcement are only part of broader societal concerns about privacy and the inherent mistrust of authority.

These concerns were exemplified by the controversy surrounding the activities of

Image Data, LLC, a small New Hampshire company that in 1999 attempted to build a national database of driver's license photographs, ostensibly to combat check and credit card fraud. After Colorado, Florida, and South Carolina had contracted to supply their license pictures, it was discovered that the photo file was also to be used to combat immigration abuses, terrorism, and other identity-related crimes. It then became known that Congress had contributed $1.5 million to the effort and that the U.S. Secret Service had lent a hand, elevating the controversy to new heights and provoking initiatives from the three States to cancel their contracts (O'Harrow and Leyden, 1999; for a more detailed analysis, see Paisner, 1999).

This type of data gathering is one of many ways in which data relating to individual persons, families, or households can be accessed and compiled. The use of branded credit cards and discount cards in stores enables retailers and marketing companies to track every purchase and develop spending profiles of consumers. When information from this kind of database is added to information that can be accessed via directories, maps, remotely sensed imagery (e.g., aerial photos, satellite images), and various and progressively more integrated public records, anxiety about privacy violations, real or imagined, understandably escalates.

Crime mapping can be seen as a piece of this privacy issue, although whether one elects to put a sinister spin on the technology is obviously a personal decision. As yet, no conspicuous backlash against crime mapping has occurred (with the possible exception of Megan's Law), but whether this type of public reaction will occur in the future is an open question.

**Public access.** Conflict over privacy and access is inevitable. For every person or group that lobbies to restrict the dissemination of crime-related information, another lobbies to gain more access. Surprisingly, access to crime data is still denied to researchers on occasion. Denying bona fide researchers access for projects that are ostensibly in the public interest clouds confidence in the data-gathering process, since it inevitably raises questions about the reasons for denial of access.[2] As noted elsewhere, it would seem that most crime data eventually are released to the public through court proceedings and so on. What could be damaging and should obviously be avoided is making unfounded data accessible to the public (e.g., on the Web), since it carries the accompanying risk of defaming the innocent.

A controversial development in recent years has been the tendency of some States to put lists of sex offenders on the Web, Virginia being the 10th State to do so in late 1998. The names of more than 4,600 violent sex offenders were made available to the public, with the effect of "giving parents a new tool to protect their children but also renewing fears about the erosion of privacy in the Information Age" (Timberg, 1998).

The names, ages, home addresses, conviction records, and photographs of Virginia offenders are listed at *http://www.vsp.state.va.us*, a Web site that recorded more than 650,000 visitors in less than 2 months after it was launched. Predictably, State officials were enthusiastic about the site, while civil libertarians suggested that it amounted to double punishment, with the additional possibility that offenders' children would be put in jeopardy. Other potential risks include the possibility of disseminating false information (from computer hackers or errors in the original files) and vigilantism. To date, registries have not been evaluated adequately, but they are greeted with enthusiasm by parents anxious to protect their children.

Many law enforcement agencies have developed Web sites displaying crime maps (see appendix and various examples throughout this guide). Some elect to show crimes in the form of point data, while others use *choropleth* or shade maps. Sharp differences of opinion have been voiced over the appropriateness of such maps. Opponents fear negative consequences for high-crime communities; under the worst case scenario, crime maps may provoke full-scale flight from neighborhoods. Proponents tend to be community-policing advocates who see full disclosure of information as a tool in crime prevention. They see Web-based maps as community resources providing citizens with unbiased, ready access to crime patterns. If citizens can see where crime is, the argument goes, they will be better collaborators in crime prevention.

## Mapping applications for the millennium

Crime mapping can be applied to the following criminal justice areas: criminal intelligence, crime prevention, courts and corrections, public information, and resource allocation and planning.

### Criminal intelligence

Building criminal cases can be a painstaking process involving the compilation of information from diverse sources. All the data have a geographic dimension, although the importance of the locational information varies from vital to unimportant. Spatial data may provide answers to obvious questions about the crime scene, such as, Where is it?, but they also provide information for less obvious questions, such as, Where is this crime scene in relation to other relevant persons or objects? What locational information can be derived from victims, offenders, and witnesses? Can the geographic data be codified in the form of a map, and, if so, would such a map be useful to investigators? Investigators might map links between a suspect and his or her associates' home addresses to identify where the suspect's daily or weekly activities take place—the *activity space*. Another possibility would involve mapping gang graffiti as a way of defining gang territory.

Geographic analysis may be helpful on radically differing scales. For example, very large scale, or high-resolution, GIS could help with representing spatial data at crime scenes, such as the arrangement of objects in various rooms in a house or the pattern of crime in a highrise building in three dimensions (for more on this, see chapter 6). Other data may be better represented on a small scale—for example, facts relating to suspect movements in other cities or states. Depending on the importance of spatial information, a mini-atlas could be compiled, bringing together all the known geographic information and putting it in the context of other data.

Moland (1998) describes a case study in crime mapping in which a "cellular phone trail" was left by one suspect, providing an opportunity to plot spatial and temporal paths of two suspects. Detectives worked with telephone company technicians to verify that various antenna locations were working and to establish various aspects of cell phone signal patterns. One of the key pieces of evidence presented in court was figure 5.7, which shows cell phone antenna locations associated with the suspects' activities. This example illustrates not only the use of mapping to develop criminal intelligence, but also the use of mapping to develop courtroom evidence. The two men ultimately were convicted and sentenced to life in prison for a gruesome murder. Maps in the courtroom helped the prosecution walk the jury through a complex set of events by illustrating the collateral spatial relationships.

The information shown in figure 5.8 could also be used to document a pattern showing where and when incidents occurred based on the times of the related calls for service, as well as to provide information to corroborate information from witnesses.

As with any new technology, the risk of overselling GIS may lead to unrealistic expectations and dashed hopes. The best case scenario would include GIS as a useful contributor to the investigative process (see also the section titled, "Geographic profiling," in chapter 6).

## Crime prevention

In a publication titled *Preventing Crime: What Works, What Doesn't, What's Promising*, Sherman et al. (1998) document "what works" for 11 crime problems. They identify approximately 30 actions or conditions as "promising."

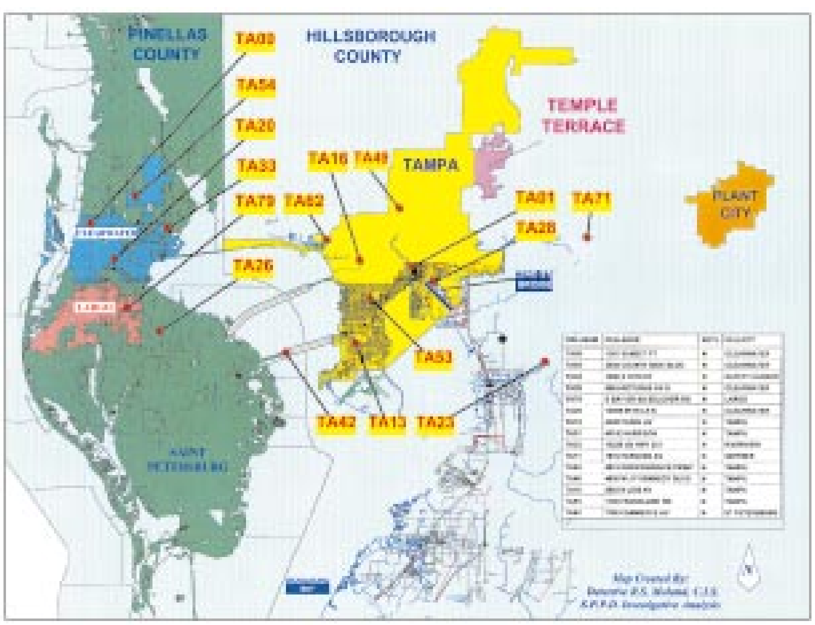



**Figure 5.7**

A map showing key telephone antenna locations delineating two suspects' activity.

*Source: Robert S. Moland, St. Petersburg, Florida, Police Department. Originally published in Moland, 1998, figure 3. Reproduced by permission.*

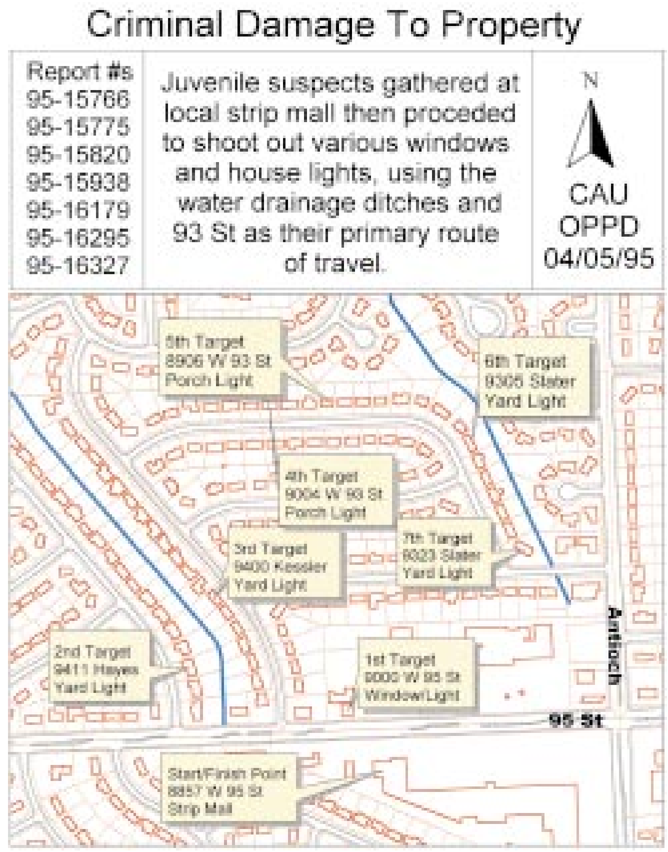



***Figure 5.8***

A map showing a pattern of criminal damage to property, Overland Park, Kansas.

*Source: Gerald G. Tallman, Manager, Crime Analysis Unit, Overland Park, Kansas, Police Department. Reproduced by permission.*

What is interesting about these lists is that many of the actions had little or nothing to do with policing. Many were amenable to the application of mapping tools, whether they were related to crime or other phenomena. This finding underscores that the label "crime mapping" is much too narrow a designation for what police departments do.

While some crime prevention actions were in the domain of schools or social service agencies, such as frequent visits by nurses to the homes of mothers and infants at risk, some were more directly connected to policing and had locational components that lent themselves to the application of geographic tools:

- **Nuisance abatement action on landlords of rental housing plagued by drug dealing.** Where are the landlords? Where are the subject properties? What properties does a certain landlord own across a city? Once mapped, how can nuisance abatement action be planned to make the best use of both time and space resources? Can a network analysis program be used to optimize visits to properties?

- **Extra police patrols for high-crime hot spots.** Where are the hot spots? How can patrol resources be optimized so that the patrol presence is proportional to the severity of crime in the hot spot? (Hot spots could be evaluated in terms of responses that allocate a fair share of the resources available on a given shift.)

- **Monitoring of high-risk repeat offenders by specialized police patrols.** Where do released repeat offenders live? What does this pattern look like? Can repeat offenders be categorized or prioritized by the degree of risk they present, including the risk of repeating and the potential severity of the crimes they are likely to commit based on their histories?

- **On-scene arrests for domestic abusers who are employed or who live in areas where most households have an employed adult.** Where are the salient locations? What are the home and work addresses of offenders? Can information on the current whereabouts of offenders and other locational data be maintained in a periodically updated registry?

- **Therapeutic community treatment programs for drug-using offenders in prison.** This action recommendation reflects the work of Harris, Huenke, and O'Connell (1998). They used mapping to increase released offenders' access to services in Delaware, plotting locations of substance abuse, mental health, employment, and other social services, and relating them to the most recent addresses of probationers or parolees.

An example of a crime prevention program using geographic data in creative ways is the *autodialer* system employed by the Baltimore County Police Department in Maryland (Canter, 1997, 1998). Analysts subjectively identify clusters of incidents that have similar modus operandi and occur relatively close to one another (figure 5.9). Then a GIS is used first to randomly select telephone numbers in the ZIP Code area coinciding with the area under analysis, and second to further narrow down the numbers to the general area of the crime hot spot. The autodialer then calls all the telephone numbers on the list with a message from the police department relaying precautions to take and asking for reports of suspicious behavior. Experience shows that because some displacement of crime seems to occur, target polygons or areas must be expanded to take this displacement into account. Evaluation of the system suggests that it influences the actions of the community, the offender, and the police. Community awareness appears to heighten (911 calls reporting suspicious persons and vehicles increase significantly), and crime appears reduced, in spite of the moderate displacement effect.

## Courts and corrections

Crime mapping can be applied to the following courts and corrections areas.

- **Probation officer service areas.** Caseload distributions can be managed by looking at the geographic location of probationers and parolees, and then using a mapping program, such as the ArcView Network Analyst, to determine the most efficient route for sequencing visits to homes, should visits be part of the designated probation officer's duties. If visits to individuals have to be made at specific times, a route can be designed to minimize time

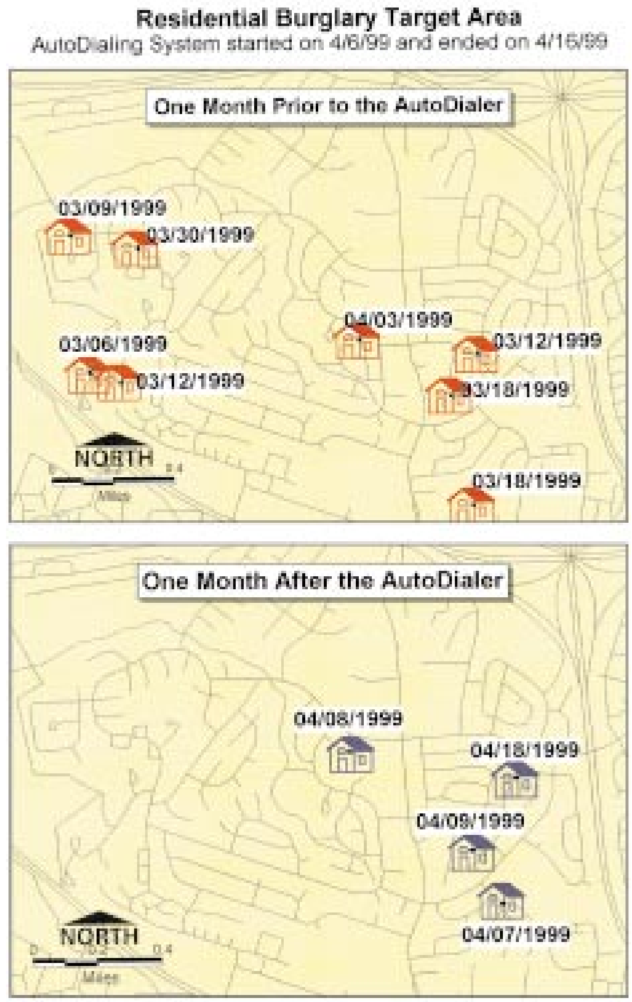



**Figure 5.9**

A map showing a residential burglary target area before and after autodialing.

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

spent traveling from one address to the next. If time is not a factor, a route to minimize overall travel time can be determined (figure 5.10).

With the development of community probation, officers are now more likely to be assigned to small community areas so that they have closer contact with probationers and community resources, including police. A program, such as MapInfo® Redistricter, could be used to draw (and periodically redraw) districts based on the distribution of caseloads. Similarly, districts could be drawn to equalize workloads for serving warrants. Other applications in the probation field could include mapping dangerous areas where probation officers should be accompanied by a police officer or mapping areas that probationers are to avoid (figure 5.11).

- **Prison location analysis.** Prison building, a booming industry in recent decades, frequently runs into the NIMBY (not in my back yard) problem. Almost everyone agrees that prisons have to be built, but few communities (with the exception of rural locations desperate for jobs) want them next door. Prison location analysis is a specialized application of GIS. Location modeling has actually been in use

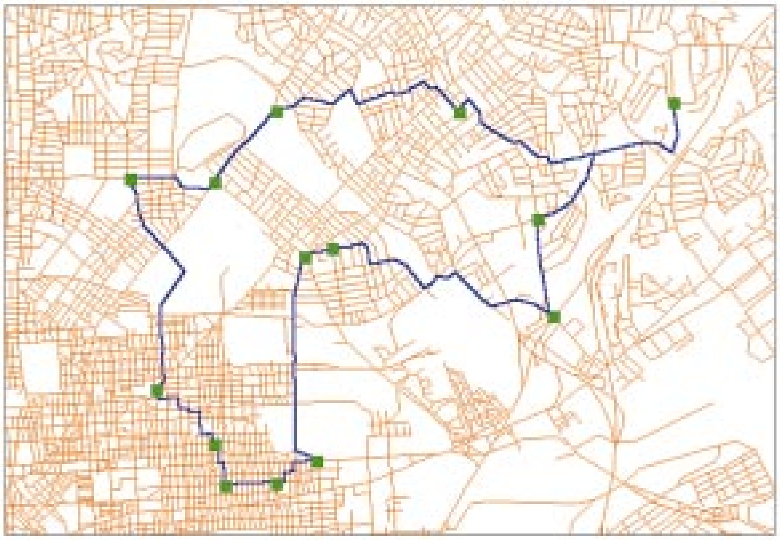


**Figure 5.10**

A map showing a route designed to minimize travel time between points determined by the ArcView® Network Analyst mapping program. The program can also print street directions.

*Source: Keith Harries.*

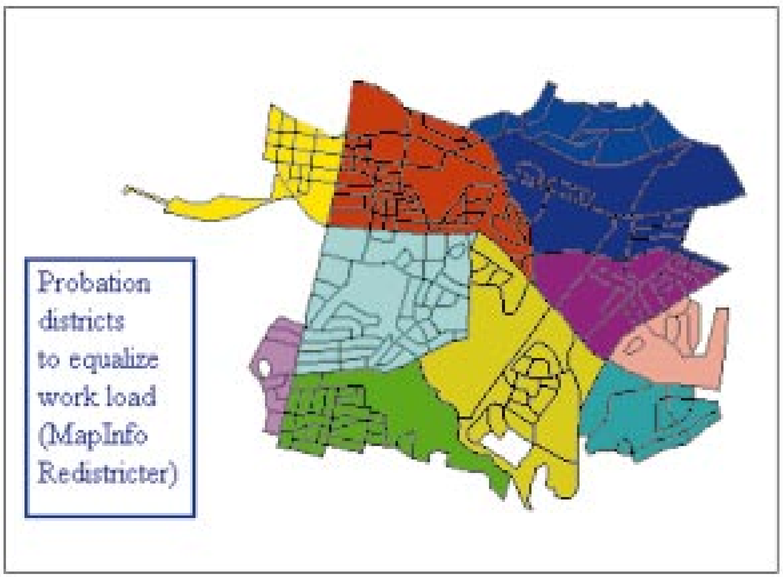



**Figure 5.11**

A map showing community probation districts mapped to equalize workloads using MapInfo® Redistricter.

*Source: Keith Harries.*

for some time. The basic approach involves mapping vacant and redevelopable land as possible sites for building, then adding layers for exclusions (due to factors such as terrain, prohibited land uses, lack of utilities, and lack of adequate transportation links) to identify the sites with the greatest potential for development. These sites can then be reviewed and prioritized with further map analysis or field investigation.

Another locational criterion could be the site's distance from communities supplying the majority of inmates. Prisons far from their feeder communities make visitation difficult and may fragment families. Minimizing travel time may be a consideration not only for families, but also for the department of corrections and the court system, because transporting prisoners to and from remote court offices will increase travel time and cost. The accessibility of a prison to a courthouse can be evaluated using ArcView Network Analyst (figure 5.12).

- **Probationer and parolee locations.** The mapping of home addresses of parolees and probationers, along with modus operandi data, enable law enforcement to quickly identify local parolees as potential perpetrators of particular crimes occurring in a neighborhood. This type of analysis is an integral part of the increasingly popular ComStat (computerized statistics) process that originated with the New York City Police Department, in which precinct commanders are quizzed regularly about crime patterns in their areas. A big screen monitor linked to a GIS can immediately show parolee locations in conjunction with offense locations (see chapter 3). Recidivism could also be mapped to identify hot spots and mobilize resources necessary to deal with the issue. Parole and probation agencies are rich in locational information that can be used to manage caseloads, including sex offender registries (figures 5.13 and 5.14).

- **Halfway house locations.** Much like prisons or group homes for mentally disabled people, halfway houses provoke NIMBY reactions. Mapping demographics and housing types may help with site selection. In an example cited by Westerfeld (1999), a Baltimore community needed to be persuaded that halfway houses were appropriate in its neighborhoods. The strategy that was developed involved geocoding the home locations of all Maryland prison inmates originally from the community in question. Maps then showed where each inmate had lived. During community presentations, it became increasingly difficult for residents to oppose receiving people who originally resided in their neighborhoods.

  However, publicity about the high number of escapes from halfway houses in some jurisdictions compounds the difficulty of locating such facilities. One solution is to seek a zoning variance to permit residential facilities in what are otherwise industrial or commercial areas. Presumably, this is a last resort.

**Figure 5.12**

A map showing accessibility to a central point. Three zones, each representing a specific travel time are mapped using ArcView® Network Analyst.

*Source: Keith Harries.*

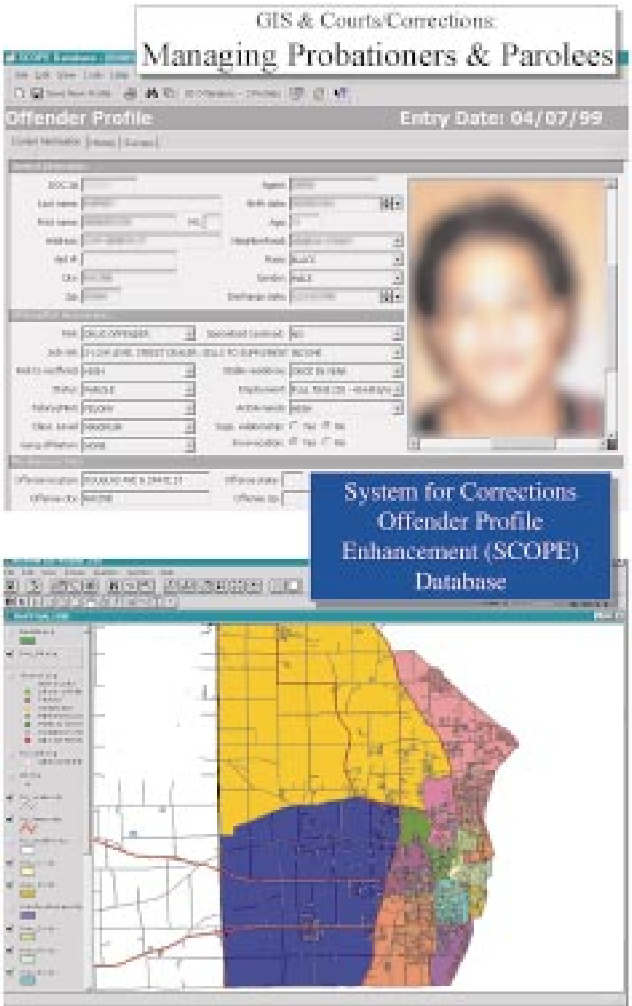



**Figure 5.13**

An offender profile and a draft map of offenders in various categories. (Details intentionally obscured.)

*Source: Eric Kim and the Wisconsin State Department of Corrections. Reproduced by permission.*

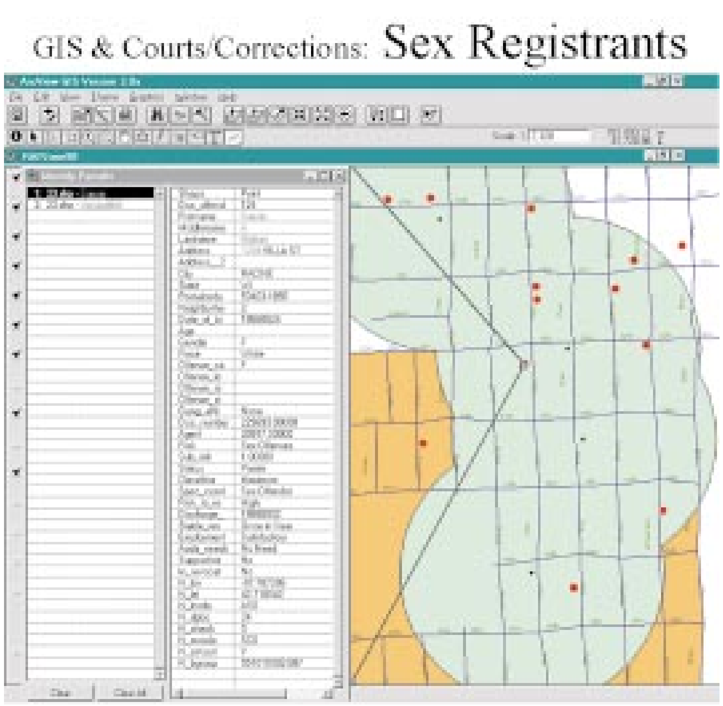



**Figure 5.14**

A draft map of buffers around the locations of sex registrants.

*Source: Eric Kim and the Wisconsin State Department of Corrections. Reproduced by permission.*

A cynical solution suggests that poor, dysfunctional communities are likely to be incapable of mobilizing themselves politically so as to make the locating of halfway houses relatively free of opposition.

- **Offender access to services.** A Delaware study (Harris, Huenke, and O'Connell, 1998) analyzed the availability of rehabilitative services for released offenders, looking at the spatial relationship between former inmate addresses, substance abuse treatment facilities, social service centers, mental health services, and unemployment offices. Nearly half of all released prisoners in Delaware return to prison within 3 years, leading to the conclusion that postprison rehabilitation services are inadequate, or at least inaccessible. Maps were used to justify the implementation of drug rehabilitation services in Kent County and the city of Dover.

- **Sentence mapping.** A mapping application used occasionally by court systems deals with the need to ensure fair sentencing. Although judicial discretion has been reduced by mandatory sentencing, it has not been eliminated (and never will be, of course), and substantial disparity remains in the sentencing of similar people for similar crimes. Like police agencies, courts in both the State and Federal systems have territories. The mapping of sentences is more technically challenging than mapping crime incident data. However, it can be done using, for example, a weighting system that assigns higher weights to more severe sentences, making sure that analysis of offender characteristics and crime types is properly controlled for. (For details on this concept and examples of geographic analyses of sentencing, see Harries and Lura, 1974, and Harries and Brunn, 1978. For a discussion of geographic issues specifically relating to capital sentencing, see Harries and Cheatwood, 1997.)

- **Courtroom presentation.** As noted in the discussion of figure 5.7, maps showing sequences of events and patterns can be used in court to provide an easily comprehended visual rendition of a criminal process. Such presentations may be constructed on any scale, from international drug trafficking to the layout of a murder scene in one room of a building. In figure 5.15, the information on a sequence of events involving sexual torture and hostage taking was mapped to provide the prosecution with a plausible chronology of events that could be readily communicated to judge and jury.

## Public information

"Public information" is a phrase that evokes mixed emotions in police departments. Some make vast amounts of data readily accessible to the public through the Web, while others are reluctant to have a Web site at all, let alone include crime data on it. At the risk of stereotyping, it could be suggested that the more defensive posture tends to reflect "old school" thinking, whereas willingness to share data represents a more contemporary, "let the light shine in" approach, consistent with community policing values.

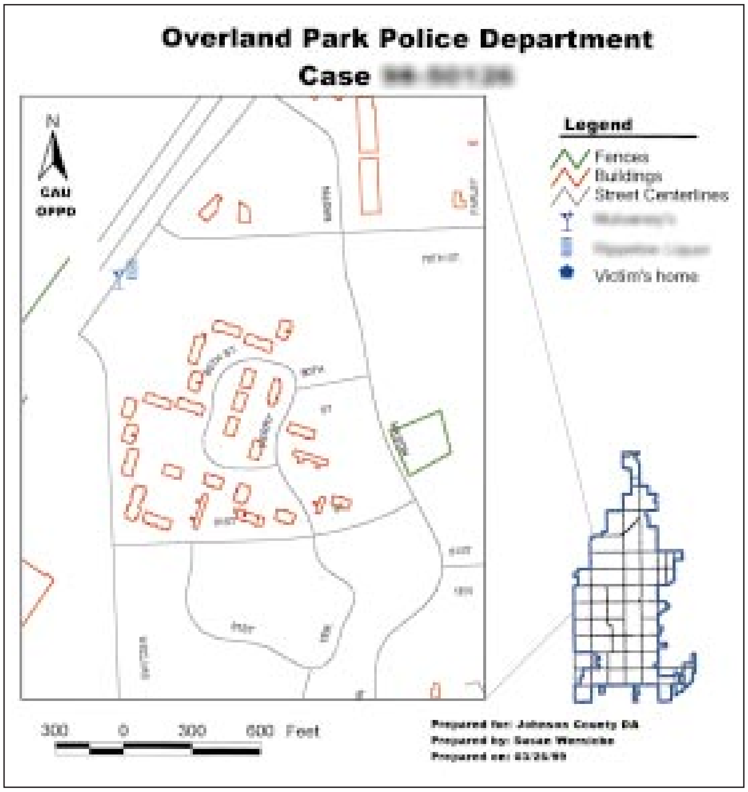



*Figure 5.15*

An example of a map used in court in Overland Park, Kansas, to substantiate the times the victim reported she was in certain places. The victim's address and other details have been modified or erased to protect the privacy of the victim in this case.

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

Even the most avid proponents of data access would concede that cases with ongoing investigations should be exempt for obvious reasons. However, beyond active cases and cases involving rape victims and juveniles, active concealment is difficult to justify. From a public policy perspective, one of the strongest justifications for open data access is that it makes putting a "political spin" on things somewhat more difficult. Every agency, at every level of government, wants to make itself look good, and to this end information is power. Limit information dissemination and the power of the opposition is crimped.

Some public constituencies also prefer to suppress crime data, and particularly crime mapping data, from public view for fear that their investments will be negatively affected. Such considerations seem of particular concern to realtors and some property owner's associations. The rationale is that any publicity about crime tends to depress property values. But what is overlooked is that publicity about crime may draw more attention to the problem with the possibility of remedial action. In this context, the possibility of long-term gain is sacrificed for short-term expediency.

The more prevalent perspective today is that an informed public can best assist law enforcement, given that police cannot be in all places at all times, and that policing will be most effective when it is performed in an environment in which the public offers active support. Clearly, maps are tools that can assist in this effort through their use at community meetings and their distribution to the media, citizen patrols, and neighborhood groups. However, maps must be tailored to each group, and a poorly designed or poorly presented map may do more harm than good by creating confusion where none may have existed before.

Internet media offer public information opportunities that go beyond merely having a Web site or providing maps. The Web also offers opportunities for feedback from the public via survey forms that solicit information about specific crimes or problem areas and neighborhood-specific bulletins. A review of police department Web sites linked through the Crime Mapping Research Center Web site (see appendix) demonstrates some of the many possibilities.

### Resource allocation and planning

As noted in chapter 3, the fundamental principle behind resource allocation is the efficient assignment of valuable resources. In theory, at least, more resources should be assigned to areas where crime is most prevalent. It was suggested in chapter 3 that calls for service be used as either a crude or weighted index to help determine the allocation of patrol resources on a per-shift basis. A choropleth map of neighborhoods classified by their levels of CFS could be the tool used for planning resource allocation.

In a community policing context, this approach can be expanded by looking not only at the calls for service themselves, but at the local social conditions associated with high levels of CFS. This not only forms a foundation for planning direct law enforcement strategies, but also sets the scene for cooperation with other criminal justice system agencies and social service agencies. An example of this approach, applied in Cincinnati, is shown in figure 5.16. The choropleth map of calls for service by neighborhood and analysis of social indicators showed that the prevalence of nonowner-occupied housing was the strongest social correlate of CFS levels. Models that relate social conditions to levels of crime or CFS take many different forms, and examples can be found in the literature on the social ecology and geography of crime (Felson, 1998; Byrne and Sampson, 1986; Harries and Powell, 1994; Harries, 1995; Taub, Taylor, and Dunham, 1984; Bursik and Grasmick, 1993; and Rose and McClain, 1990).

## Crime analysis and the census

Postings on the Crime Mapping Research Center's listserv indicate that the manipulation of census data is a confusing obstacle for many analysts. This is not surprising, since census data and census geography are somewhat complex, or can be, depending on what you are trying to do. Among the most problematic areas are linking census geographies to data and misunderstandings relating to what can reasonably be, and not be, done with specific census "counts" and variables.

For example, what measure of income should be used? The census contains data on *family* income and *household* income. Families are subsets of households, so these data for families exclude single persons living alone or unrelated persons living together (who constitute households). Family income will be higher than household income because the average family has more wage earners than the average household. Normally, because

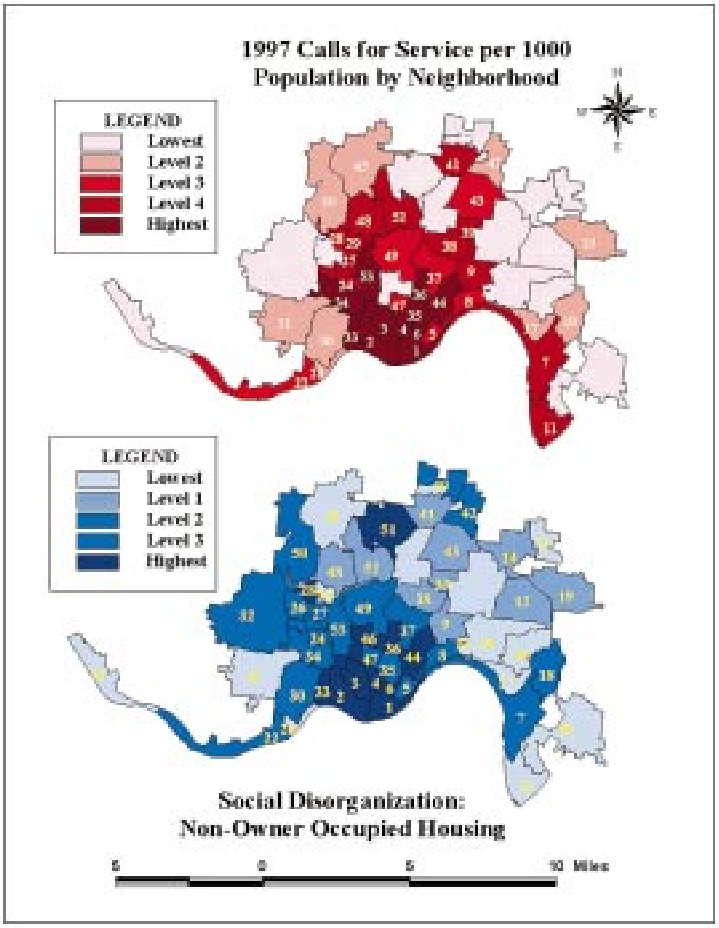



**Figure 5.16**

(Top) A map showing calls for service in 1997 per 1,000 people by neighborhood in Cincinnati, Ohio. (Bottom) A map showing nonowner-occupied housing, which can be used as an index of possible social disorganization.

*Sources: Shape files and analysis by A. Ball, COPS Regional Institute, and M. Neumann, Cincinnati, Ohio, Police Department. Adapted by permission.*

it is more inclusive, the preferred measure is household income.

A second question arises: Is it best to use *median* income or *mean* income? The mean has the advantage of being able to be manipulated mathematically, but in a skewed distribution, such as is found with income, the mean may be “pulled” to the right by the very high values of the extremely rich (the so-called Bill Gates Effect!). For such skewed distributions, the median is usually preferred since it gives a more accurate description.

Detailed treatment of these questions is beyond the scope of this guide. An excellent review of issues in census geography and the analysis of change using census data can be found in Myers (1992).

## Conclusion

Mapping criminal justice elements is well advanced, although unevenly distributed among police agencies. Most applications are horizontal, which is to say within the various levels of the criminal justice system. The real challenge is to integrate mapping applications vertically, so that agencies can be linked according to specific problems and be regionally integrated. This is a tall order given the political insularity of agencies and turf and control issues. The perfect world of analysis and mapping might look something like table 5.1. Ideally, mapping applications would be integrated to permit automated multistep analyses. Quite apart from political impediments to data integration, technical obstacles can make integrated analysis

**Table 5.1. Horizontal and vertical linkages in analysis and mapping among criminal justice entities**

| Agencies | Current Mode | Ideal Mode | + Region |
|---|---|---|---|
| Law enforcement ↔ | Independent analysis | ↕ | ↕ |
| Courts ↔ | Independent analysis | | |
| Corrections ↔ | Independent analysis | | |

*Source: Keith Harries.*

quite cumbersome because many *spatial joins*, which link databases according to their geography, are needed to indicate how records relate to geographic areas.

## Summary

Chapter 5 has explained:

- The characteristics of crime mapping for the new millennium.
- How crime mapping can be applied to:
    - Criminal intelligence.
    - Crime prevention.
    - Courts and corrections.
    - Public information.
    - Resource allocation and planning.
- Where to obtain a better understanding of census geography and analysis.
- How crime mapping applications could be broadened to improve their effectiveness.

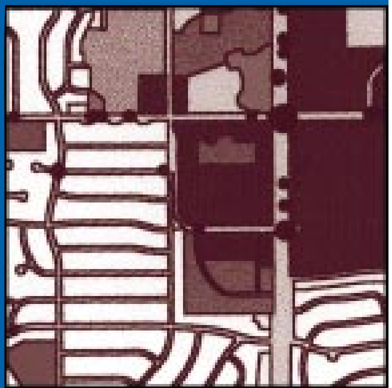
## Notes

1. Personal communication from Michael Ratcliffe, U.S. Census Bureau, Population Division, January 25, 1999.

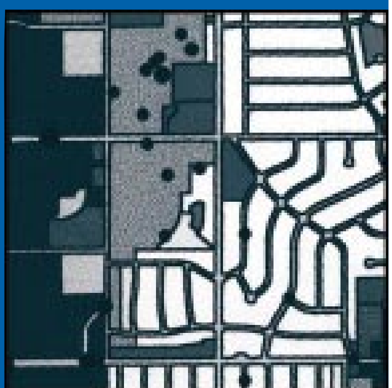
2. While most law enforcement-academic collaborations are amicable and productive, this is not always the case owing to the vagaries of human nature that occasionally leave either or both parties feeling used and abused. As in other relationships, the key to success seems to be the unsurprising revelation that all parties should be sensitive to the others and avoid exploitive actions.

### What's Next in Chapter 6?

- *Types of changes that may be expected in the next decade.*
- *Geographic profiling.*
- *High-resolution GIS.*
- *The use of complex statistical methods in spatial forecasting.*
- *Aerial photography.*
- *How various kinds of data visualization can be integrated productively.*
- *GIS and global positioning systems (GPS).*
- *The possibility of limits to data access.*
- *Applications of multimedia and integration technologies.*

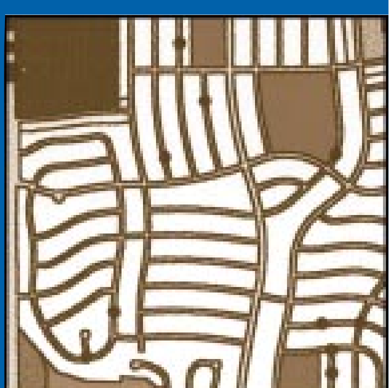


# Chapter 6:
## Crime Mapping Futures



Applications in crime mapping are becoming increasingly sophisticated and integrated. The hallmark of the first decade or so of the modern era of crime mapping was the use of geographic information systems (GIS). Perhaps the next decade will see the integration of previously separate technologies such as global positioning systems (GPS), orthophotography, digital photography, digital videography, and a wide range of local databases with relevance to policing—and the World Wide Web. Another realm of potential progress lies in forecasting. A remarkable indication of the level of interest in crime mapping and related technologies was contained in President Clinton's State of the Union Address on January 19, 1999, in which he said:

> Tonight, I propose a 21st century Crime Bill to deploy the latest technologies and tactics . . . [to] put up to 50,000 more police on the street in the areas hardest hit by crime, and *then to equip them with new tools—from crime-mapping computers to digital mug shots.* [Emphasis added.]



While it is not possible to explain or even identify all the innovative crime mapping applications in the field or under development, the following are outlined below to provide a sense of the kinds of methods and technologies that are likely to find increasing acceptance in the years ahead: geographic profiling, which has already found wide recognition and is representative of a method that creatively combines various tools of spatial analysis; high-resolution GIS; statistical methods and forecasting; digital aerial photography; and the integration of GIS and GPS.

## Geographic profiling[1]

Geographic profiling is an investigative methodology that uses the locations of a connected series of crimes to determine the most probable area that an offender lives in. Although it is generally applied in serial murder, rape, arson, robbery, and bombing cases, geographic profiling also can be used in single crimes that involve multiple scenes or other significant geographic characteristics.

Developed from research conducted at Simon Fraser University's School of Criminology and rooted in the pathbreaking work of Brantingham and Brantingham (1981), the methodology is based on a model that describes the hunting behavior of the offender. The criminal geographic targeting (CGT) program uses overlapping distance-decay functions centered on each crime location to produce *jeopardy surfaces*—three-dimensional probability surfaces that indicate the area where the offender probably lives. The distance-decay concept (see chapter 1) conveys the idea that people, including criminals, generally take more short trips and fewer long trips in the course of their daily lives, which may include criminal activities. Thus *overlapping distance-decay functions* are sets of curves expressing this phenomenon and suggesting, for example, that it is more likely that offenders live close to the sites of their crimes than far away. Probability surfaces can be displayed on both two- and three-dimensional color isopleth maps, which then provide a focus for investigative efforts (see chapter 1 for a description of isopleth maps).

This research has led to the development of *Rigel*, a computerized geographic profiling workstation that incorporates an analytic engine, GIS capability, database management, and powerful visualization tools. Crime locations, which are broken down by type (e.g., victim encounter, murder, and body dump sites for a murder), are entered by address, latitude/longitude, or digitization. Scenarios wherein crime locations are weighted based on certain theoretical and methodological principles are created next and examined. The addresses of suspects can then be evaluated according to their "hit" percentage on a probability chart known as a z-score histogram, which can prioritize registered sex offenders, other known criminals, task force tips, and other information contained in databases.

Geographic profiling can be used as the basis for several investigative strategies. Some of the more common ones include:

- Suspect and tip prioritization.
- Address-based searches of police record systems.
- Patrol saturation and surveillance.
- Canvasses and searches.
- Mass DNA screening prioritization.

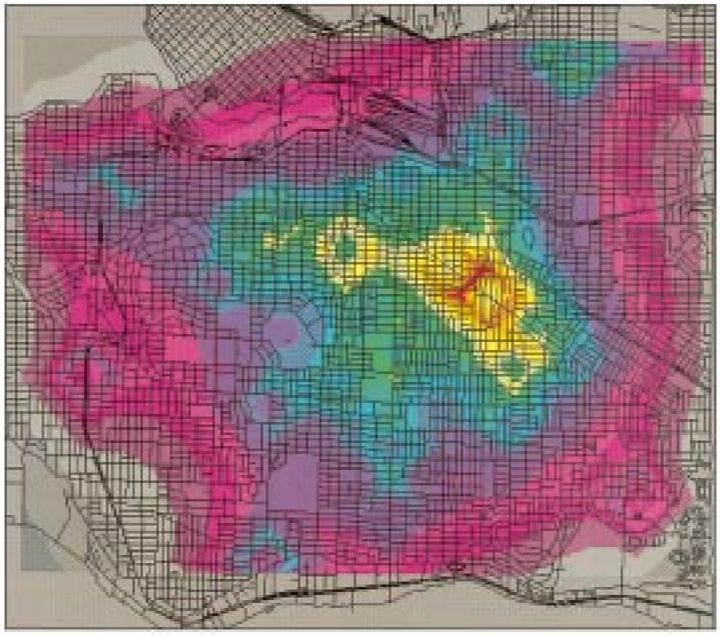


**Figure 6.1**

A geoprofile of a series of armed robberies in Vancouver, British Columbia, Canada.

*Source: Det. Insp. D. Kim Rossmo, Vancouver, British Columbia, Police Department. Reproduced by permission.*

- Department of motor vehicles searches.
- ZIP Code prioritization.
- Information request mailouts.

Figure 6.1 displays the geoprofile produced from the analysis of 32 armed robberies that occurred over a period of approximately 12 months in the city of Vancouver, British Columbia, Canada. The purple areas around the periphery are less likely to include offenders' residences, and the yellow and orange areas in the center are more likely to include offenders' residences. Three strategies were predicated on the geographic profile in this case. First, a search was conducted of the Vancouver Police Department's Records Management System for known robbery offenders who matched the criminals' descriptions and resided within the top 5 percent of geographic areas identified in the geoprofile. This did not produce any viable matches, as neither offender had had a previous conviction for robbery.

Second, a simplified geoprofile, displaying only the top 2 percent (0.7 square miles) of potential offender residences, was produced for patrol officers. Previous research determined that robbery offenders usually return home after committing a crime. It was therefore suggested that, in addition to responding to a crime scene after the report of a new robbery, patrol members should also search the most likely area of offender residence, paying particular attention to logical routes of travel. This also was unsuccessful as the offenders were using stolen cars and no reliable vehicle descriptions were ever obtained (even though the geoprofile was used by police units to search for stolen automobiles that might be abandoned prior to a new robbery).

Third, the results of the geoprofile were released on the television show "CrimeStoppers." This approach was successful, producing results that allowed the detectives to identify the offenders responsible for the series of robberies. The primary offender's address was located within the top 1 percent of the peak area of the geoprofile.

It is important to stress that geographic profiling does not solve cases, but rather provides a means for managing the large volume of information typically generated in major crime investigations. It should be regarded as one of several powerful decision support tools available to the detective and is best employed in conjunction with other police methods. Geographic crime patterns are clues that, when properly decoded, can be used to point in the direction of the offender.[2]

Currently, geographic profiling services are available from the Vancouver Police Department, Geographic Profiling Section, Vancouver, British Columbia, Canada; the Royal Canadian Mounted Police, Pacific Region ViCLAS Section, also in Vancouver; and the Ontario Provincial Police, Behavioral Sciences Section, Orillia, Ontario, Canada. It will be available in the near future from the British National Crime Faculty, Bramshill, United Kingdom.

Concerned about the mapping and prediction of serial crimes, Geggie (1998) reported on the work of Officer Timothy Meicher of the Los Angeles Police Department. The case related to robberies involving a perpetrator who rode a motorcycle and snatched purses from elderly victims in shopping center parking lots—hence the title "the Los Angeles Motorcycle Bandit." Employing basic statistical concepts—mean and standard deviation—Meicher produced a map with boundaries indicating two probability levels for the next bandit strike, one at 68 percent and the other at 95 percent (figure 6.2). Meicher then collaborated with Geggie to automate the process of producing the probability map. Their model was subsequently distributed both inside and outside the Los Angeles Police Department.

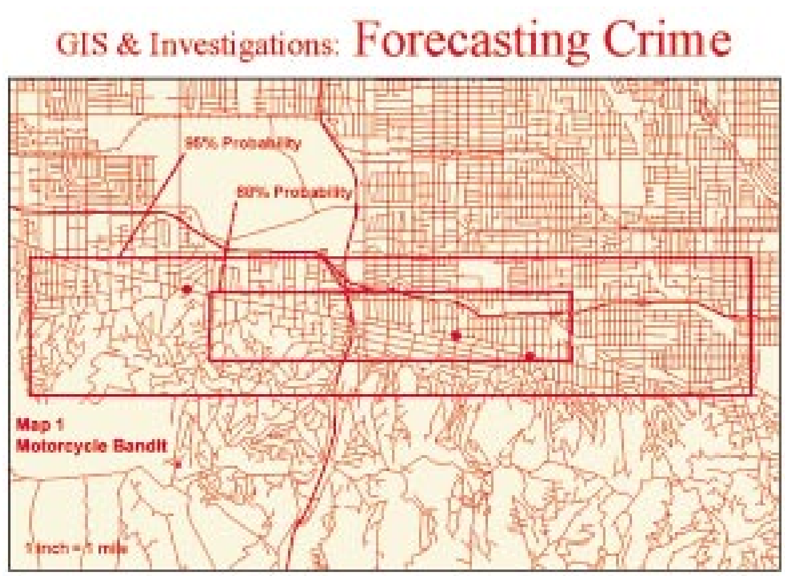



**Figure 6.2**

A map showing probability boundaries in the Los Angeles, California, Motorcycle Bandit case.

*Source: Geggie, 1998. Reproduced by permission.*

## High-resolution GIS

We often lose sight of the fact that GIS can be useful on any geographic scale, from global (small scale) to small (large scale), such as a room. Most crime analysis is conducted on what could be labeled medium scale, typically representing a city or neighborhoods within a city. Rengert, Mattson, and Henderson (1998) have reported on GIS applied to individual buildings or other small areas, such as street segments, terming this approach high-resolution GIS. The four panels of figure 6.3 contain several views representative of this approach. In the upper left panel, a "plan" view shows the footprint of a highrise building on the Temple University campus in Philadelphia. Crime incidents have been compressed so that they are all seen as if at one level. This compression enables law enforcement to determine whether incidents might be clustered around elevator shafts, for example, or restrooms, which tend to be at identical locations on each floor of a highrise. The upper right panel provides a perspective of the building with incident locations in their three-dimensional positions. At lower left, a technique for delineating clusters uses spheres to provide a sense of what might be called "highrise hot spots." Then at lower right, a cluster within a cluster defines the limits of the larger pattern of incidents and then focuses on the denser pattern within.

## Forecasting: Complex statistical methods and crime mapping

In cooperation with the Pittsburgh Police Department, Olligschlaeger (1997) employed advanced statistical methods in an attempt to identify *emerging* drug markets, which

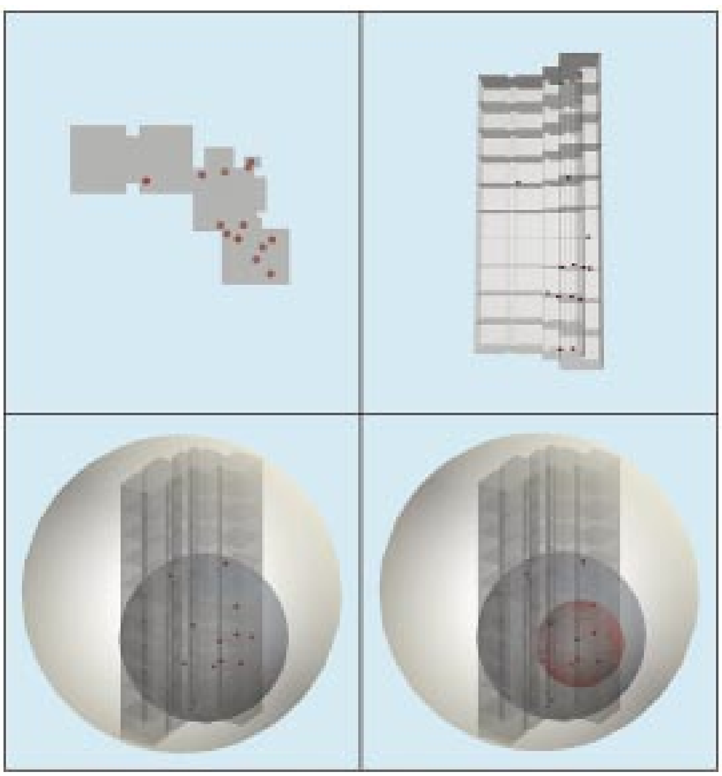


**Figure 6.3**

A map using high-resolution GIS to show crime in a highrise building.

*Source: Rengert, Mattson, and Henderson, 1998. Reproduced by permission.*

are relatively difficult to detect by conventional means. This is because they often are revealed only indirectly through the commission of other crimes, such as robberies or burglaries, and then only after a delay. Given the importance of drug markets as crime generators, early warning is useful. Three types of calls for service (CFS) were used to develop models: *weapon-related*, *robbery*, and *assault*. *Commercial land use* and *seasonality* were also included as model criteria based on evidence in the literature. A grid of cells measuring 2,150 square feet was then superimposed on the city, with the size of the cells determined by the need to have cells big enough to represent a reasonable number of CFS, but small enough to supply an adequate number to satisfy statistical modeling requirements. The grids were then used as the framework for choropleth maps.

Following rules based on gaming simulation, a statistical model estimated the consequences of the various types of CFS at certain levels. (For details of the model's architecture and specifications, see Olligschlaeger, 1997). Then forecasts from different methods were compared with actual patterns to provide a basis for evaluation.

Experience showed that a type of gaming simulation model known as the neural model did better than other types tested. A difficulty with the analysis—namely, the use of large quantities of computer resources—becomes less of a problem as the power of personal computer processors increases. Overall, the analysis suggested that advanced methods of the type tested—the neural model—could be useful tools in spatial forecasting.

## Mapping change: From pins to grids

Also employing a grid mode of representation for Pittsburgh, Gorr used 750-foot cells approximating four city blocks. Based on a pin map, a grid map (figure 6.4)

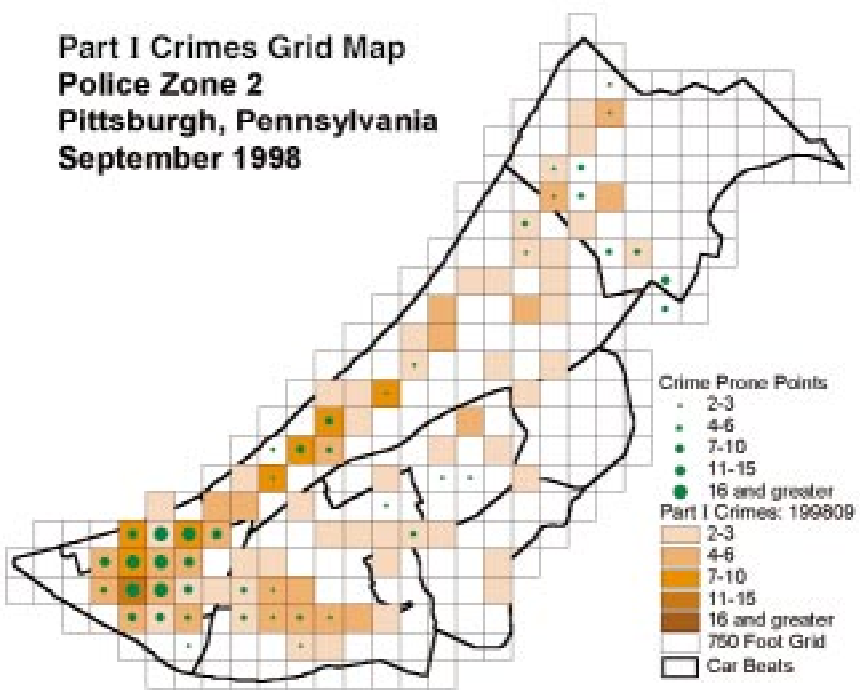



**Figure 6.4**

A map of grid cells. Reproduced by permission.

*Source: Wilpen Gorr, Heinz School of Public Policy and Management, Carnegie Mellon University, Pittsburgh, Pennsylvania. Reproduced by permission.*

displays the Part I crimes from the pin map in each grid cell, suppressing cells with only one crime. The grids show the total demand for serious crime suppression, in combination with an indicator of crime-prone land uses. The latter indicator came from the PhoneDisc®[3] yellow pages and includes the total number of restaurants, fast-food stands, bars, drug stores, retail stores, pawn shops, jewelry stores, etc., by grid cell, suppressing cells with only one such establishment. This example shows how the reformulation of information and the introduction of a related layer (or layers) of data can provide new and more useful interpretations than the original data alone.

As shown in figure 6.5, this methodology was used to analyze change by converting the two pin maps into grids and then subtracting one from the other to get the measure of change. Grid cells have several advantages:

- They clearly show crime intensity in places with many overlapping point markers.
- Their data are in the form needed for time-series plots, bar charts, and statistical analyses, which are examples of crime space/time series, with one "slice" shown in figure 6.5.

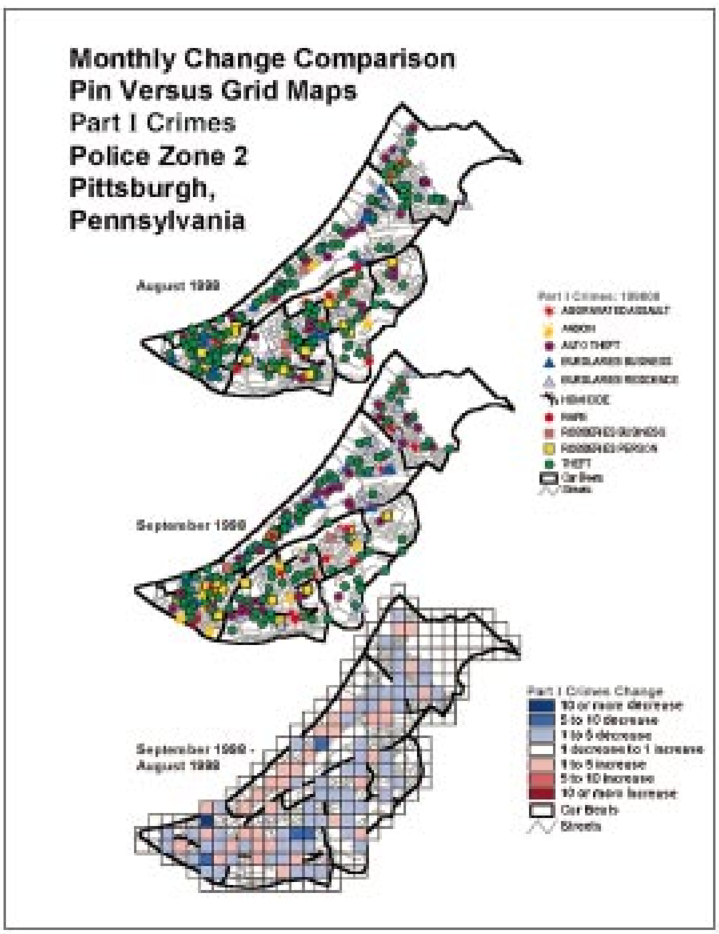



**Figure 6.5**

Two pin maps and a change map for August–September 1998, based on pin maps of Part I crimes for Pittsburgh Police Zone 2 (the equivalent to a precinct). The pin maps include streets and car beats for the zone, as well as downtown Pittsburgh, Pennsylvania, (the two beats on the left) and several neighborhoods.

*Source: Wilpen Gorr, Heinz School of Public Policy and Management, Carnegie Mellon University, Pittsburgh, Pennsylvania. Reproduced by permission.*

- The grids can be used to produce change maps that are more legible than pin maps.

## Making maps come to life[4]

Application of Virtual Reality Modeling Language (VRML) to crime data allows the user to change a viewpoint by rotating, translating, zooming in and out, and tilting maps, providing a dynamic way of viewing crime. The images shown in figures 6.6 and 6.7 are part of an animation that depicts different crime types reported to police for various time periods in Vancouver, British Columbia, Canada. In

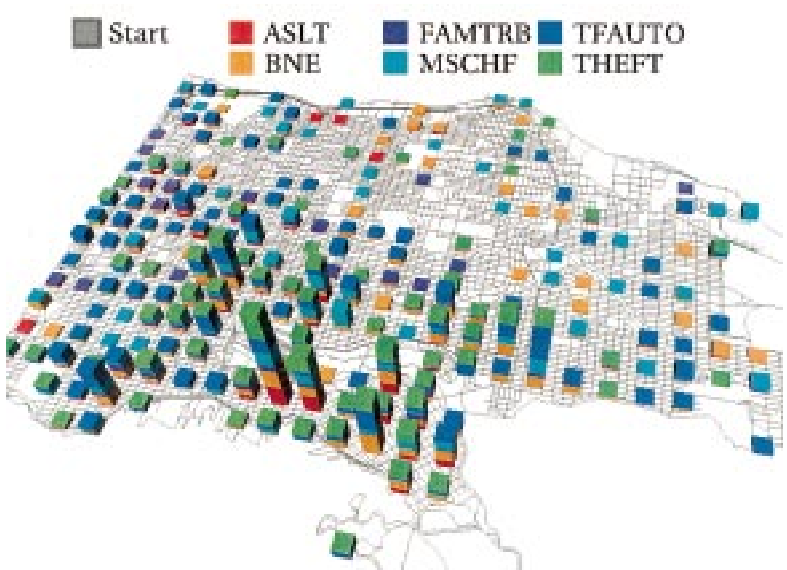



**Figure 6.6**

A rotated view of six types of crimes on a map of Vancouver, British Columbia, Canada. Different crime types are mapped to different colors and stacked in three dimensions.

*Source: Lodha and Verma, 1999. Reproduced by permission.*

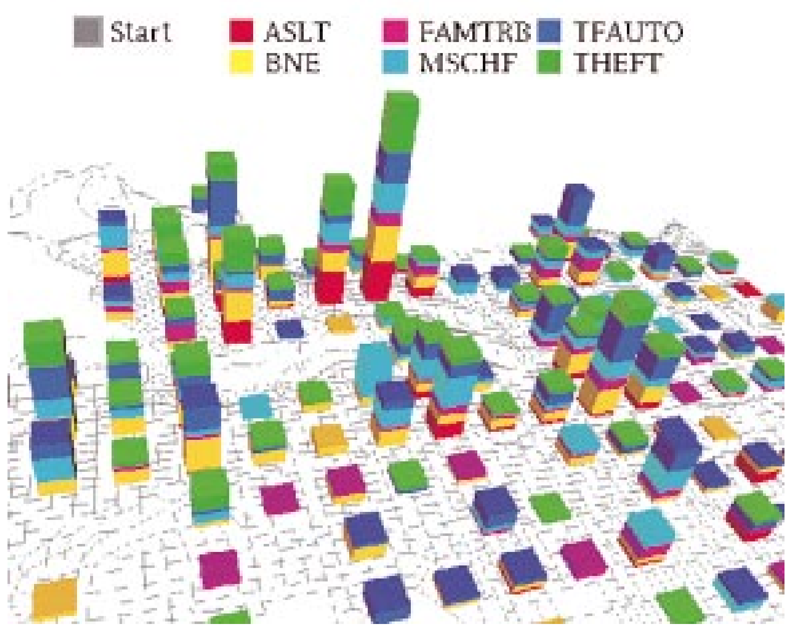



**Figure 6.7**

A zoomed-in view of six types of crimes on a map of Vancouver, British Columbia, Canada.

*Source: Lodha and Verma, 1999. Reproduced by permission.*

its original context, this animation could be activated by clicking the start button shown in the images. The process of creating the images involves first rasterizing the data, then developing a color code key for the crime types, and, finally, designing a system for displaying the crime—in this case, as a histogram.

In figures 6.6 and 6.7, six different types of crime are illustrated: assault (ASLT), breaking and entering (BNE), family trouble (FAMTRB), mischief (MSCHF), auto theft (TFAUTO), and theft (THEFT). The height of the stack is proportional to the total number of crimes in an area, so hot spots can be recognized as "highrises." The two figures display the same data—the same map—from different viewpoints after rotating and zooming in.

Another approach that is easy and yet quite effective as a means of visualizing change involves animating a two-dimensional map. In figure 6.8, calls for service in Mesa, Arizona, were mapped and (in the original) animated. This map uses isoline mapping (joining points of equal value—in this case, equal CFS counts[5]). The animation is a rapid-sequence display of a series of maps of successive arbitrary time intervals giving the visual impression of movement, much like an animated cartoon.

These applications illustrate how we can expect maps to become more dynamic, more maneuverable, in the years ahead. Not only is it likely that the flexibility of maps will improve, but a more user-friendly environment will likely evolve in parallel. The average analyst will simply not have time to do the programming that Lodha and Verma (1999) did to produce their maps, and tools of this sort will, of necessity, become easier to use.

## Digital aerial photography in policing

As noted throughout this guide, police departments employ GIS technology in various applications, including criminal

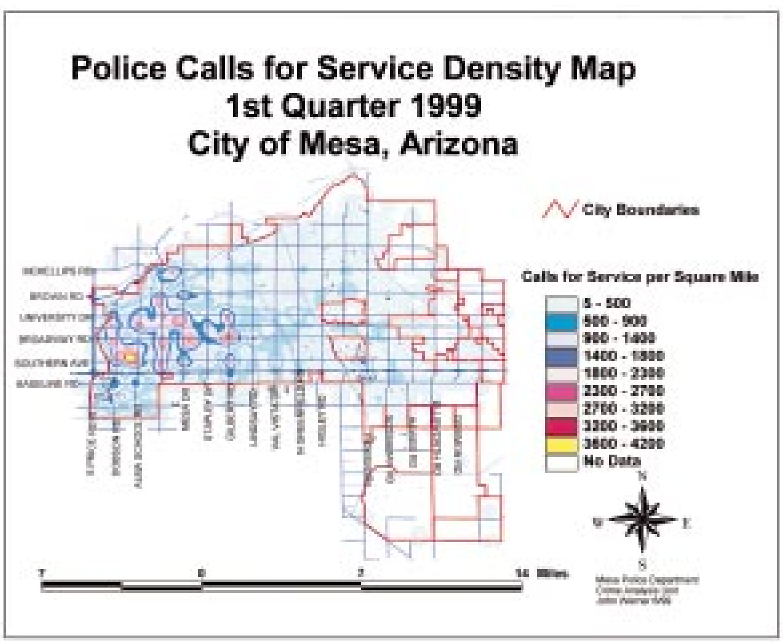



**Figure 6.8**

A map showing the density of police calls for service in the first quarter of 1999 in Mesa, Arizona.

*Source: J. Werner and the Crime Analysis Unit, Mesa, Arizona, Police Department. Reproduced by permission.*

intelligence and crime analysis, crime prevention, public information, and community policing. Typical GIS applications involve taking a georeferenced crime database, filtering the data as needed, and mapping it over a street database to put the crime data in its spatial context. Other data layers may be used, such as census tracts, ZIP Codes, or council districts, but the most frequent underlying context is city streets.

Digital street maps typically provide extremely limited contextual information. Streets are represented as single lines and sometimes color coded to indicate their type (e.g., freeway, arterial, collector). They can be labeled, if necessary, to enhance the level of detail, but the information provided by the street database is quite limited. In recent years it has become clear that the visualization of crime data needs to be improved to provide opportunities for better communication within and between the internal and external constituencies of police departments.

We can portray the general context of visualization along a continuum from complete abstraction, at one extreme, to reality at the other (figure 6.9). Most existing crime maps would be located left of center on the continuum. The crime mapping future will see increasing movement to the right, toward more realistic presentations.

Confidentiality and privacy considerations will probably set limits on how far to the right the process moves. Ultimately, these limits will be culturally conditioned, with more detail where public information and geographic precision are prized and less detail where values put more emphasis on privacy. This variation will be seen, and is already seen, from city to city, State to State, and nation to nation.

Increasingly, police departments are using large-scale (representative fraction 1:2,400) digital aerial orthophotos, also known as DOQ, for digital orthophoto quadrangles. The "ortho" part means

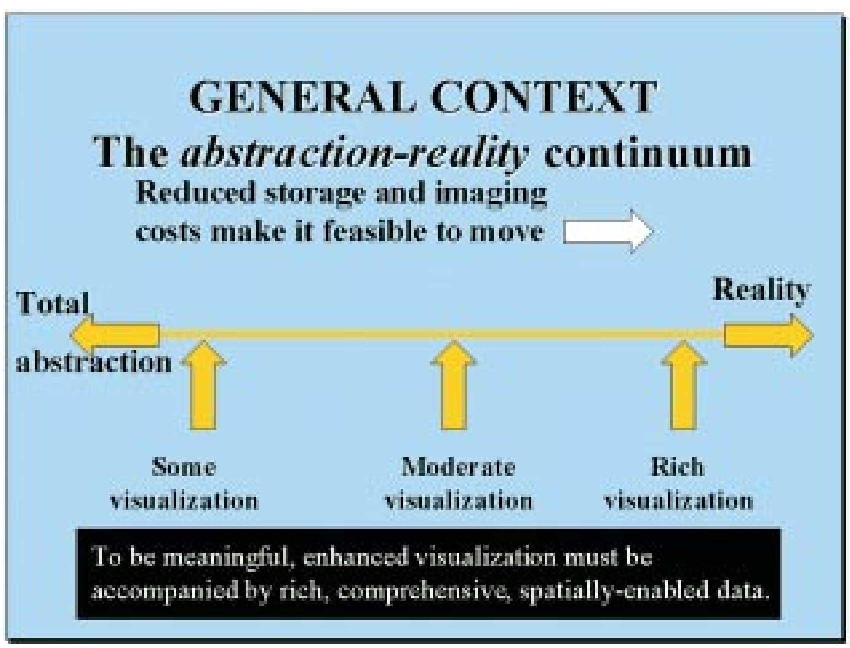



**Figure 6.9**

A diagram illustrating the abstraction-reality continuum.

*Source: Keith Harries.*

perpendicular to the Earth's surface, just as *ortho*dontics corrects teeth so that they are perpendicular to gums. Photos are produced in "tiles," or rectangles, such that each tile typically represents about a square mile (4,000 feet by 6,000 feet or 24 million square feet[6]). The tiles are rectified for errors due to edge distortion (which increases away from the camera lens), other distortions due to the attitude (or position) of the airplane, and terrain. The edges of the tiles must match perfectly. The raster images (see chapter 4) are registered to the center lines of the appropriate digital street-based maps so that geocoded crime data can be accurately portrayed in their "real" spatial context, permitting the identification of land uses, landmarks, and virtually any relevant landscape features.

Furthermore, other coverages are typically digitized and made available as part of the orthophoto package, including spot heights, building footprints, topography, street boundaries, water bodies, and open space. These can be quite useful with or without the associated orthophoto. The data within the photos and the associated digitized coverages are so rich that they could find applications in tactical team operations, for example, where land elevation, terrain, building heights, building footprints, fences, and water bodies can be used to plan where to place officers and determine what their sight lines will be.

While maps have progressed from two dimensions to three, so have aerial photos. Just as three-dimensional maps have limited specialized applications, the applications of three-dimensional photos are likewise limited at present, but potential uses are numerous and ultimately limited only by the user's imagination. As the example in figure 6.10 shows, images can be quite striking in their depth and realism and add to the crime analyst's arsenal of environmental data.

Potential applications of aerial photography are numerous. Any geocoded

**Figure 6.10**

A three-dimensional orthophoto cityscape.

*Source: Orthophoto imagery and three-dimensional model courtesy of ASDI Technologies, Colorado Springs, Colorado. Reproduced by permission.*

information can be superimposed on the photos, including census data, liquor license locations, drug-market data, injury locations, probationer addresses, housing and zoning code violations, and other data that may be relevant to the needs of community policing (see, for example, figure 4.4 in chapter 4). Eventually, we may see orthophotos supplanting "traditional" street-based maps in some, if not all, of the applications where such maps have typically been used.

Integration of orthophotos with conventional data is by no means the only possibility for enhanced visual display. For example, other raster images may be keyed to the orthophotos. One possibility explored in a pilot project[7] in Baltimore County, Maryland, was the development of an archive of ground-level digital photos intended to characterize neighborhoods and landmarks, precinct by precinct.

These ground-level images were linked to a land use map database, and symbols were placed on the land use map at all locations where a ground-level photo had been taken. In ArcView®, hot links were established between the symbols and the database; when the symbols were clicked on, the ground-level picture would pop up, as shown in figure 6.11 (for specific directions, see ESRI, Inc., 1997, chapter 16, "Creating Hot Links"). Yet another possibility is the use of virtual reality to enhance the visualization of scenes in a way that provides somewhat more flexibility than an analog videotape. A set of digital photos is taken in a circle using a special tripod, with the number of pictures calibrated to the focal length of the camera lens. Then a program is used to splice the pictures together at the edges. A viewer with pan and zoom capabilities enables re-creation of the 360-degree panorama. Free viewers are available for

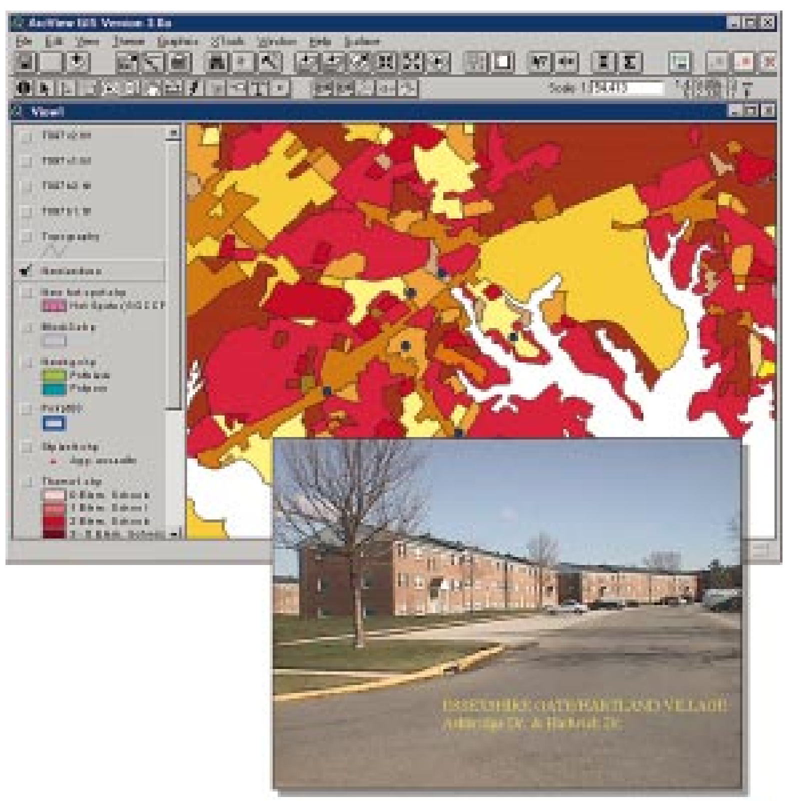


**Figure 6.11**

A ground-level photograph that pops up when linked to a land use map in ArcView®.

*Source: Keith Harries.*

**Figure 6.12**

A 360-degree panorama (top), and a selected part (bottom), of interest owing to the potential conflict between public housing and owner-occupied housing residents. A wall was built to separate the two "neighborhoods."

*Source: Keith Harries and Thomas Rabenhorst.*

downloading (see appendix). This technology could be used for training purposes, for documenting a crime scene that could serve as evidence in court, or for community meetings when a specific location may be the focal point of interest (figure 6.12).

The 360-degree view provides a sense of the local environment that may not be conveyed by either a ground-level still picture or an orthophoto. Virtual reality presentations could be linked to maps or orthos, too. To get a sense of what virtual reality is like, go the National Gallery of Art Web site (*http://www.nga.gov/home.htm*), where virtual reality tours are available (see appendix).

Until recently, the costs of storage and random access memory (RAM) limited the use of memory-intensive applications, such as the display of orthophotos. Each tile, with its associated coverages, requires about 30 megabytes of hard drive space. A city like Baltimore or Washington, D.C., each somewhat less than 100 square miles, would need more than 3 gigabytes (GB) dedicated to it. But with hard drives of 20+ GB readily available at modest cost, this limitation no longer poses a problem. Likewise, the relatively low cost of RAM permits the fast manipulation of large graphics files.

Anticipated applications of orthophotos in community policing include:

- Community residents being able to select their homes or apartment buildings and seeing how the locations of crime incidents or other illicit activities relate to their own locations even if they have no firsthand experience of the events.

- Officers more easily recognizing and contextualizing information, whether that information involves crime locations or various social or environmental problems.

- Police dispatchers (who are increasingly likely to be civilians relatively unfamiliar with the detailed community geography of the city) having the capability to enrich dispatching information with landmarks as reference points provided by photos that pop up on their computer screens. Dispatching technology could be enhanced dramatically if both dispatchers and officers in the field could simultaneously see orthophotographic images displaying the origins of calls.

- Crime prevention officers, analysts, commanders, and administrators being able to present more persuasive visual evidence of problems and communicate better with legislative bodies, community groups, and their professional colleagues.
- Planning being enhanced by realistic and accurate perceptions of the size and scope of proposed actions.

## The integration of GIS and GPS

The integration of data and technologies will be pushed to the limit to extract as much value as possible. The possibilities are limited only by our imaginations. Whereas GIS offers a powerful toolbox, GPS, another technology with untapped potential in law enforcement, permits accurate location finding in field settings. Triangulating from 24 satellites (put in orbit at a cost of $12 billion by the U.S. Air Force), GPS, in its more advanced modes, can provide accuracy to one centimeter, or about half an inch. (For a tutorial explaining how GPS works, go to *http://www.trimble.com*.)

In reality, however, structural and environmental limitations, such as tall buildings, a forest canopy, or operations in mountainous terrain, and the ability of the Air Force to manipulate the accuracy available to civilians may mean an error of up to 100 meters. These problems can be overcome by using GPS base stations with established locations and manipulations that have come to be referred to as *differential positioning* GPS or DGPS. This is defined by *GPS World Magazine* as:

> A technique used to improve positioning or navigation accuracy by determining the positioning error at a known location and subsequently incorporating a corrective factor (by real-time transmission of corrections or by postprocessing) into the position calculations of another receiver operating in the same area and simultaneously tracking the same satellites.

The bottom line, however, is that users should generally be prepared for considerably lower resolution than some numbers quoted in promotional materials.

Another possibility for integrating technologies involves the combined use of GIS, GPS, and management information systems (MIS). This would allow close to real-time crime mapping, since the geocoding step would be eliminated (Sorensen, 1997). However, some operational questions need to be examined. For example, with how much certainty will incident locations be reported? A patrol officer may report “arrived” status prematurely, sending what in theory should be the incident location, but what in practice may be erroneous. On the other hand, GPS offers the possibility of accurately reporting places that have no meaningful street address. A shopping mall covering 100 acres may have a conventional street address that is meaningless in terms of conveying locational precision. With GPS, the precise spot of an auto theft in the parking lot could be pinpointed, providing potentially useful information for protecting areas of the parking lot that are prone to theft. Crime inside the mall building could be reported with greater precision, whether in stores or in public spaces, provided a reasonably close line-of-sight GPS reading could be obtained. This type of "precision mapping" is already being performed in Charlotte, North Carolina, where GPS is used to plot exactly where crimes occur, even for locations without street addresses.

An application of GPS that is in development is in the area of probation and parole—tracking probationers and parolees if the terms of their release require limitations on their mobility. Indeed, future crime mapping applications will go beyond crime mapping per se and into other components of the criminal justice system, including corrections. One can expect to see the manipulation of spatial information and the application of new tools and technologies evolving in the coming decade. While developments in other branches of criminal justice will likely parallel spatial analysis developments in policing, we also can expect to see the development of specialized methods adapted to particular needs.

## Postscript: The future of GIS in policing

When asked, "Why bother to discuss the future of GIS?," Clarke (1997) responded with three reasons that might apply equally to crime mapping:

- The need to plan equipment purchases in the most efficient way, anticipating trends.
- The need to stay abreast of the new field spawned by GIS called *geographic information science.*
- The need to be prepared for cross-fertilization of different criminal justice fields using GIS.

Clarke suggested that we can classify speculation into two types:

- The forward extension of current trends.
- Pure speculation, with the likelihood that some ideas will become reality while others will fade away.

Clarke also noted that data will become more complete, more detailed, more timely, and more varied than ever before. This will be helpful to GIS as an "end user" of data—if the core data get richer, then possibilities for enhanced analysis also increase. But Clarke was referring to GIS in general. Can we have the same expectations for crime mapping?

Given that most crime data are already point defined (address-type), could they be improved in terms of spatial definition? Yes, at least marginally, through the use of GPS technology to remove address ambiguities, of which there are many. Whether locational data can be improved across the board may depend on the GPS protocols that develop, one police department at a time. Data quality will probably improve, and addresses will probably become more precise as more agencies use automated field reporting and integrated computer-assisted dispatching and records management systems.

## More on GPS and policing

Equipping patrol units with GPS would mean that their locations could be known as often as each unit is "polled," or automatically asked to respond, perhaps every few minutes. This would be an excellent security device for officers, since their location could be determined at any time, and, if an officer were down or needed help, knowing his or her location would save valuable time.

But will GPS units typically be located in patrol cars? If so, some ambiguities in incident location will remain, since the car will not always be parked precisely where the incident takes place. If GPS units are hand held, or incorporated into officers' uniforms, accuracy may improve significantly. The caveat on GPS data, however, is that the physical environment may not permit a satellite reading owing to the presence of tall buildings or other obstacles. Such difficulties aside, the era of real-time access to spatially enabled crime data is rapidly approaching—a development that will force us to reconsider what we are doing and why and how we are doing it. This development is not without risks, such as the temptation to jump to premature conclusions on the basis of real-time, but possibly unconfirmed, information.

## The Web: Already a force in the dissemination of police information

A development that may have the greatest impact on the manipulation of crime data may be the use of the Web for access to data that have already been geocoded and are in the public domain, such as census data, including census geography. A corollary development will likely be demands for local data on Web sites. Currently, police departments are split on this issue, with some routinely putting their less sensitive data on the Web, and others refraining from doing so. The power of the Web to facilitate data sharing will invite more open data dissemination protocols, but these will be offset to some extent by security and privacy concerns.

## Public information revisited: How much public access to allow

A pervasive force at work in the background is the historical culture of policing that has generally frowned on easy public access to crime data. This reluctance is borne of several factors, including fear of misuse and misinterpretation; the indisputable need for confidentiality for some crimes, such as rape and juvenile offenses; fear of political reprisals when crime rates are increasing; and a reluctance to expend scarce resources on data dissemination. In the background was, and is, a certain degree of proprietorship regarding data and a somewhat natural reluctance to simply give information away, even though it might be in the public domain already, at least in theory. A subtext to this is the view that crime data should not be made available to the public if they do not have to be, since public disclosure only constitutes another potential source of problems.

On the other hand, undermining nondisclosure is the fact that many city and neighborhood newspapers routinely publish lists of local crimes, complete with addresses. The only missing link is the codification necessary to produce a citywide map. Criminal matters most often come before the courts and, in so doing, jump squarely into the public domain. In the long term, it is increasingly difficult to see how most crime data could be kept private, particularly data related to incidents for which there is no active investigative interest and no need to protect victims. Indeed, some departments that were secretive a decade ago are now beginning to put their data out on CD-ROMs or at least are talking about doing so. Others refuse to release data, even for legitimate apolitical research.

One certainty is that, in addition to technological and methodological innovations in crime mapping and in collateral fields that can be productively integrated into mapping methods, a debate about the disclosure and exposure of crime data will continue into the foreseeable future.

### Multimedia and integration

Multimedia and integration are likely to be among the most prominent themes that evolve in the crime mapping arena over the next decade. Crime mappers will certainly take advantage of all the new technological advances, often using multimedia in ways that their developers might not have anticipated. Integration of various technologies, with data archiving (or warehousing) and data mining becoming more prominent, will be inevitable. Crime mapping may find itself merging into an enterprisewide GIS, as governments network access to data and standardize GIS platforms across entire jurisdictions to ensure compatibility and reduce costs. Change is certain. The only uncertainty is how the rate of change will vary from place to place.

## Conclusion

Rapid change is the order of the day in crime mapping. It’s tempting to hold out and ride the next wave of innovation, skipping the present phase that is doomed to obsolescence as soon as the shrinkwrap comes off the software package or hardware box. This seems to have two advantages in the short term: minimizing costs and reducing the need for training. The problem with this approach is that the time is never right because another wave of innovation is always on its way.

Policing is undergoing a paradigm shift resembling the kind of change that Kuhn (1962) described three decades ago in his book *The Structure of Scientific Revolutions*. A paradigm shift is the idea that, from time to time, various realms of human endeavor experience dramatic—almost revolutionary—changes. Kuhn applied the term to changes in science, such as the transition in biology from thinking in terms of whole organisms to a molecular or genetic perspective. Although it is pretentious to put changes in crime mapping on the same level with major changes in natural science, it is realistic to use the notion of a paradigm shift to understand the nature of changes in the technology of policing.

It is easy to underestimate or overestimate the rate of change and the long-term impact of technological changes in policing—including crime mapping. While current and future advances promise to lend substantial support to law enforcement, we should remember that technologies such as crime mapping are only tools and, like other tools, their benefits to society depend on the human agents who wield them.

## Summary

Chapter 6 has explained:

- What types of changes may be expected in crime mapping in the next decade.
- What geographic profiling is and how it can be useful.
- High-resolution GIS and how it can be applied.
- How complex statistical methods can be used in spatial forecasting.
- Why digital aerial photography is finding applications in crime mapping.
- How various kinds of data visualization can be productively integrated.
- How GIS and GPS can work together.
- How the World Wide Web may both increase and limit data access.
- Why we can expect continuing debate on public access to crime data and the results of crime analysis.
- What to expect in terms of applications of multimedia and integration technologies.

## Notes

1. This interpretation and the accompanying map were provided by Det. Insp. D. Kim Rossmo of the Geographic Profiling Section, Vancouver Police Department, Vancouver, British Columbia, Canada.

2. According to a reviewer with profiling experience, however, profiling is an extremely specialized and expensive process demanding a skill level and financial commitment that few agencies can realistically afford, at least not with the currently available technology.

3. For more information on yellow pages and phone books on CD-ROM, see *http://www.phonedisc.com/*.

4. I am indebted to Dr. S.K. Lodha (University of California, Santa Cruz) and Dr. Armind Verma (Indiana University) for the maps and accompanying interpretation. The maps shown are from Lodha and Verma, 1999. Available online at *http://wcr.sonoma.edu/v1n2/lodha.html*.

5. See chapter 2 for additional explanation.

6. A square mile is 1,760 yards x 3 = 5,280 feet$^2$ or 27,878,400 square feet.

7. This pilot project was known as OPRA, for *O*rtho*p*hotographic *R*epresentation and *A*nalysis.

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# Appendix:

## Internet Resources for Crime Mapping

### U.S. Department of Justice

| | |
|---|---|
| Crime Mapping Research Center (CMRC) Web site<br>Office of Justice Programs<br>National Institute of Justice<br><br>Provides links to police departments, software vendors, and government agencies and is a good starting point for an exploration of crime mapping. | *http://www.ojp.usdoj.gov/cmrc* |
| Crimemap listserv<br><br>Connects interested subscribers to one another and to CMRC and broadcasts messages to subscribers, such as announcements of upcoming conferences and solicitations. Participants can share knowledge and questions through this e-mail address. | *listproc@aspensys.com*<br><br>In the body of the message, type:<br>SUBSCRIBE CRIMEMAP Your Name |
| Spatial Crime Analysis Section, Criminal Division, Web site | *http://www.usdoj.gov/criminal/gis/scashome.htm* |
| Crime Mapping and Analysis Program, National Law Enforcement and Corrections Technology Center | *http://www.nlectc.org/nlectcrm/cmap.html* |

### Web Sites Displaying Crime Maps

| | |
|---|---|
| Berkeley, CA, Police Department | *http://inberkeley3.ci.berkeley.ca.us/annual_rpts/annual.html* |
| Cambridge, MA, Police Department | *http://www.ci.cambridge.ma.us/~CPD* |

| | |
|---|---|
| Charlotte-Mecklenburg, NC, Police Department | *http://www.ci.charlotte.nc.us/cipolice/spab/gis/cmpd_gis.htm* |
| Clearwater-Pinellas County, FL, Police Department | *http://www.co.pinellas.fl.us/bcc/juscoord/enforcer.htm* |
| Detroit (Tri-County), MI, Police Department | *http://www.cus.wayne.edu/U_safety/pdfs/handbook.pdf* |
| Evansville Courier & Press, Evansville, IN | *http://www.evansville.net/courier/crime* |
| Portland, OR, Police Department | *http://www.worldstar.com/~carltown/crmemap.htm* |
| Sacramento, CA, Police Department | *http://www.sacpd.org/templates/f-nstart.html* |
| Salinas, CA, Police Department | *http://www.salinaspd.com/maps.html* |
| San Antonio, TX, Police Department | *http://www.ci.sat.tx.us/sapd/maps.htm* |
| San Diego, CA, Police Department | *http://www.sannet.gov/police/crime-facts/crimanal.shtml* |
| Tempe, AZ, Police Department | *http://www.tempe.gov/cau* |

Note: This current list can be found at *http://www.ojp.usdoj.gov/cmrc/weblinks/welcome.html*.

## GIS and Analysis Software and Other Resources

| | |
|---|---|
| Environmental Systems Research Institute (ESRI): Arc/Info®, ArcView® | *http://www.esri.com* |
| MapInfo® | *http://www.mapinfo.com* |
| Idrisi | *http://www.clarklabs.org* |
| Illinois Criminal Justice Information Authority and Spatial and Temporal Analysis of Crime (STAC) User's Forum | *http://www.icjia.state.il.us* |
| *Guidebook for Measuring Crime in Public Housing with Geographic Information Systems*, $5. | *http://huduser.org/publications/pubasst/gis/html* |

## GIS Tutorial

| | |
|---|---|
| GISTutorial Workbook | *http://www.heinz.cmu.edu/gistutorial* |

## Hot Spot Identification Methods (see Jefferis, 1999)

| | |
|---|---|
| Geographic Analysis Machine (GAM) | *http://www.ccg.leeds.ac.uk/smart/gam/gamin.html* |
| Spatial and Space-Time Scan Statistic (SaTScan) | *http://www.dcpc.nci.nih.gov/bb/software.html* |
| Spatial Pattern Analysis Machine (SPAM) | *http://athene.csu.edu.au/~jratclif/ware/spam1.htm* |
| Spatial and Temporal Analysis of Crime (STAC) (PDF format) | *http://www.icjia.org/* |
| Vertical Mapper™ | *http://www.northwoodgeo.com* |
| Spatial Analyst | *http://www.esri.com/software/arcview/extensions/spatext.html* |
| Idrisi | *http://www.clarklabs.org* |
| CrimeStat | *http://www.icpsr.umich.edu/NACJD/crimestat.html* |
| SpaceStat | *http://www.bruton.utdallas.edu/anselin/anselin.htm* |

Note: This current list can be found at *http://www.ojp.usdoj.gov/cmrc/weblinks/welcome.html*

## Research Organization

| | |
|---|---|
| Police Executive Research Forum: *Crime Mapping Case Studies*, Volumes I and II, and other issues relating to law enforcement | *http://www.policeforum.org/* |

## Computer Mapping Laboratory

| | |
|---|---|
| Police Foundation: Publishes *Crime Mapping News*, a quarterly bulletin on crime mapping, which emphasizes successful implementation of computer mapping in law enforcement | *http://www.policefoundation.org* |

## Free Sources of Census Data

| | |
|---|---|
| CIESIN | *http://www.ciesin.org* |
| U.S. Census Bureau | *http://www.census.gov* |

## Proprietary Source of Census Data

| | |
|---|---|
| GeoLytics: Sells CensusCD+Maps™ directly for $249.95 for a single user license; $750 for LAN/CD-Tower license. | *http://www.censuscd.com/cdmaps/censuscd_maps.htm* |

## Global Positioning Systems (GPS)

| | |
|---|---|
| Tutorial | *http://www.trimble.com* |
| Overview | *http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html* |
| *Global Positioning Systems World Magazine* | *http://www.gpsworld.com* |

## Virtual Reality (VR) Viewers

| | |
|---|---|
| Sample VR tour | *http://www.nga.gov/exhibitions/webtours.htm* |
| Quick-time viewer | *http://www.apple.com* |
| Live-picture viewer | *http://www.livepicture.com* |
| Examples of VR applications in a police department | *http://www.nashville.net/~police/VRMovies/index.htm* |

## Other Sources

| | |
|---|---|
| Coordinate Systems | *http://www.utexas.edu/depts/grg/gcraft/notes/coordsys/coordsys.html* |
| Hunter College, New York, NY | *http://everest.hunter.cuny.edu/capse/projects/nij/crime.html* |
| International Association of Crime Analysts | *http://www.iaca.net/* |
| Metadata Standards and Information | *http://fgdc.gov/standards/standards.html*<br>*http://www.blm.gov/gis/nsdi.html*<br>*http://www.blm.gov/gis/meta/minimum.html* |
| The Omega Group (CrimeView® geographic analysis product) Map Gallery | *http://www.theomegagroup.com/crimevw.htm* |
| University Consortium for Geographic Information Science | *http://www.ucgis.org* |

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# Index

For more information on the National Institute of Justice, please contact:

**National Criminal Justice Reference Service**
P.O. Box 6000
Rockville, MD 20849–6000
800–851–3420
E-mail: *askncjrs@ncjrs.org*

To access the World Wide Web site, go to
*http://www.ncjrs.org*

If you have any questions, call or e-mail NCJRS.

# About the National Institute of Justice

The National Institute of Justice (NIJ), a component of the Office of Justice Programs, is the research agency of the U.S. Department of Justice. Created by the Omnibus Crime Control and Safe Streets Act of 1968, as amended, NIJ is authorized to support research, evaluation, and demonstration programs, development of technology, and both national and international information dissemination. Specific mandates of the Act direct NIJ to:

- Sponsor special projects, and research and development programs, that will improve and strengthen the criminal justice system and reduce or prevent crime.
- Conduct national demonstration projects that employ innovative or promising approaches for improving criminal justice.
- Develop new technologies to fight crime and improve criminal justice.
- Evaluate the effectiveness of criminal justice programs and identify programs that promise to be successful if continued or repeated.
- Recommend actions that can be taken by Federal, State, and local governments as well as by private organizations to improve criminal justice.
- Carry out research on criminal behavior.
- Develop new methods of crime prevention and reduction of crime and delinquency.

In recent years, NIJ has greatly expanded its initiatives, the result of the Violent Crime Control and Law Enforcement Act of 1994 (the Crime Act), partnerships with other Federal agencies and private foundations, advances in technology, and a new international focus. Some examples of these new initiatives:

- New research and evaluation are exploring key issues in community policing, violence against women, sentencing reforms, and specialized courts such as drug courts.
- Dual-use technologies are being developed to support national defense and local law enforcement needs.
- The causes, treatment, and prevention of violence against women and violence within the family are being investigated in cooperation with several agencies of the U.S. Department of Health and Human Services.
- NIJ's links with the international community are being strengthened through membership in the United Nations network of criminological institutes; participation in developing the U.N. Criminal Justice Information Network; initiation of UNOJUST (U.N. Online Justice Clearinghouse), which electronically links the institutes to the U.N. network; and establishment of an NIJ International Center.
- The NIJ-administered criminal justice information clearinghouse, the world's largest, has improved its online capability.
- The Institute's Drug Use Forecasting (DUF) program has been expanded and enhanced. Renamed ADAM (Arrestee Drug Abuse Monitoring), the program will increase the number of drug-testing sites, and its role as a "platform" for studying drug-related crime will grow.
- NIJ's new Crime Mapping Research Center will provide training in computer mapping technology, collect and archive geocoded crime data, and develop analytic software.
- The Institute's program of intramural research has been expanded and enhanced.

The Institute Director, who is appointed by the President and confirmed by the Senate, establishes the Institute's objectives, guided by the priorities of the Office of Justice Programs, the Department of Justice, and the needs of the criminal justice field. The Institute actively solicits the views of criminal justice professionals and researchers in the continuing search for answers that inform public policymaking in crime and justice.