# 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.
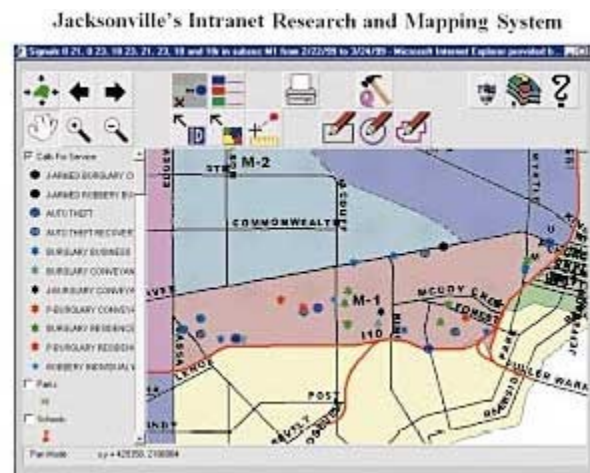
Figure 3.2

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.
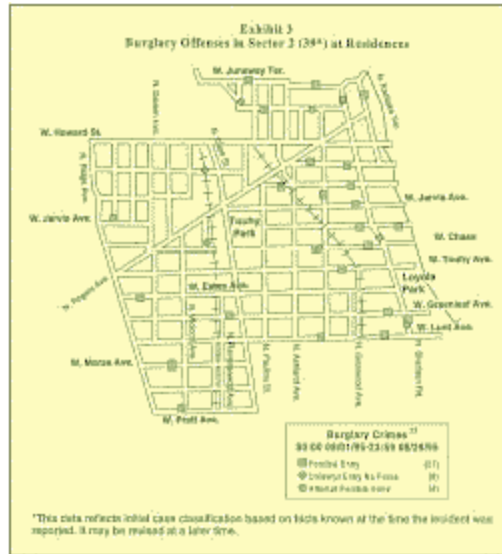
Figure 3.3

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

Source: Rich, 1996, p. 13.

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

Figure 3.4

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

Source: Keith Harries.

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 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 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.)

GIS & Management:
Resource Allocation

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.
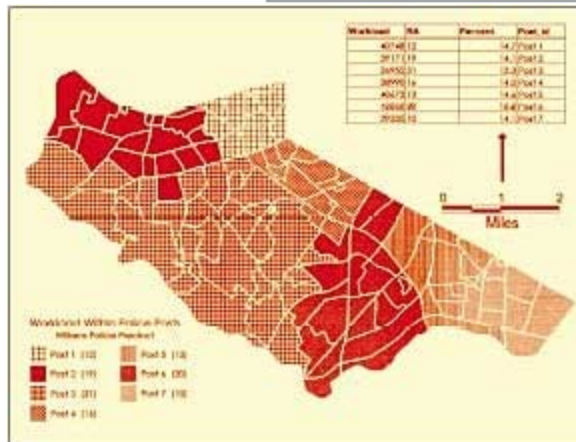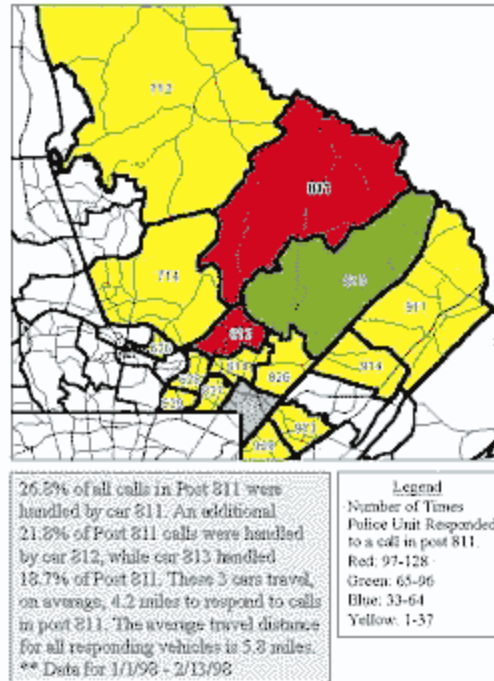
26.5% of all calls in Post 811 were handled by car 811. An additional 21.8% of Post 811 calls were handled by car 812, while car 813 handled 18.7% of Post 811. These 3 cars travel, on average, 4.2 miles to respond to calls in post 811. The average travel distance for all responding vehicles is 5.8 miles. ** Data for 1/1/98 - 2/13/98

Legend
Number of Times
Police Unit Responded
to a call in post 811.
Red: 97-128
Green: 65-96
Blue: 33-64
Yellow: 1-37

Figure 3.6

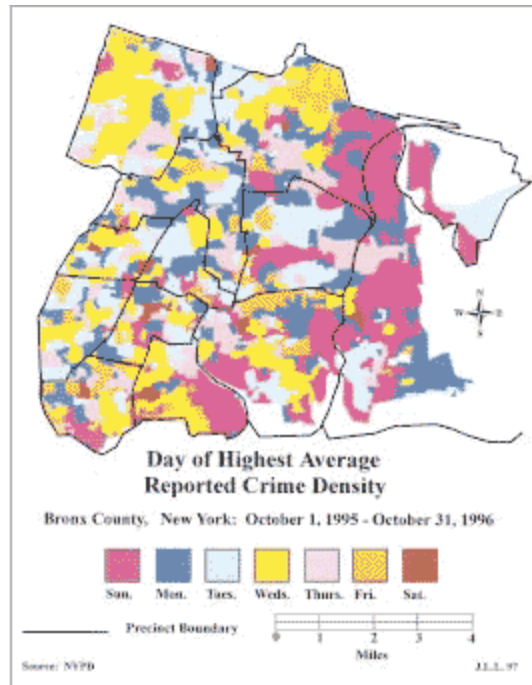A map showing police posts based on work-load assignments by reporting area.

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

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

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.

Day of Highest Average Reported Crime Density

Bronx County, New York: October 1, 1995 - October 31, 1996

Sun. Mon. Tues. Weds. Thurs. Fri. Sat.

Precinct Boundary

0 1 2 3 4
Miles

Source: NYPD

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:
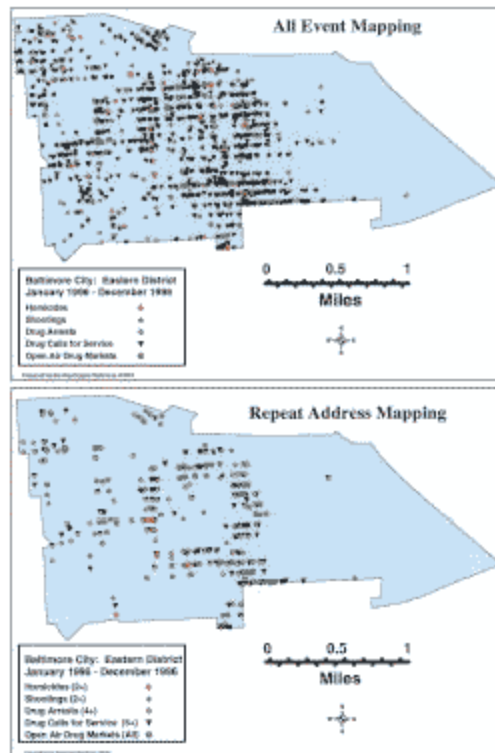
Figure 3.8

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.

- 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.
- 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).

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.

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).

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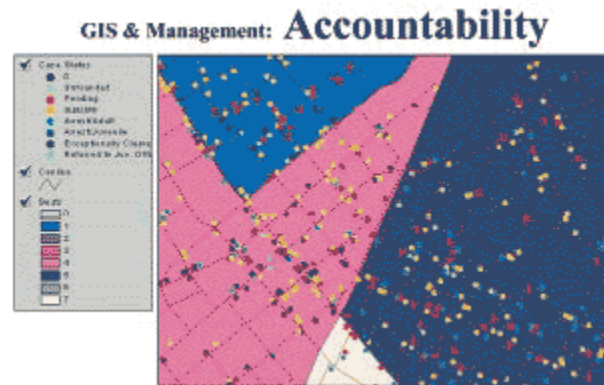

GIS & Management: **Accountability**

Figure 3.16

A case status map, Wilson, North Carolina.

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

- 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.
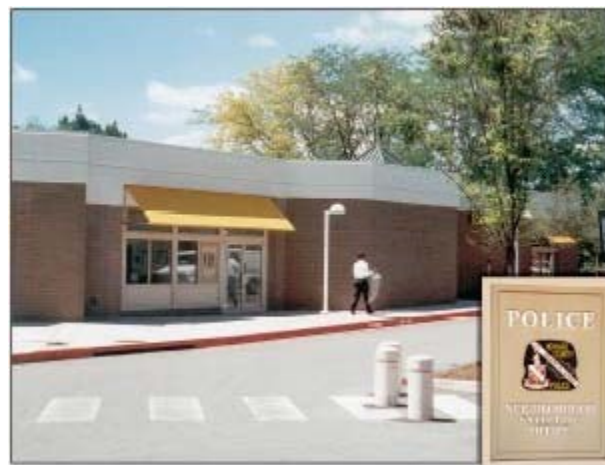

Figure 3.17

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.

- 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

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, recreation, 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.

Figure 3.18

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

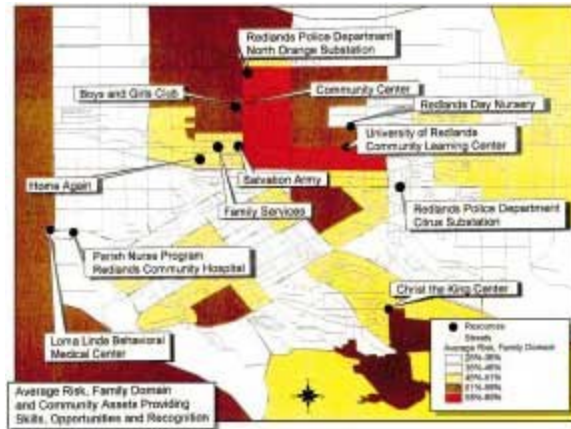*Source: City of Redlands, California, 1999. Reproduced by permission.*
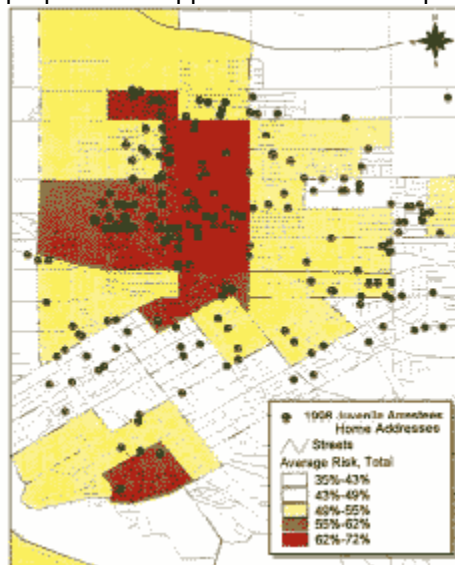
Figure 3.19

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

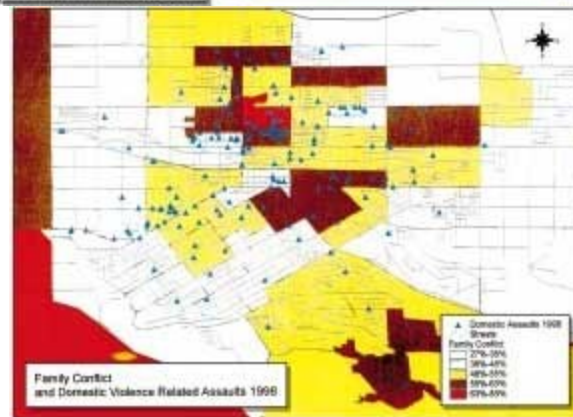*Source: City of Redlands, California, 1999. Reproduced by permission.*

Figure 3.20

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

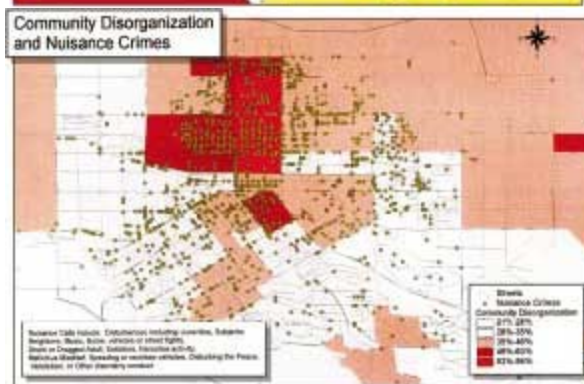*Source: City of Redlands, California, 1999. Reproduced by permission.*

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.

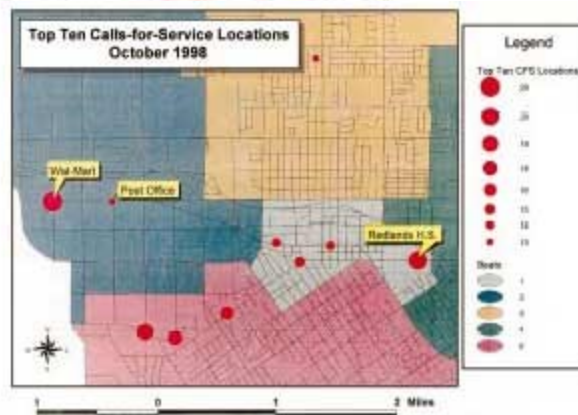*Source: City of Redlands, California, 1999. Reproduced by permission.*

Comparison of Neighborhood Survey Traffic Responses with Collisions and Citations: October 1998

Figure 3.23

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

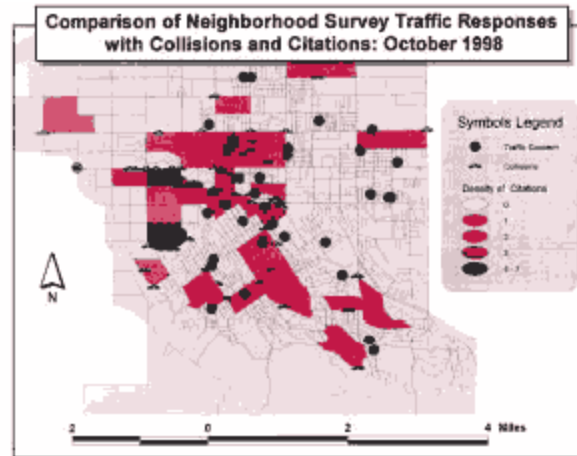*Source: City of Redlands, California, 1999. Reproduced by permission.*

Figure 3.24

A map of where bats tested positive for rabies.

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

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.

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.

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 addition to forensic and intrainstitutional investigative work, GIS has applications in resource allocation, offender tracking and monitoring, and facility location.

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).

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.
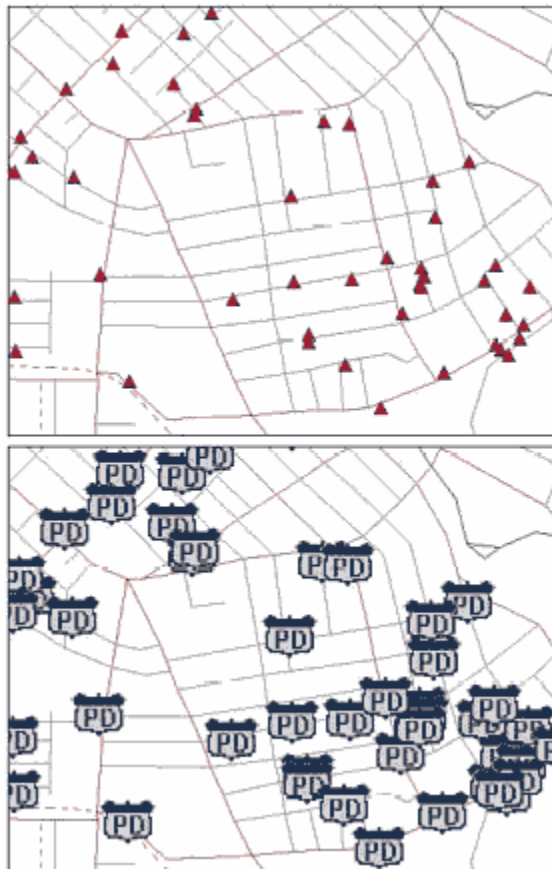
As noted, another issue to be considered is management of the presentation. How will the map(s) be presented? Using hard copy? As a presentation? (If a presentation, will it use computer software, an overhead projector, slides, or what?) By fax? In a report? (If a report, will it be printed in color 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.
- 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.

GIS & the Community:
Problem Solving Partnerships

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.

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.

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 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.

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 "s" stands for "system(s)," while other object that this is too narrow and the "s" should stand for "science."

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.)

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.

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 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.
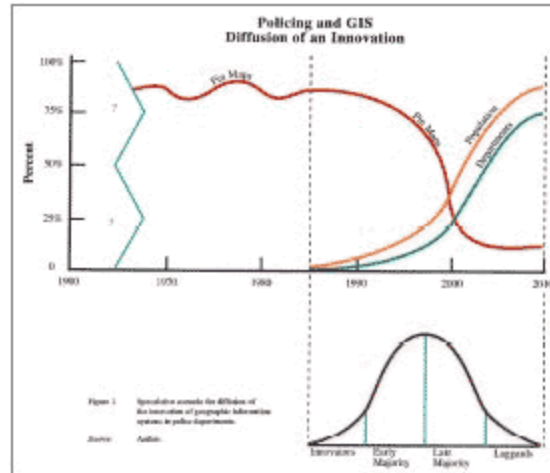
Figure 4.3

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 drawbacks. For example, lines in raster displays 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.
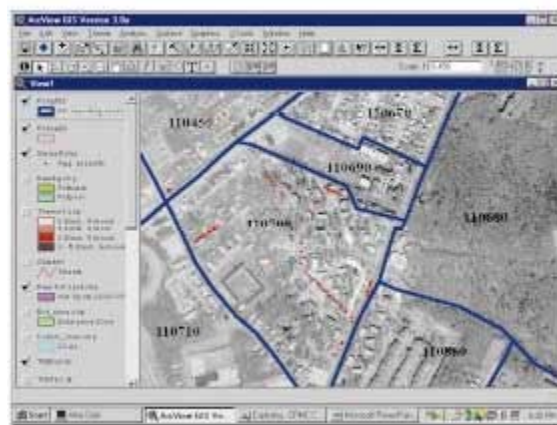

Figure 4.4

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).

Figure 4.5

A map showing TIGER/Line™ address range basics.

Source: U.S. Census Bureau, 1997, figure 3-1, pp. 3-9.
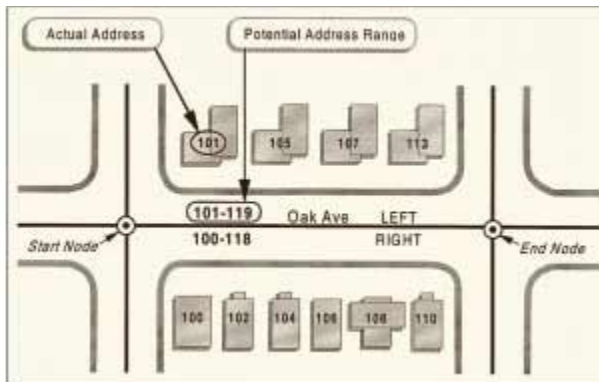
Geocoding is vitally important for crime mapping since it is the most commonly used way of getting crime or crime-related data into a GIS. Crime records almost always have street addresses or other locational attributes, and this information enables the link between the database and the map.

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.

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).

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.
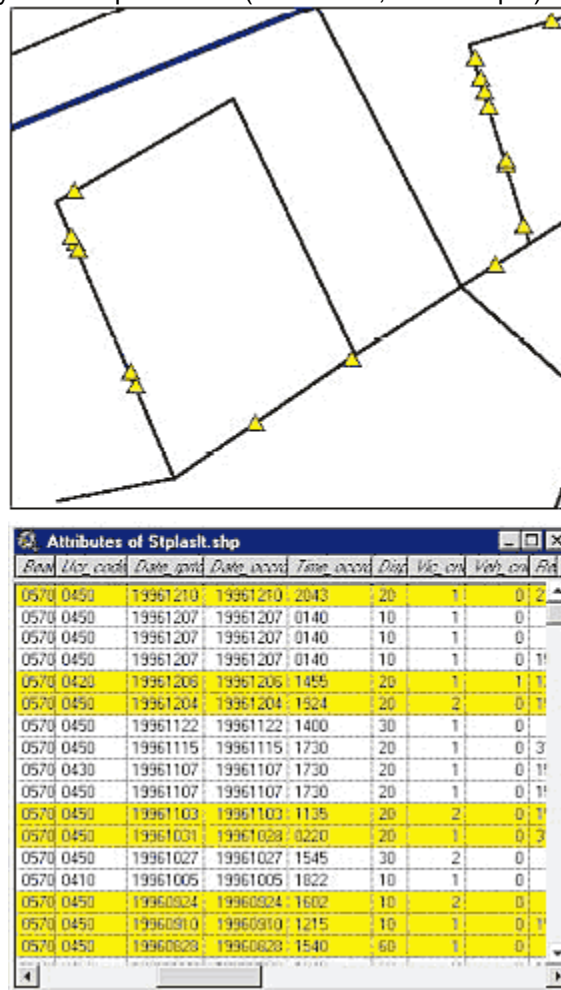

Figure 4.6

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.
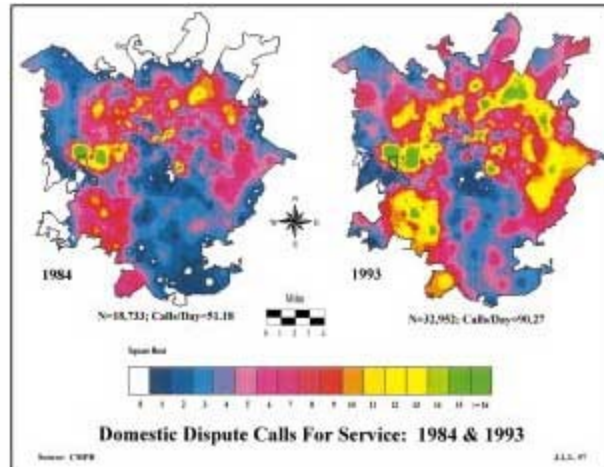
Time geography is viewed through a different lens as shown in figure 4.8. Using methods similar to those used to produce figure 4.7, seven daily maps were constructed, followed by an eighth map to denote the day of the week with the highest frequency of calls for each of the 537 response areas. Maps 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 the general population, or per unit of the male youth population. A few alternative base maps are shown in figure 4.9.

Figure 4.9

Some alternate base maps for use in crime mapping.

Source: Keith Harries.
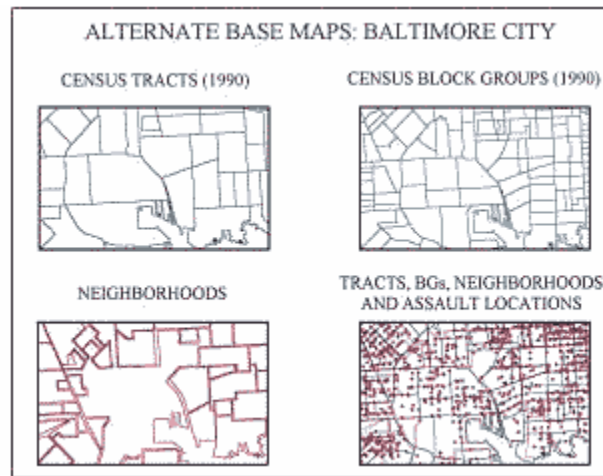
Mapping incident types and modus operandi

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.

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 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?

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.

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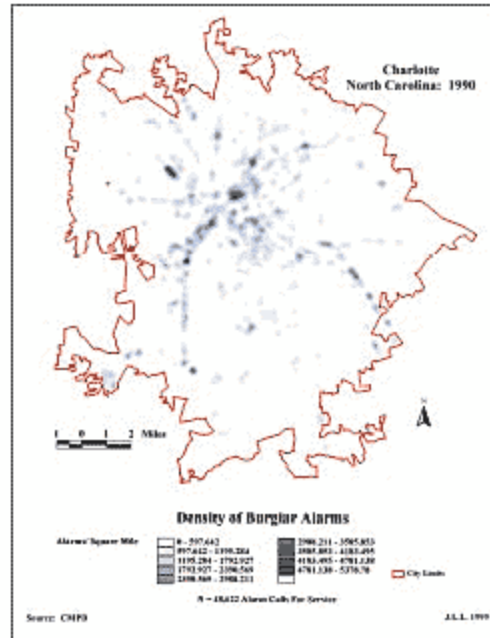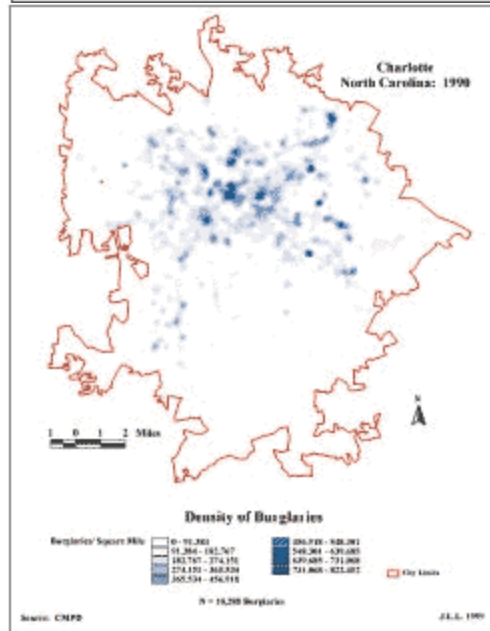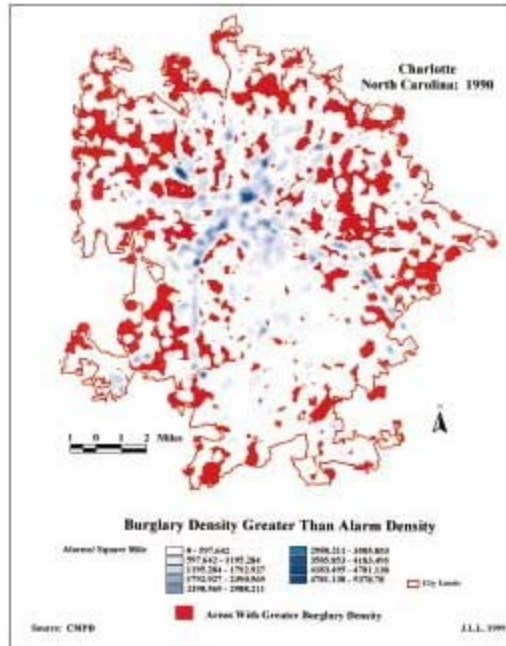
The various types of measurement now available in GIS programs are too numerous to describe. However, a few types of measurement will be outlined to provide a sense of what can be done.

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 additional explanation, see Harries and Powell (1994).

Figure 4.14

A map based on an Urban Pathology Index.

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

BALTIMORE, MD
Juvenile Gun Crimes
& High Social Stress Census Tracts
1980-90

N=2,639
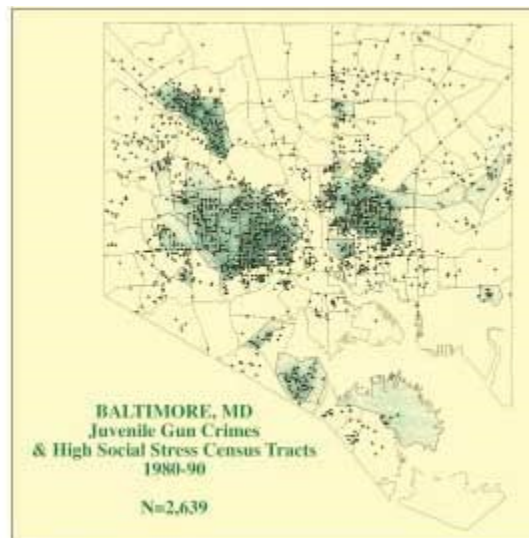
GIS as a tool for data integration and exploration

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).
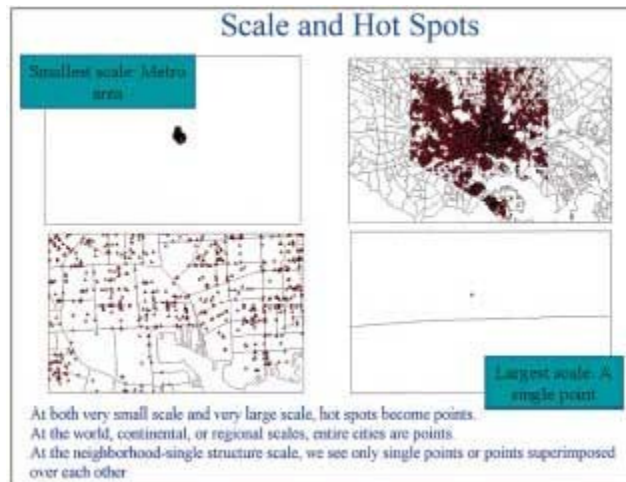

Figure 4.15

An illustration of the scale-dependency of hot spots.

Source: Keith Harries.

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 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.)

GIS Analysis Tools:
Hot spots: Change over Time

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.

Arson Hot Spots in Detroit 1994 & 1997

1997 Fire Location
1997 Fire "Hot Spot"
1994 Fire "Hot Spot"
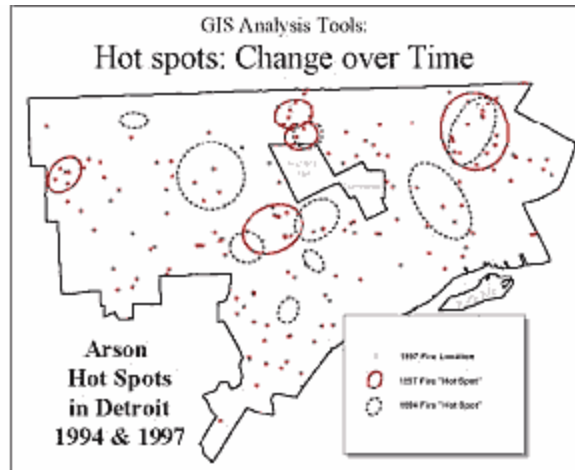
Definition and measurement

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).
- 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.
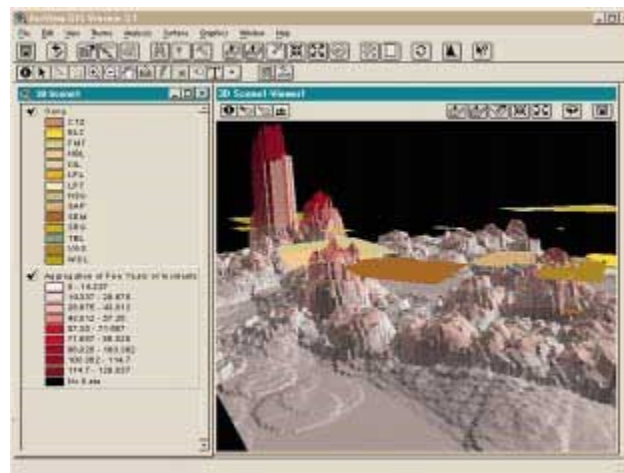
Figure 4.19

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.
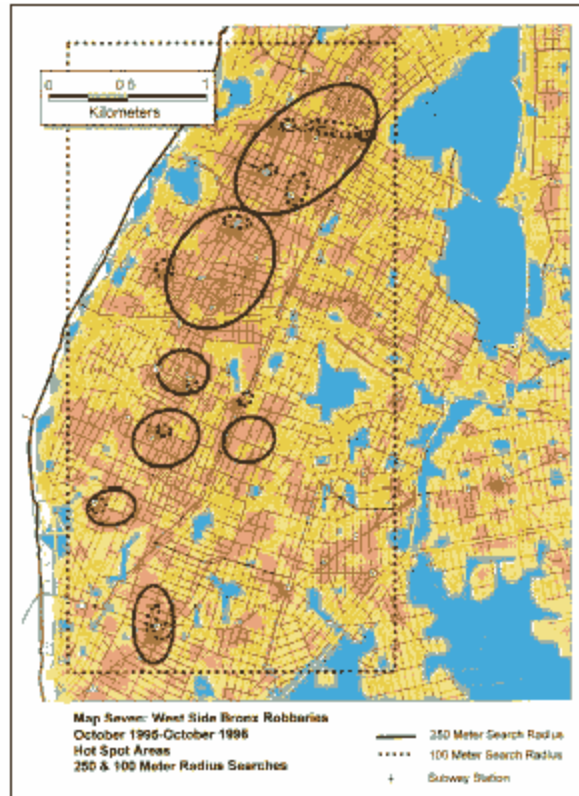
- ▪ **Spatial autocorrelation.** This concept relies on the idea that events that happen in different locations may be related. In a crime hot spot, for example, underlying social and environmental processes generate crimes in a small area. Multiple events, such as the presence of drug markets, may have 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).
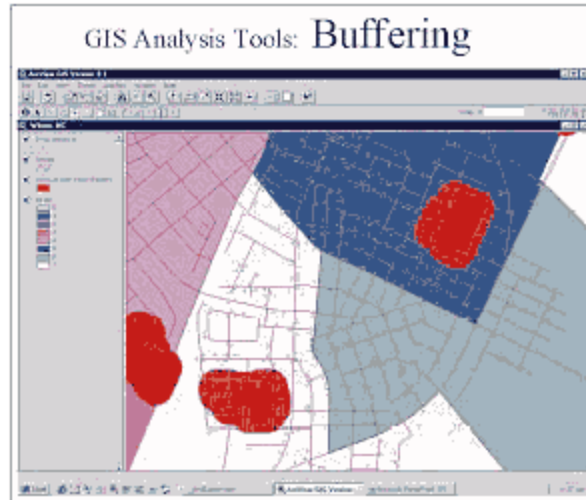
GIS Analysis Tools: **Buffering**

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.

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 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).

Figure 4.22

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

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

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).

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-Mecklenburg Police Department. Reproduced by permission.
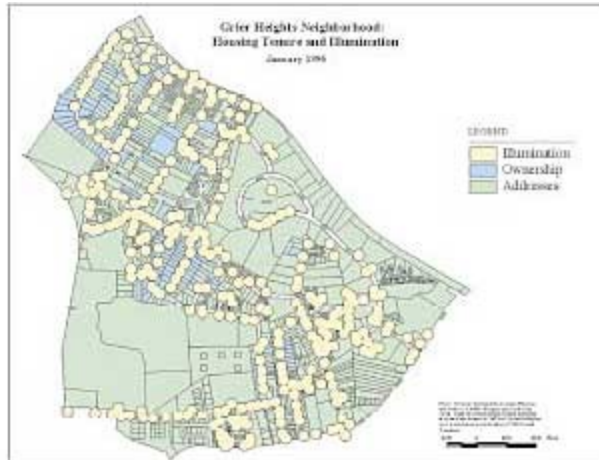
Also in the context of community policing, an extremely disruptive phenomenon is house fires. This is especially true in older neighborhoods with substandard row houses, where the likelihood of fire spreading from one home to adjacent houses is great. In one study, buffers were drawn around residences 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 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).

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

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 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.

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.

Synthesis 2010

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?

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?

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.

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 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]

Figure 5.2

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.

Bulletin 23

S Mc Clintock Dr

S Los Feliz Dr

S Country Club Wy

S Price Rd

Shalimar Golf Course

S Southern Av

- Tempe, Beat 17
- Resid. Burglaries
- March 5 - April 15
- Related by location, location type and time of day

GIS & Investigations:
Crime Pattern Detection

Scale
.15 mile   N

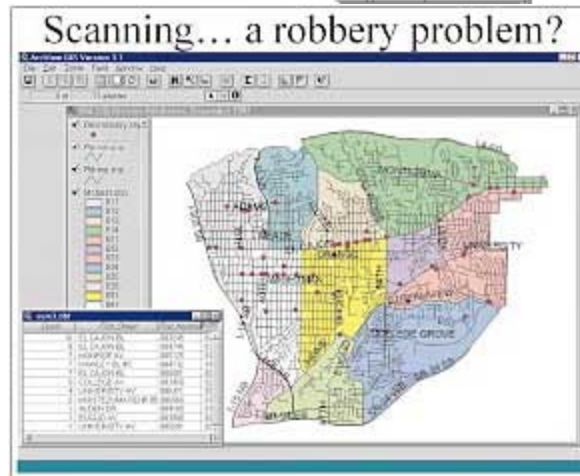Scanning... a robbery problem?

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.

Analysis... time of day, recent?

Crime Review

Housebreaks

October 24, 1998 to November 23, 1998

Last updated: Wednesday, November 25, 1998 02:39:00 PM

Symbol Legend: Color Legend:
● Daytime Break   ■ During Past 7 Days
★ Nighttime Break   ▨ During Past 23-30 days
▲ Unknown Time

Domestic and Landlord/Tenant related breaks are excluded from this map.
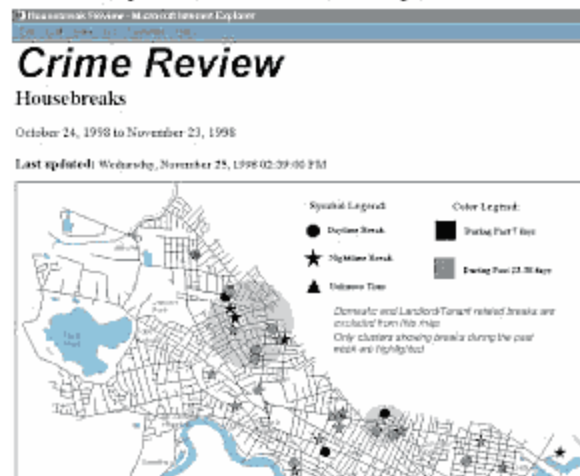Only clusters showing breaks during the past week are highlighted.

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.

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.)

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.
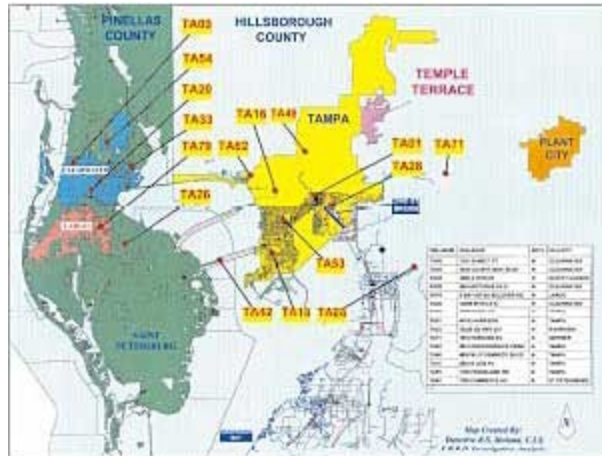
Figure 5.7

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.

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.
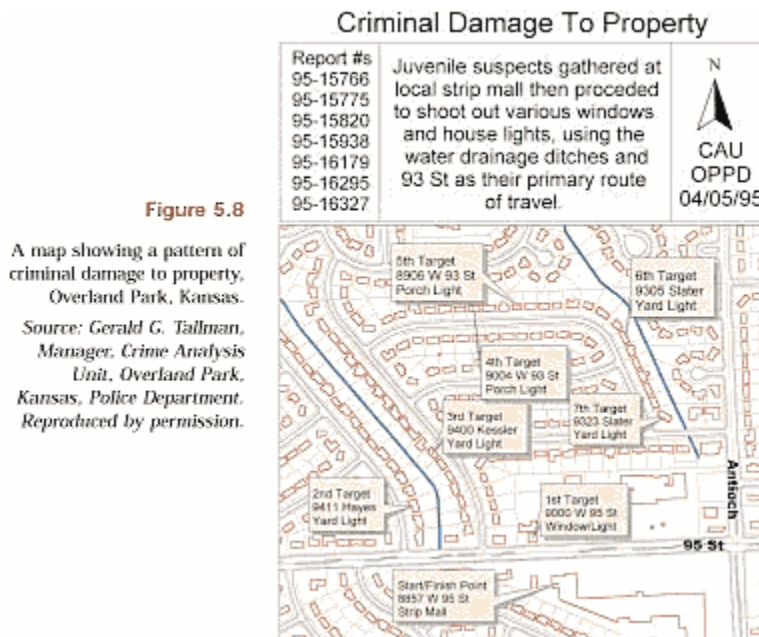

Figure 5.8

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.

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." 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.

Residential Burglary Target Area
AutoDialing System started on 4/6/99 and ended on 4/16/99

One Month Prior to the AutoDialer

One Month After the AutoDialer

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.
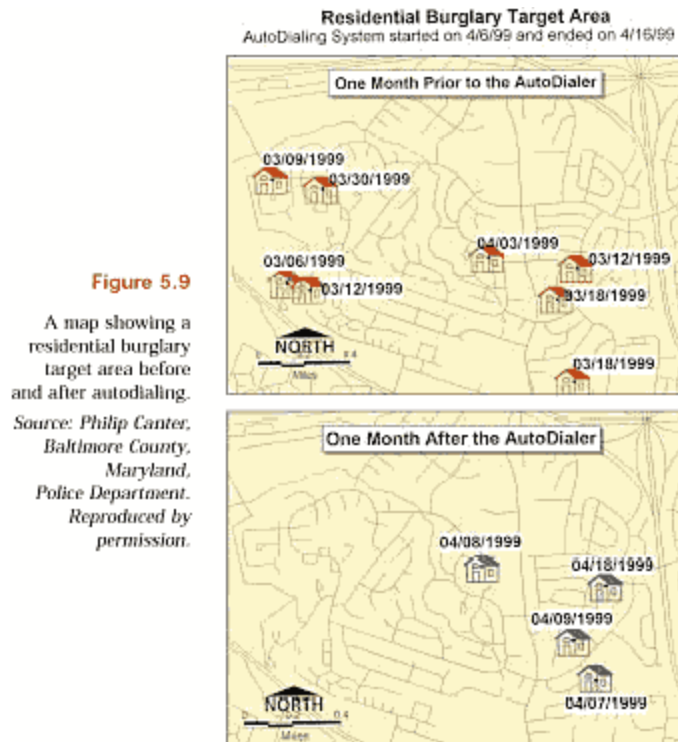
Crime analysis and the census

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

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.

Geographic profiling

Geographic profiling[1] 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).
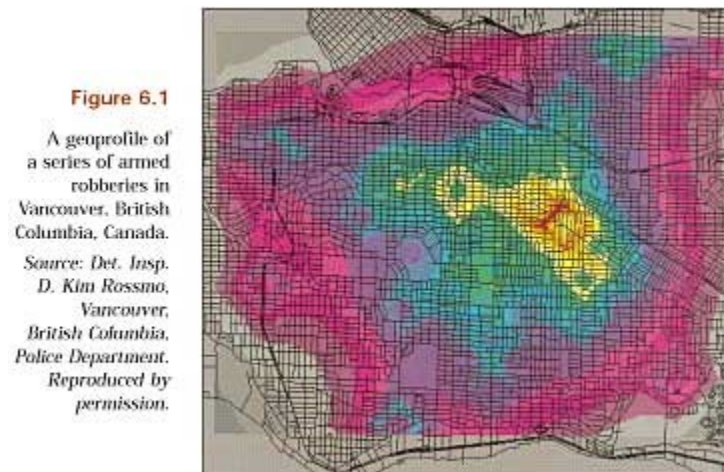
This research has led to the development of *Rigel*, a computerized geographic profiling workstation that incorporates an analytic engine, GIS capability, database management, and powerful visualization tools. Crime locations, which are broken down by type (e.g., victim encounter, murder, and body dump 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.
- 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.

Figure 6.1

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

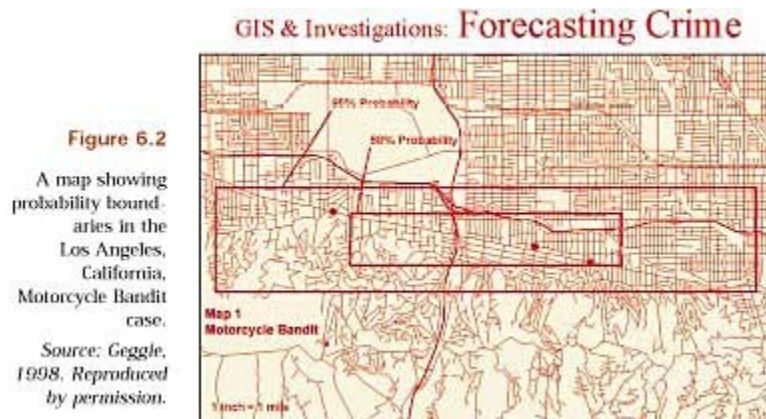Source: Det. Insp. D. Kim Rossmo, Vancouver, British Columbia, Police Department. Reproduced by permission.

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.

GIS & Investigations: Forecasting Crime

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.
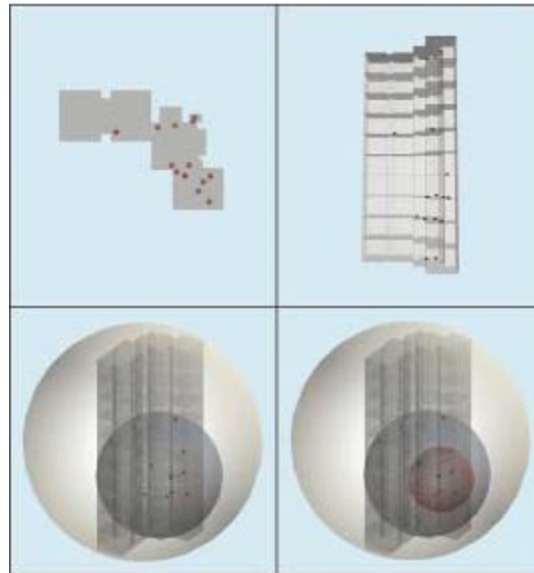
Figure 6.3

A map using high-resolution GIS to show crime in a highrise building.
Source: Rengert, Mattson, and Henderson, 1998. Reproduced by permission.

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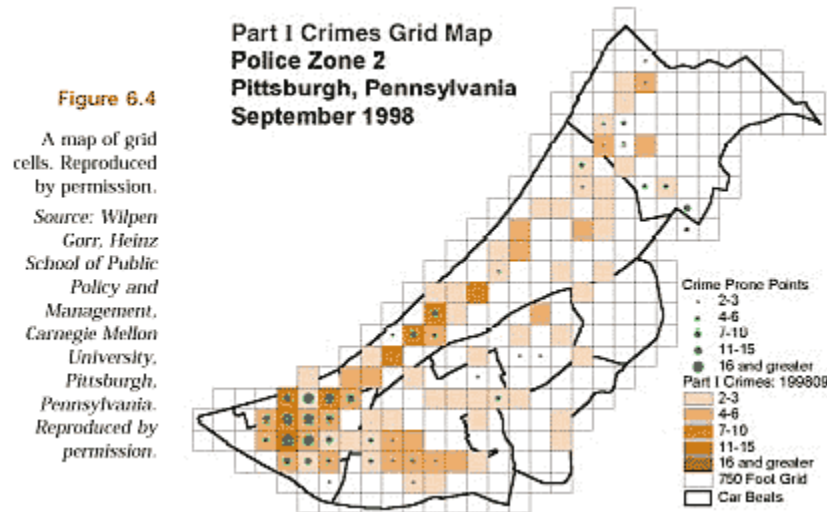
Following rules based on gaming simulation, a statistical model estimated the consequences of the various types of CFS at certain levels. (For details of the model's architecture and specifications, see Olligschlaeger, 1997). Then forecasts from different methods were compared with actual patterns to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

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.

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:
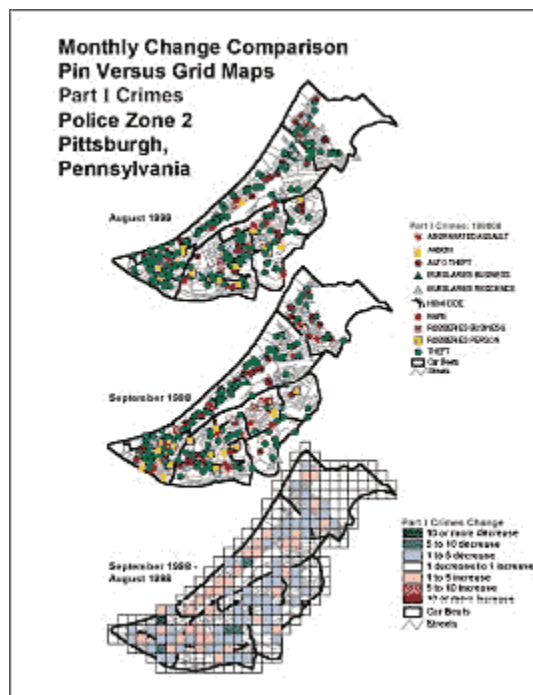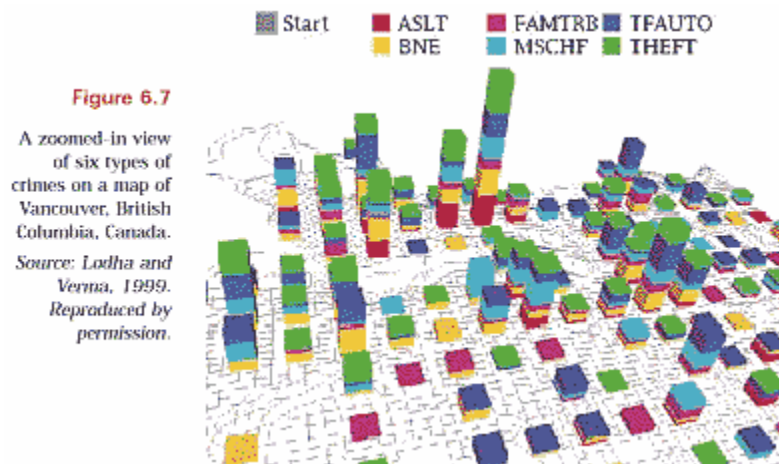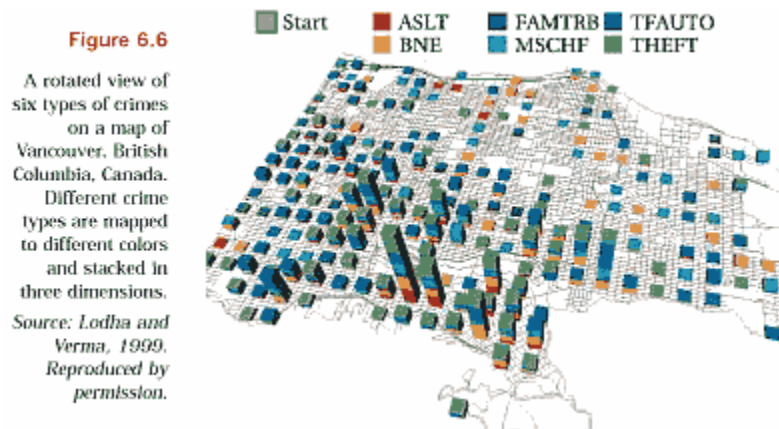

Figure 6.5

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.

- 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.
- 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 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.

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.

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.
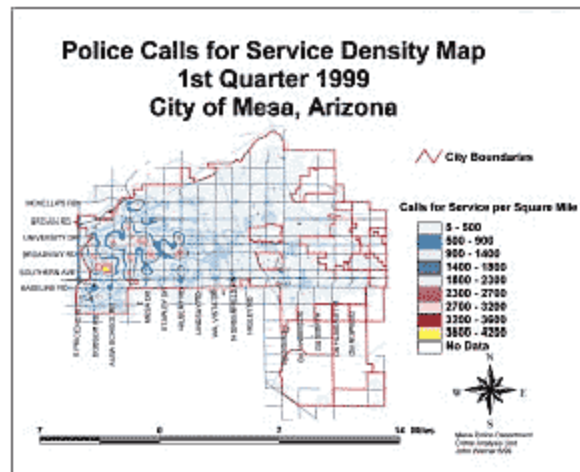
Figure 6.8

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.

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 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.

Figure 6.9

A diagram illustrating the abstraction-reality continuum.

Source: Keith Harries.
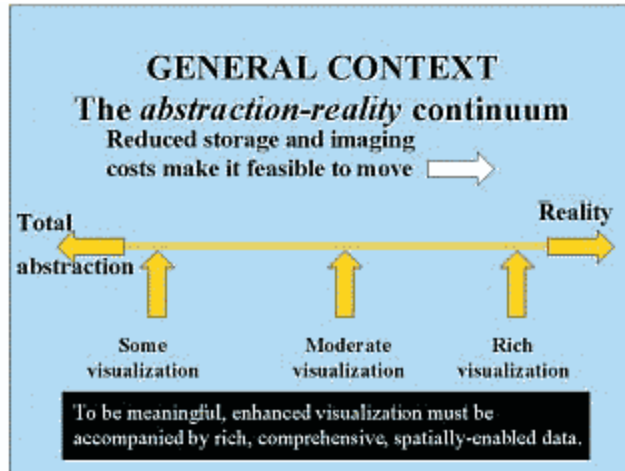
Confidentiality and privacy considerations will probably set limits on how far to the right the process moves. Ultimately, these limits will be culturally conditioned, with more detail where public information and geographic precision are prized and less detail where values put more emphasis on privacy. 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 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.

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.

Potential applications of aerial photography are numerous. Any geocoded 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 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).

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.

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 shrink-wrap 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.