Chapter 1
Introducing GIS for police work

Introduction

This chapter introduces crime mapping and analysis using Esri's ArcGIS Desktop for meeting the day-to-day information needs of police organizations. Topics include user requirements for crime mapping, spatial coordinates systems, spatial data formats, map compositions, and police operations management systems. The chapter concludes with an overview of the book as well as references on underlying criminological theories for crime analysis.

GIS for police work

GIS is a major innovation for police organizations, enabling crime analysts, intelligence officers, uniformed officers, detectives, and command staff to improve the effectiveness of day-to-day work of law enforcement and crime prevention. The innovation stems from high-powered visualization of crime patterns on maps and unique spatial processing of crime data for analysis. Here are some examples of GIS applications covered in this book:

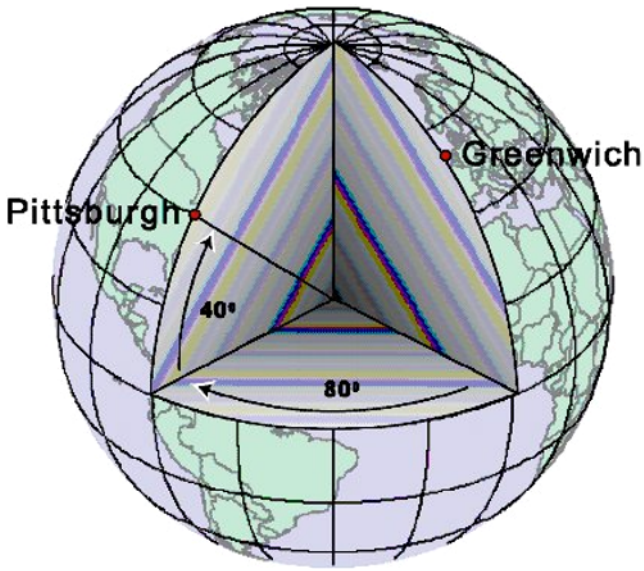
- *Pin maps* for field officers increase situation awareness of crime patterns for diagnosis and action. Before GIS existed, crime maps were on paper and taped onto corkboard wall displays, with colored pins pushed in at crime locations; hence the name "pin maps." As you can imagine, paper pin maps were cumbersome and required manual labor to produce them. Today, GIS easily produces real-time, interactive pin maps on computers, using point markers at crime locations with shape, color, and icons for distinguishing crime types. Field police officers quickly became enthusiastic, expert users of pin maps. Those officers benefit from a complete picture of crime in their patrol sectors, including crimes for times during which they were not on duty and in neighboring areas that might spill over into their areas.

- *Early warning maps* enable command staff at headquarters and special crime squads (such as for violent crimes, burglary, and auto theft) to detect crime pattern changes for allocation of police resources. At the jurisdiction level, these maps show areas with high crime levels and substantial changes in crime. Then when zoomed into an area of interest, the maps show detailed information on individual crimes, much like the field officers' pin map. Early warning maps, with accompanying statistics, are also useful for accountability, review, and planning, such as in CrimeStat programs first started in New York City.
- *Crime maps for public use* help citizens protect themselves and their property from crime. Such maps and accompanying statistics are often the basis of police-sponsored meetings with neighborhood groups such as Neighborhood Watch. Maps for public use, however, must be constructed in ways that protect the privacy of individuals, including crime victims and witnesses. One such protection is "geomasking," which moves crime incident locations from incident street addresses to random points within the incidents' street segments or blocks.
- *Crime hot spot maps* identify locations with high crime concentrations that police command staff use to target police patrols for crime prevention. Crime analysts have a range of methods to predict crime hot spots. The simple methods are accurate for highly persistent (chronic) hot spots generally occurring in commercial areas, while complex methods are needed for temporary hot spots that tend to occur more widely, including residential areas.

Spatial coordinates

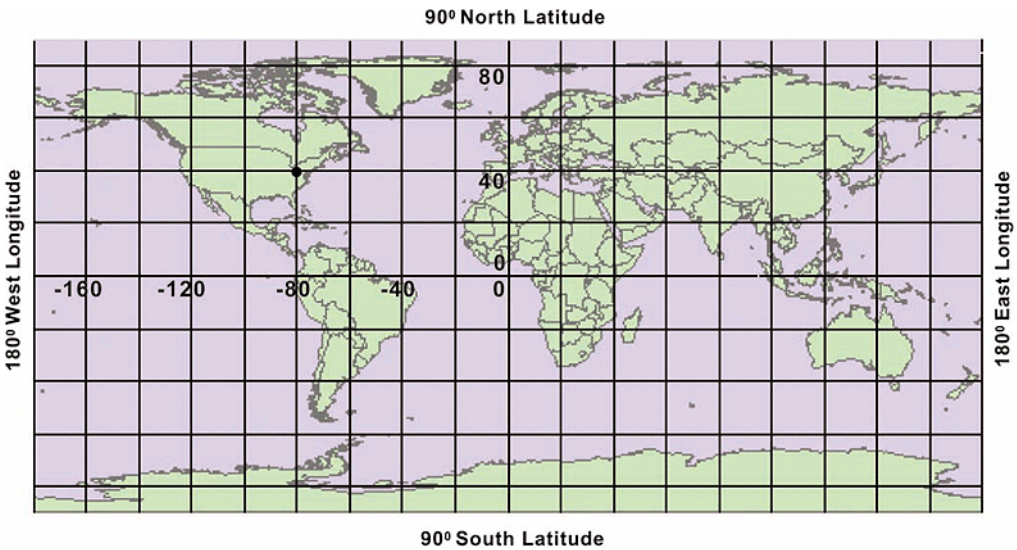
The best way to learn about GIS is to get an introduction to geographic coordinate systems and how features and events from Earth's surface are represented and stored as spatial data on a computer.

The basis of GIS is the set of world coordinates—latitude and longitude—that locate spatial features on Earth. Latitude and longitude are spherical coordinates, angles of rotation of a radius anchored at Earth's center that range from 0^0 to 360^0 around the equator for longitude and from 0^0 to 90^0 from the equator to the North and South Poles for latitude. The (0^0, 0^0) coordinate is the intersection of the equator and the great circle passing through the poles and Greenwich, England, as seen in the next figure. Pittsburgh is approximately at 80^0 longitude and 40^0 latitude.



Representation of latitude and longitude

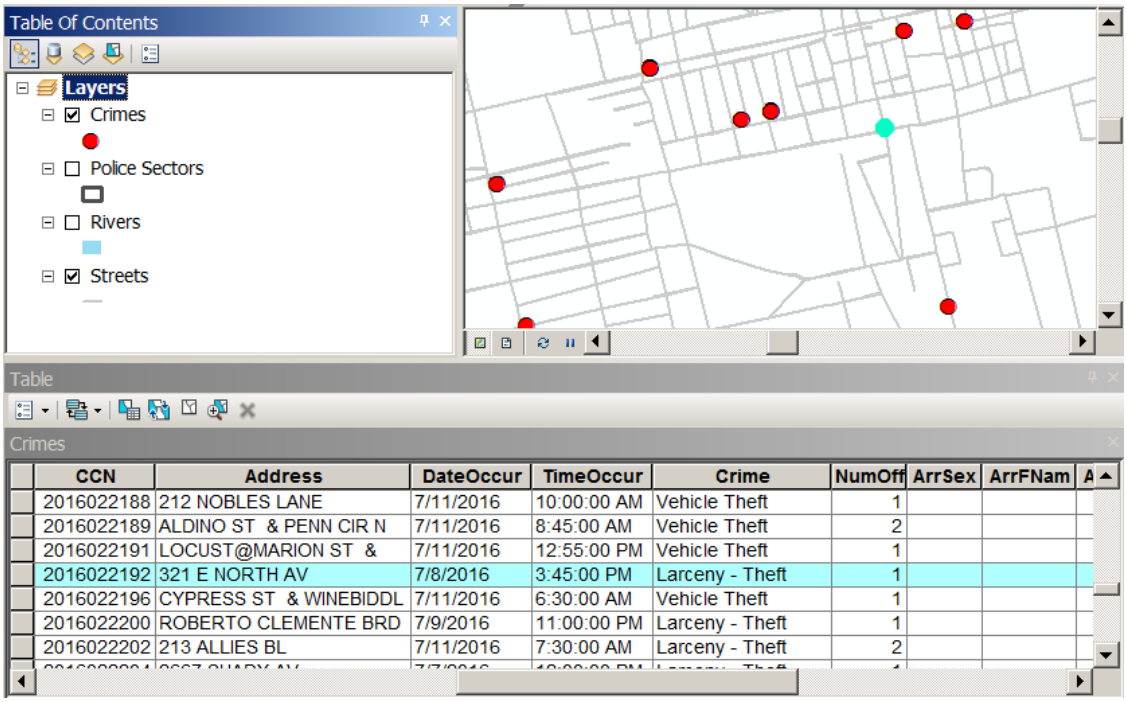
Geographic coordinates should not be used directly for display on a paper map or computer screen, as seen in the next figure, but instead must first be transformed, or projected, to flat Cartesian coordinates. Otherwise, enormous distortions occur. For example, the top and bottom boundaries of the map in the figure are *points*—the North and South Poles! There are hundreds of projections, and all of them result in some distortion of location, area, or shape because of flattening. Local governments in the US often use projections from the State Plane Coordinate System, which tunes projections for accuracy in zones that are made up of counties within states. With the localized tuning and given that state plane zones are relatively small portions of Earth, corresponding projection errors are negligible. State plane projections measure distance in feet and exist only for the US and its possessions. An alternative for the entire world is the Universal Transverse Mercator (UTM) coordinate system, which divides Earth into 60 zones, each with its own projection and with distance measured in meters.



Geographic coordinates for countries plotted as if they were rectangular coordinates

Spatial data

A feature class is a data store for discrete spatial features such as crimes, streets, or patrol sectors that GIS can process and display on a map. Each feature in a feature class has a record in a corresponding attribute table. For example, suppose Crimes is the name of a feature class for storing point locations of crime incidents along with attribute data such as crime type, date, time, and street address, as seen in the next figure. The map has one location and its record selected, as seen highlighted with the bluish-green selection color. Streets is another feature class, storing block-long street line segments that share endpoints to represent the street network of a city. PoliceSectors is a feature class storing polygons that form the boundaries of patrol sectors where adjacent sectors share boundary lines. Note that feature class names should not have imbedded blank spaces, so Police Sectors is given the name PoliceSectors; however, in the Table of Contents of the next figure, the corresponding map layer is given the label (called an alias) Police Sectors for readability. These three example feature classes have the vector data type made up of stored points, lines, or polygons.



CCN	Address	DateOccur	TimeOccur	Crime	NumOff	ArrSex	ArrFNam	A
2016022188	212 NOBLES LANE	7/11/2016	10:00:00 AM	Vehicle Theft	1			
2016022189	ALDINO ST & PENN CIR N	7/11/2016	8:45:00 AM	Vehicle Theft	2			
2016022191	LOCUST@MARION ST &	7/11/2016	12:55:00 PM	Vehicle Theft	1			
2016022192	321 E NORTH AV	7/8/2016	3:45:00 PM	Larceny - Theft	1			
2016022196	CYPRESS ST & WINEBIDDL	7/11/2016	6:30:00 AM	Vehicle Theft	1			
2016022200	ROBERTO CLEMENTE BRD	7/9/2016	11:00:00 PM	Larceny - Theft	1			
2016022202	213 ALLIES BL	7/11/2016	7:30:00 AM	Larceny - Theft	2			

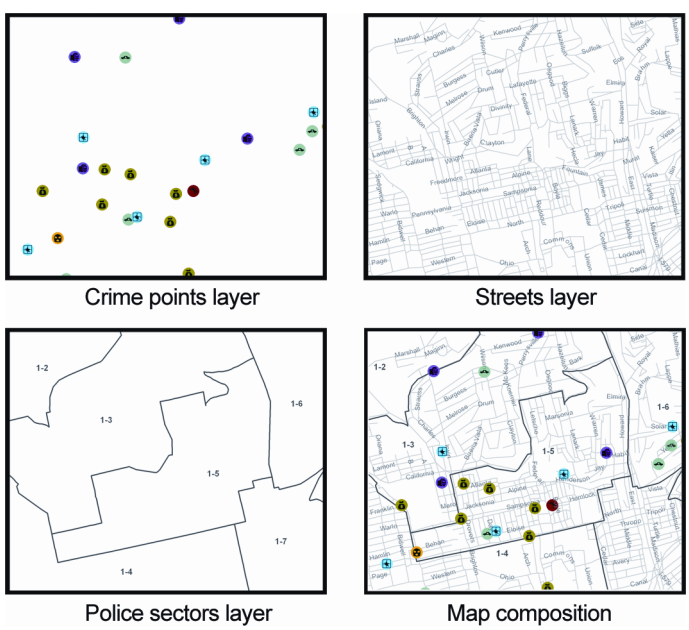
Mapped crimes and corresponding attribute records

This section briefly describes spatial data formats and their use in making maps.

- A *file geodatabase* is Esri's simplified spatial database format for individual and small groups of ArcGIS users and is the primary database type used in this book. This database is composed of a computer folder with ".gdb" at the end of its name that can store a collection of feature classes and other spatial data types. A file geodatabase can meet the needs of small- and medium-sized police organizations, but large police departments may need to use Esri's ArcSDE® (spatial database engine) software geodatabase with a commercial relational database package. The crime mapping and analysis system of this book uses two file geodatabases, Police.gdb for crime data and Pittsburgh.gdb for police jurisdiction feature classes, including Streets and PatrolSectors.
- A *raster dataset* (or raster) is another major type of spatial data, along with vector data, for 2D mapping. (3D mapping uses a third type of spatial data, triangulated irregular network, or TIN, that models 3D surfaces.) Many rasters are satellite images made up of pixels—square areas with solid colors so small that you can't see them individually until you zoom quite far in. More generally, a raster is a rectangular table with numbers in cells (the pixels) and with cells referenced to geographic coordinates. For images, the stored numbers

correspond to assigned colors. For elevation, the numbers are elevation above sea level in meters or feet.

- A *basemap* is a raster map, such as a satellite image or elevation data, provided as a web service from one of Esri's web servers for use on your computer as a general background for your maps. It's also possible to create your own basemaps, but you will not do that in this book.
- A *map composition*, or map for short, has one or more feature classes plus possibly a basemap. A thematic map is a map that has a specific purpose and subject, such as a crime map. When a feature class, which is stored spatial data, is plotted on a map, it's called a map layer. The example map composition in the next figure is composed of three map layers from the Crimes, Streets, and PoliceSectors feature classes. The map layers overlay each other because they are for the same area and have the same projection, the state plane for the southern Pennsylvania zone, as plotted.



Three map layers—Crimes, Streets, and PoliceSectors—overlaid to form a crime map

Police operations management systems and GIS

GIS textbooks generally stress knowledge and skills for completing one-time projects, such as studying the demographics of a region or finding locations for new facilities such as retail stores. This book, however, is aimed at operations management in support of the delivery of police services. "Operations" refers to day-to-day activities that an organization carries out to fulfill its mission—enforcing laws

and preventing crimes. "Management" refers to the efficient and effective allocation of an organization's resources. In a city, that might mean assigning officers to areas in proportion to the need for policing in those areas, and directing patrols to specific locations within those areas to prevent the most crimes. The corresponding police operations management system, based on computer-aided dispatch (CAD) and a record management system (RMS), processes the flow of new crime data as input and provides output reports and data to support the workings of a police department. GIS enhances this system by producing crime maps and other spatial outputs for different user groups.

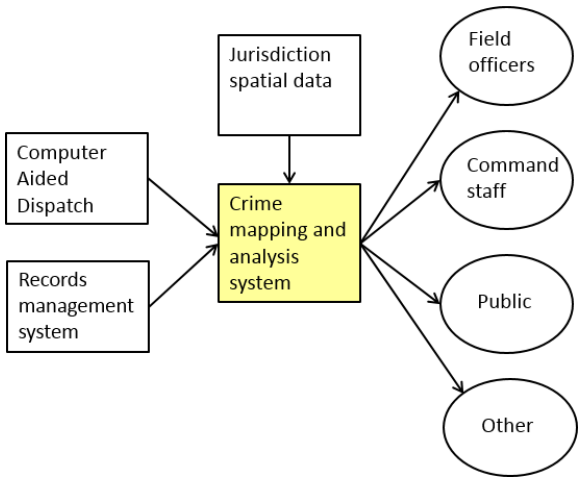
CAD is the database system that inputs and stores 911 calls for emergency services for police, fire, and medical personnel. Each emergency call has an incident data record with a CAD ID primary key, which is a sequence number, along with date, time, location, call type, nature of call code, and other data.

RMS has data entry forms for input of crime incident reports, arrests, and other police administrative data, which is stored in related data tables linked together by primary keys (unique identifiers) for each crime incident, victim, arrested person, and other entities. For example, the primary key for a crime incident in Pittsburgh is a serial number called Crime Control Number (CCN). In Pittsburgh, every crime incident has a corresponding CAD record, and as a result, each record has a CAD ID identifier to refer back to the initiating CAD call.

A crime mapping and analysis system—the subject of this book—processes, analyzes, and visualizes crime data spatially. Think of this system as both an enhancement and major subsystem of police operations management systems. CAD and RMS data serve as inputs, and GIS is the engine that transforms that data into output maps and spatial analyses.

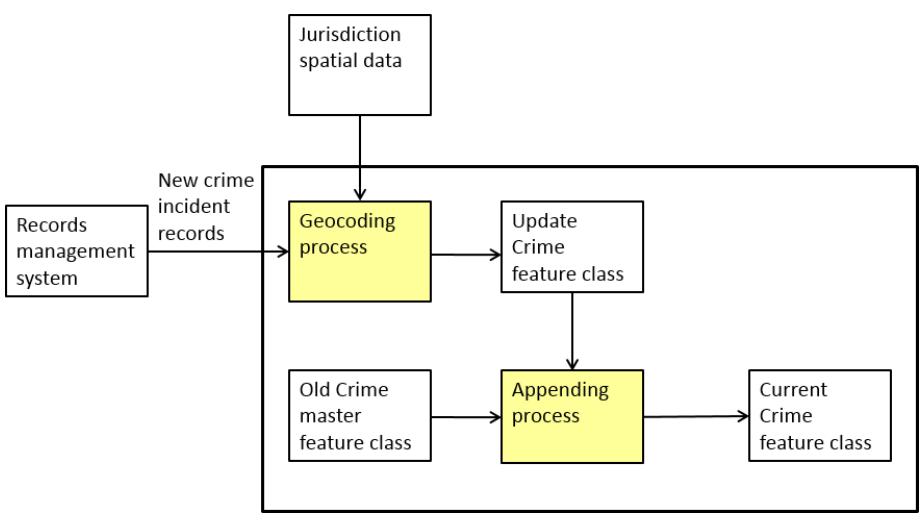
Both CAD and criminal incident records contain street address attributes for location, including house number, street name, street type, street direction, and city (when combined, these attributes yield an address, such as 123 Oak Street W, Pittsburgh). Instead of a street address, a location may be given by street intersection (for example, Oak Street & 5th Avenue, Pittsburgh). GIS uses a matching process called "geocoding" that matches location attributes in crime incident data with corresponding attributes of a Street feature class. This process assigns XY coordinates of Streets to crime incident records for mapping. It's essential that CAD's first responders get dispatched to correct incident locations. Hence, CAD systems have fine-tuned and accurate geocoding. If responding units have GPS (Global Positioning System) receivers, location data may be updated with precise XY data. When CAD data has XY data written to its records, analysts can link to that data for use in criminal report records using a process called a join. The join process matches the CAD IDs in the criminal offense records with corresponding CAD IDs in CAD records.

The figure is a flow diagram of a crime mapping and analysis system. Besides CAD and RMS data, inputs include jurisdiction spatial data (for example, Streets and PoliceSectors) that provide spatial context for crimes. Outputs are maps and analyses for different user types.



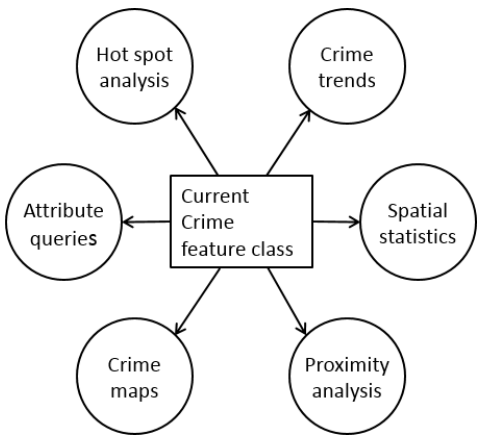
Flowchart of a crime mapping and analysis system

The next figure shows the internal workings of the RMS portion of input and processing in the crime analysis and mapping system, assuming that RMS records must be geocoded. New crime incident records from the RMS serve as input to the geocoding GIS process, along with Streets from Jurisdiction spatial data. The output of the geocoding process is an Update Crime feature class with new RMS records geocoded. The updated data is then appended to the Old Crime master feature class to create the Current Crime feature class.



Spatial data processing of a crime mapping and analysis system

The final figure in this series shows that the Current Crime feature class is the input (along with the Current CAD master feature class) to outputs of the system.



The updated Current Crime feature class, a major source of data for crime mapping and analysis

Overview of the book

The rest of this chapter describes the knowledge and skills you will gain from this book, chapter by chapter.

Exploring ArcGIS Desktop

ArcGIS Desktop is a collection of software packages that comprises a vast and exhaustive storehouse of GIS functions for processing spatial data and building and analyzing electronic maps of any kind. Consequently, ArcGIS has a large and multilayered user interface. Chapter 2 provides a hands-on introduction to the user interfaces for ArcMap and ArcCatalog, the two major components of ArcGIS Desktop, as you explore an informative crime map. ArcMap is a primary ArcGIS application for authoring, editing, publishing, and using maps and for performing analysis. ArcCatalog provides an interface for spatial data utility programs; for example, for importing, copying, and exporting feature classes.

Using crime maps

In chapter 3, you will learn about the information needs of different types of crime map users (field officers, command staff and investigators, and the public) and how to use corresponding maps. Map use includes navigation, information retrieval, and output. Included are zooming in and out of maps, panning maps, finding features, exporting map images, changing layer display order, setting selectable

layers, selecting features and records, changing the selection color, using the Identify tool, measuring distances, drawing shapes on maps, sorting data in attribute tables, and getting statistics from attribute tables. Also included are spatial bookmarks, visibility ranges, magnifier and overview windows, attribute field properties, and hyperlinks.

Building crime maps

Chapter 4 gives you the skills to design and build effective crime maps by applying cartographic principles and the functionality of ArcMap. Crime maps aim to identify crime patterns that are targets for law enforcement and crime prevention. While crime maps should be attractive in their design, their primary purpose is to convey information effectively. In this chapter, you will build the maps you used in chapter 3. Particular ArcMap skills covered include creating a new map document, adding layers to a map, labeling layers on the map, setting visibility ranges, setting definition queries to display a subset of a feature class, symbolizing a map layer using unique values, using special crime mapping point markers for crimes, customizing point markers, setting field properties, setting selectable layers, adding hyperlinks to points, saving layer files, joining data tables to maps, creating custom numerical scales for choropleth maps, creating size-graduated point markers, and creating map layouts.

Querying crime maps

In chapter 5, you will conduct attribute and spatial map queries, which is at the heart of crime analysis. Attribute queries use the logical criteria or filtering part of the Structured Query Language (SQL), the de facto standard query language of database management systems. SQL allows you to select and extract the needed information from records (answering the standard questions of what, where, who, why, and how). GIS also queries in a second, unique way by using the locations or coordinates of mapped features that are proximate to other features. For example, spatial queries can find all crimes within a specified distance of land uses, such as taverns and bars, which tend to attract crime. After completing the chapter, you will know how to create simple and compound queries; create numerical range, subsetting, day of week, and time of day queries; create simple and multiple-ring buffers; and conduct spatial queries using buffers.

Assembling jurisdiction feature classes

If you introduce crime mapping to a police department or want to update or add new jurisdiction maps to an existing crime mapping and analysis system, you will need to know how to extract, combine, and digitize feature classes. You can download feature classes for free from the Internet or get them from your city's planning department or vendors. Chapter 6 covers downloading feature classes, including street centerlines, political boundaries, water features, census tracts, and census data.

Generally, a police jurisdiction does not match the geographic boundaries of available polygon feature classes and instead is composed of either subsets or collections of feature classes. Thus, chapter 6 provides instruction on tools for extracting and assembling jurisdiction feature classes to meet a police department's needs. Police departments may also have unique boundaries of their own, so chapter 6 also covers digitizing feature classes, such as patrol sectors or Neighborhood Watch areas, using street centerlines as guides.

Geocoding crime incident data

Every hour of the day produces new CAD and RMS data records that a police department must process. Chapter 7 assumes that these data do not have spatial coordinates and therefore must be geocoded (address matched) using ArcGIS algorithms that assign spatial coordinates derived from street centerline feature classes. The chapter also covers aggregation of crime point data to space and time series data; for example, counting burglaries per month for each patrol sector. Such data allows you to create maps showing crime levels and changes by area such as patrol sectors.

Automating crime mapping

Chapter 8 introduces ModelBuilder—a visual programming technology available in ArcGIS— for automating crime data updating and map production. ModelBuilder models are macros that you build by dragging and dropping tools from a toolbox and specifying inputs and outputs of each tool in a series of tools that complete tasks. You'll learn how to automate the geocoding processes of chapter 7, appending update data to master feature classes, and produce the major crime map types of chapters 3 and 4.

Conducting predictive policing for crime hot spots

Hot spot analysis and prediction is a widely used approach for crime prevention by police organizations. Chapter 9 provides methods for predicting crime hot spots and an approach for evaluating prediction accuracy of crime hot spots. The corresponding effectiveness curve is directly useful for sizing a hot spot program to match available police resources for crime prevention work.

Environmental criminology literature

Whether you are a self-learning professional or a student enrolled in a course, you will benefit from reading the environmental criminology literature underlying crime mapping and analysis. If you are in a class, your instructor can assign readings to accompany working through chapters in this book.

If you are a self-learner, you can comfortably work through chapters, learning some theory from the provided text, and then follow up through self-directed readings from the literature.

Underlying the success of crime mapping and analysis are environmental criminology theories on how place affects crime (and vice versa), including broken-windows theory, routine-activity theory, and travel-to-crime theory. These theories are covered in a variety of books and other resources, so this workbook does not repeat them here. Instead, it is recommended that you purchase one or more supplemental books listed in the references. In addition, visit the websites of the following organizations for articles and other materials on crime mapping and analysis: Esri, the International Association of Crime Analysts (IACA), the National Institute of Justice, and the Jill Dando Institute of Security and Crime Science.

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