Geospatial Technologies and crime Investigation

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Cyber crime is becoming more of a problem for internet users, with hackers developing new skills constantly, making it challenging for particularly sensitive information to be kept away from those who aim to capture it and use it in detrimental ways.

Abstract : ***Forensics is the application of science to solve crime. Geographic Information Science, encompassing geospalial information and technology (GIT), has become established within the criminology and forensic fields in the last decade. Law enforcement agencies and forensic investigators embrace geospalial science and technologies for collecting, storing, manipulating, analyzing, and displaying spatial data, resulting in new information, procedures, and models for investigation, policy, and decision making. Applications, acceptability, relevance, and procedural legality of geospalial technologies vary substantially, leading to the assessment of their roles in law enforcement, rules of evidence, protection of privacy, and constitutional liberties. This paper discusses the context and principles of geospalial technologies and the integration of geospalial tools, principles, and methods into a five-stage model of crime analysis and investigation.***

Keywords - Forensic science • Geographic Information Science • Geospatial technology • Geographic Information Systems (GIS) • Global Positioning System (GPS) • Remote sensing

1.1 Introduction

As geospalial science and technologi become ubiquitous in society, a wide range of disciplines and professions adopt them for collecting, storing, manipulating, analyzing, and displaying spatial data, resulting in the generation of new information and models for policy and decision making. Forensics is the application of science to solve crime. The geospatial science and associated technologies emerge, they make a distinct and unique contribution to forensics (McKinley et al.

2008; Noond et al. 2002; Wolff and Asche 2009). Law enforcement agencies and forensic investigators have adopted geospatial technologies to profile serial offenders, track suspects, and guide crime reduction efforts, among other purposes. Legal experts utilize the analytical and visual capabilities of geospatial technologies lo present, demonstrate, and explain complex information in the courtroom. Citizen groups have fought successfully against environmental discrimination and have engaged in class-fiaction lawsuits, strengthened by the collection, analysis, and presentation of geospatial data. Geospalial technologies have a long history of use in a broad range of applications such as environmental conservation, real estate, military and security, municipal planning, epidemiology, and agriculture. Recently, Listi et al. (2007) observed an increased popularity of what they described as the field of forensic spatial analysis, citing the evident increase in geospatial technology use presented at forensic-oriented conferences. Despite a relative lack of published research articles in criminology and forensic-related journals, geospatial technologies also serve as highly useful tools in criminal investigations. Geospalial technologies have unique capabilities which are ideally suited to collecting and analyzing spatial data. Traditional methods of investigation, such as pin maps, are largely unable to cope with volumes of multifaceted spatial information in any meaningful manner capable of assisting in identifying an offender or excluding possibilities. Digital spatial technologies result in a more efficient investigation, linking people, places, and objects in a way that assists in optimizing time and resources in pursuit of guilty parties. Conversely, traditional methods of investigation remain vitally important. The merging of spatial tools and methods into investigative practices to establish facts admissible in court is therefore a practice that should be recognized. The application of spatial tools to assist in established investigative practice by adding a spatial perspective is the focus of forensic G1S.

The widespread use of geospatial technologies has increasingly exposed courtrooms to the demonstrative powers of spatial technologies in civil and criminal cases. This paper integrates a five-stage workflow for crime analysis and investigation with the comparable stages of GIS. In Supreme court of India , the High courts of states ,and district courts have ruled on the legality of the use of geospatial technologies under various circumstances. Higher courts have overruled the judgment of lower courts, which has introduced a degree of debate and contention into the legal uses of various geospatial technologies. This paper is intended as a guide to understanding the various roles geospatial technologies provide in investigating crime, providing evidence, and developing policy within the legal system, broadly defined, and how these roles have changed with advances in the technology itself and the legal challenges involved in using the technology for investigation and providing evidence.

1.2 Geospatial Technologies

Recent innovations in information technology have had "dramatic and profound effects in the criminal justice system and will likely have both intended and unintended consequences" (Byrne 2008: 10). Many of these new technologies, incorporating advances in both hardware and software, have proven to be effective improvements over previous technologies for the purposes of investigating, prosecuting, convicting, and exonerating suspects, as well as pursuing civil suits . Geospatial information and technology (GIT), or simply geospatial technology or geomatics outside the United States, has increased in prominence significantly within the criminology and forensic fields in the last decade. While geospatial technologies have been commonly associated with hundreds of applications over the past 50 years, they have only recently begun to be employed in investigative applications as a common practice, as their acceptance in the legal system increases and decreased costs make their use effective.

To identify geospatial technology competencies within the general workforce, here defined geospatial technology as an information technology field of practice that acquires, manages, interprets, integrates, displays, analyzes, or otherwise uses data focusing on the geographic, temporal, and spatial context. It also includes development and life-cycle management of information technology tools to support the above. Although such a definition is very general and all encompassing, it recognizes the extensive nature and roles of GIT across many subject domains. DiBiase el al. (2010) recognized that because of their breadth and diversity, geospalial technologies mean very different things to different people. ranging from a scientific discipline to a collection of tools and from a profession to an industry. However geospatial technologies are interpreted, they are identilied as an opportunity for many fields and many disciplines. Goodchild (2008: 352) called geospatial technologies "powerful extensions of the senses, revealing things that would be impossible to obtain in any other way." At a minimum geospatial technologies include those tools or techniques which are commonly applied to geographic or spatial data. Frequently, Geographic Information Systems (GIS), Global Positioning System (GPS), and remote sensing are categorized as the three main geospatial technologies (see Bossier et al. 2010) which are well-established fields of study and in general public use across a wide range of applications (e.g., conservation, real estate, military applications, municipal planning, epidemiology, and agriculture).

1.2.1 Geographic Information Systems, Science, and Studies

Although the acronym "GIS" is typically reserved as an abbreviation for Geographic Information Systems, it is often applied somewhat ambiguously to distinctly different subfields of study. Goodchild (1992) suggested GIS was not only a "system" but also a "science" receding substantial differences in usage. Scholars (Forer and Unwin 1999; Longley et al. 2005) later associated the "S" with "studies," expressing the GlS acronym as either Geographic Information Systems, Geographic Information Science, or Geographic Information Studies. To avoid confusion and provide the precise context of the acronym, distinctions can be made. Geographic Information Science is often differentiated as GIScience, GISci, or GIs(c), and the field of Geographic Information Studies is typically denoted as either GIStudies or GIs. Goodchild (2008) and Longley el al. (2005) elaborated the differences of meaning in the various GIS acronyms. A Geographic Information System (GIS) is defined as a computer system for capturing, managing, integrating, manipulating, analyzing, and displaying geographically referenced data. It can be seen as consisting of five components: hardware, software, data, methods, and people connected by a computer network (Longley et al. 2005). In a GIS, location becomes the common denominator between disparate datasets, enabling them to be correlated, merged together, and managed to explore relationships between data in order to identify patterns and trends in the form of maps, analytical reports, and charts.

Geographic Information Science (GISci) emphasizes underlying principles and fundamental questions, as well as the research and development raised by the use of GIS through strong scientific and intellectual components (Goodchild 1992; Getis et al. 2000). Research into, and extension of the concepts of, scale, dimensionality, topology, and spatiotemporal representation drives GISci inquiry. In a synergetic relation, GISci affects the implementation of GIS while the functionality of GIS advances the theory and practice of GISci (Gold 2006). Mark (2003) provided a more thorough explanation of GISci, which he summarized as a multidisciplinary research field for redefining geographic theories, concepts, and uses. Geographic Information Studies (GIStudies) emphasize G1S in a societal context and examine issues such as privacy, ethics, legality, and return on investment (Forer and Unwin 1999; Chrisman 2005).

GIS, GISci, and GIStudies each has associated applications and challenges in crime investigation and the production of evidence. GIS, and remote sensing are combined to merge spatial datasets to create maps of legal boundaries. Using this information, researchers and law enforcement agencies are able to reproduce, update, and distribute standardized maps and atlases to identify and monitor areas of illegal encroachment on protected forest land. The maps identifying encroachment within the legal forest boundaries are then used to provide evidence to the court system. This paper focuses on GISci as the authors develop a prototype crime mapping and decision support system for law enforcement agencies in the Web environment. A focus on publicly available Web maps of registered offender's residences . This paper explores aspects of GIS studies to examine societal issues of geospatial technology that are both beneficial to public safety and potentially injurious to offenders who may become targeted victims of harassment, arson, assault, and murder. The challenges are numerous when applying GIS, GISci, or GIS studies to crime investigation or providing evidence arising from concerns with associated hardware, software, data, methods, and people. Problems arise with the selection of appropriate data collection, storage, analysis, integration, and display. Underlying theories and principles have been questioned as well as the interpretation of results and societal impacts. This study explores such challenges to illustrate what is required under the rules of evidence and admissibility for geospatial technology.

1.2.2 Global Positioning Systems

Among the family of geospatial technologies, satellite navigation systems are perhaps the most familiar, of which the Global Positioning System (GPS) is the most frequently used. The availability of GPS devices for outdoor activities, such as hiking and geocaching, as well as vehicle navigation and location-based services provided through cellular phones and mobile computing devices permeate contemporary society. Equally, no other geospatial technology has affected the geospatial industry and discipline as profoundly as GPS (Bossier et al. 2010). The GPS has advanced to provide real-time, centimeter-level positional accuracy across much of the globe through the use of networks of satellites that orbit the earth. Satellite navigation systems in various stages of development and accessibility is very useful in searching of the criminals.

The advantages of real-time positional data for investigating crime and providing evidence are abundant. Law enforcement agencies, judicial systems, and citizens have embraced the tracking ability of GPS; for example, law enforcement agencies have solved criminal investigations with a record of a suspect's movements captured by a GPS device (Byrne 2008). Courts commonly order the attachment of ankle bracelets fitted with a GPS to offenders to ensure compliance with restrictions (e.g., in-home confinement or restraining orders). Citizens equip vehicle and equipment with devices such as LoJack which allow for tracking and recovery of stolen equipment; however, as with many other technologies, GPS has an established track record of misuse (e.g., for stalking victims) and has been subject to numerous legal controversies and challenges (e.g., violations of the fourth amendment (United States v. Jones 2012).

1.2.3 Remote Sensing

The oldest geospatial technology, remote sensing is a mature discipline with well-understood concepts and principles and a range of versatile applications ranging from aerial photography to LiDAR (Warner et al. 2009). Jensen (2007) provided eight definitions of remote sensing with the common premise that remote sensing is the art and science of acquiring data and information about an object without making physical contact with that object, ensuring the object is not disturbed or altered through the act of measurement. There are two types of remote sensing: passive and active. Passive remote sensing detects and collects energy emitted from an object, such as reflected sunlight captured in photographs or sensors. Active remote sensing emits energy in order to measure the reflected energy from the object of observation. Some active remote sensing (e.g.. X-ray) has the potential of affecting targeted objects, but longer wavelengths such as visible light or RADAR do not. Remote sensing sensors can be employed on ground platforms (e.g., vehicles or structures), in the air (e.g., attached to aircraft such as unmanned drones), and in space (e.g., satellites).

Just as GIS and GPS have benefited investigations and provided evidence, the long history of remote sensing has ensured its widespread use. As new technological advances and capabilities continue to emerge, the potential applications for investigations and evidence will continue to increase. However, there are, and will continue to be, controversies and challenges associated with the surveillance and data storage capabilities inherent to remote sensing and other geospatial technologies.

1.3 Spatial Data

Spatial data are distinctive in that they contain linked information about location and attributes (Gabrosek and Cressie 2002). Goodchild et al. (2000) noted that the term spatial is in fact shorthand for spatiotemporal. as it refers to data and phenomenon that have both spatial and temporal dimensions of variation. In having integrated components of location (places and times) and attributes, spatial data require specialized data storage, handling, and management. Although the terms geospatial and spatial are often used interchangeably, spatial is the more generalized term denoting locational context at any scale, while geospatial refers to data with a location component that can be referenced lo a point on the earth (Longley et al. 2005). Spatial data is an extremely valuable and versatile resource, which is subject to widely accepted international standards (Boer et al. 2007). Rooted in the spatial science tradition of the discipline of geography (see Martin and James 1993), the spatial perspective emphasizes the role of location and scale as important variables in understanding patterns, processes, and causality.

Because of its unique composition, spatial data are handled differently from non-spatial data to address the role of location. For example, any location has the potential for the occurrence of a crime incident; however, certain spatial relationships significantly increase the chances of places having an incident, such as within blighted neighborhoods, near alcohol outlets, outside gated communities, along particular streets, adjacent to wooded lots, or combinations of such factors. As may be gathered from these examples, location is an important component in not only understanding crime but also in the investigation and prosecution of crime. The use of geographic principles and spatial perspectives assist in efforts to investigate crime and apprehend offenders and increasingly takes on a forensic role, especially in the form of geographic profiling (Brantingham and Brantingham 1981; Rossmo 2000).

Spatial data have several advantages over nonspatial data. Given known location and attributes, spatial data can be mapped and analyzed readily. Mapping allows for the visual recognition and empirical demonstration of patterns from complex dalasets, such as the detection of clusters of crime incidents within a large database of all police events. Crime mapping and analysis takes advantage of these clusters or hot-spot areas for tactical and strategic planning to prevent and reduce crime . A growing number of police departments routinely map and analyze crime data for different purposes Through georeferencing, spatial data also provides a commonality between disparate datasels based on their common geographic location or footprint. Consider the Internet for example - a user can search any set of locations and retrieve data on people, businesses, attractions, items for sale, weather, and news events for the set of locations. An investigator may become more informed in identifying vehicles, weapons, parolees, warrants, or calls for service to a particular location by querying disparate but georeferenced databases using one or more addresses. Similarly, the investigator is able to expand the query to include all records within a given distance of the address, without the need to know and query every specific individual address within the given distance.

Clearly modern spatial data are also digital. Whether collected by, or stored in computers, these data can be easily exchanged and shared through clearing houses like the National Crime Research Beuro (NCRB). Vast amounts of spatial data have been produced by the governments with many local government partners. In India, much of the governmentally produced spatial data is in the public domain and covers large geographic areas at ever-increasing spatial resolution, which allows for cross-jurisdictional analysis with little difficulty. The wide availability of spatial data generates a wealth of informalion for decision making, policy, and management, and the dynamic and interactive nature of spatial data provides an additional advantage. Given dynamic data, the user can update results and explore new relationships and trends. For example, a common application is to identify routes using an Internet map service. A user can specify whether the user wants the quickest route, the shortest route, the route with most or least use of interstate highways, or even a route which avoids tolls and construction activities. Regardless of the linal choice, GIS presents the user with options, informs the user with results, and produces new information, while not altering the original underlying data in generating the results.

1.4 Forensic GIS

According to the American Heritage Dictionary of the English Language,1 forensics is "the use of science and technology to investigate and establish facts in criminal or civil courts of law." More broadly interpreted, forensics is the application of any science or technology used to investigate and establish facts. As a result, the concepts of location, place, and scale are intrinsically embedded within forensic investigations, analyses, and through the presentation of evidence, as are spatiotemporal relationships.

Burrough and McDonnell (1986: 11) defined GIS as "a powerful tool capable of storing, retrieving, transforming and displaying spatial data for a particular purpose." Applying the Burrough and McDonnell definition with its emphasis on a particular purpose, the phrase "forensic GIS" can be said to establish that purpose. A distinction made for forensic GIS is necessary due to the overwhelming volume of literature pertaining to GIS in general and in other specific fields. The term and concept of forensic GIS is introduced here, not as a new or unique field so much as a way to provide the forensic and criminal justice-related communities with a distinction pertinent to their purposes and interests. As such, it is anticipated that new ideas and research in this area will not get lost among the volumes of GIS literature in general, but will stand out as a forensic GIS literature.

The main utility of forensic GIS is to provide associative evidence, which assists in either proving or disproving links between people, places, and objects as they relate to the court of law. It should be stressed that a forensic GIS acts to assist traditional investigative techniques by adding a spatial perspective and should not be considered as a technological replacement for them.

Access to GIS technology and spatial data has accelerated over the last two decades and is clearly impacting the ways investigations are performed and evidence is presented in court. Technology has become a more reliable and efficient means of generating evidence than police hunches . The National Police academy Hydrabad , identified high-priority needs for criminal justice technology within the scope of five functional areas, one of which was enabling informed decision making. The NCRB reports listed a range of needs for spatial analysis tools and technologies that included the need to analyze geographic linkages among people of interest to criminal justice agencies, extend the current capabilities of crime-related databases, provide compatibility with mobile/handheld devices, and identify and extract hidden relationships in large and complex datasets.

Although a definition of forensic GIS has yet to be formally established. Morrow-Jones et al. (2005: 19) set forth the concept of a "forensic GIS" as a way to "collect, explore, and analyze spatial data in order to detect irregularities that may violate law or fair practice." However, this definition is rather narrowly based on the terms "detect" and "irregularities." An alternative definition is the application of geographic and spatial tools, principles, and methodologies to investigate and establish facts within the boundaries of forensics. As such, under the basic definition of forensics. spatial science serves as a specified science, and geospatial technology is the technology used to investigate and establish facts that may be presented in criminal or civil courts of law.

The boundaries of forensic GIS are not clearly defined and may overlap with other forensic or spatial science subdisciplines. However, an examination of closely related fields reveals important characteristic differences. Forensic geography, geoforensics, forensic geoscience, forensic mapping, and environmental forensics are often closely associated with geospatial technologies and geographic theories and principles. Forensic GIS is set apart in thai the use of geospatial technologies is not discipline specific and the geospatial analyst does not necessarily need to be an expert trained in spatial science. For example, anyone (from any discipline with any level of spatial expertise) can use an online Web mapping service to determine distances and time requirements for travel between two locations to determine the possibility, or improbability, of a suspect conforming to an established timeline of events.

Forensic geography is a subdiscipline of geography wherein a geographer or other expert does research . Geoforensics and forensic geoscience are synonymous with each other and, although there are varying definitions, refer to the application of "geo" or earth sciences to forensic investigations (Morgan and Bull 2007; Pye and Croft 2004; Ruffell 2006; Ruffell and McKinley 2008). Schmitz et al. (2013) categorized forensic mapping as a field of forensic geography that maps criminal activity using location data from GPS devices and cell phone usage data. Environmental forensics focuses exclusively on environmental concerns and enforcement (Brilis et al. 2000, 2001; Grip et al. 2000; Ruffell and McKinley 2008). There are numerous other "forensic" fields, such as forensic archeology (Obledo 2009), forensic geology (Murray 2004), forensic geomorphology (Ruffell and McKinley 2005), forensic seismology (Ruffell and McKinley 2005), and forensic palynology (Mathewes 2006; Mildenhall et al. 2006). The time is ripe to develop the study of forensic GIS.

1.5 Stages of Crime Analysis and Investigation

Zhao et al. (2003) divided crime analysis and investigation into five workflow stages: (1) collecting crime data; (2) processing and storing crime data and documents; (3) searching, retrieving, and collecting additional information for crime analysis; (4) analyzing information to find clues; and (5) using information to prosecute (or defend) individuals. These workflow stages are organized to follow a seamless timeline (temporal continuum) beginning before a crime is committed and culminating in the obtainment of either a prosecution or acquittal before the cycle is repeated. Noticeably, the five workflow stages of crime analysis and investigation are similar to the six workflow stages used to define (ilS (capture, manage, integrate, manipulate, analyze, and display spatial data). Calling it the "geographic approach," Dangermond (2007) referred to the integration of GIS as a new way of thinking. Conceptually, forensic GIS can be viewed as a new way of thinking which integrates the five workflow stages of crime analysis and investigation with the defining workflow stages of GIS along a temporal continuum that extends from a spatially enabled pre-crime capability to the courtroom presentation of spatial data.

1.5.1 Stage I: Collecting Crime Data

Crime scenes exist in time and space. Concepts of location, place, and relative location (next, near, overlapping) are intrinsic to investigation and evidence. Location, place, and scale are embedded within the data, as are spatiotemporal relationships. The challenge in establishing a spatially enabled forensic GIS crime database is first to collect and store the information and then to use and reuse it during the investigative process (Oatley et al. 2006; Rossmo 2006). Information about any particular crime should be collected with the understanding that it will be used in future analysis, including spatial analysis. Oatley et al. (2006) contended that while a single recorded crime may have little value, when a diversity of information from an event is collected and stored in a comprehensive crime database, it provides a powerful retrospective investigative tool. Rossmo (2000, 2006) similarly stated that information must be properly collected, analyzed, and shared if it is to be of any value to investigators. Because a forensic GIS identifies spatial relationships, it is important to have a precise and accurate location of a crime scene to facilitate confidence in the results of any future analysis.

1.5.2 Stage 11: Processing and Storing Crime Data

As Nelson (1999) pointed out. law enforcement is about information management and location. Unlike traditional record management databases, a GIS database supports traditional tabular-based data, such as spreadsheets, and additional multimedia porls traditional tabular-based data, such as spreadsheets, and additional multimedia-based information, such as word processing documents, digital pictures, and video and audio recordings. However, analysis is currently restricted to the spalial and nonspatial component of the tabular data, excluding the images, video, and audio recordings. This limitation may eventually disappear with advances in technology. For example, integrating facial recognition software with GIS will provide further linkages between suspects and crime scenes based on collected and stored photographic evidence.

1.5.3 Stage III: Searching, Retrieving, and Collecting Additional Information for Crime Analysis

The investigation process involves asking specific questions, and the responses are essential in establishing links in criminal activity. A simple example is determining if a crime scene has distinctive characteristics that are similar to those at other crime scenes. Two crime scenes which share distinctive characteristics might indicate to investigators that the same offender was possibly involved in both incidents and provide a link between an offender and crime scenes; however, the ability of a forensic GIS lo link criminal activities efficiently relies on an investigator formulating the relevant questions (Adderley and Musgrove 2001). Traditional GIS investigations have focused on suspect identification and pattern analysis in linking activities with offenses (Groff and La Vigne 1998; LaVigne and Groff 2001). Descriptive factors and locations of crime scenes serve as starting points to identify potential suspects from additional databases which can be linked to the GIS.

During this third phase, information collected is examined to determine what is available and what remains to be collected for further investigation. Any necessary additional information is then obtained. A common means of obtaining additional information is through the process of querying additional law enforcement databases, such as sex offender registries or parolee databanks, as well as government record databanks such as motor vehicle registration or through third-party databanks, such as utility companies and cell phone providers. A forensic GIS enables investigators to search for information not only based upon attribute linkages but also by spatial linkages. An example might be to identify registered sex offenders living nearest to a sexual assault scene (spatial link) or to identify a list of previous offenders on parole/probation who may not be properly registered (attribute link). The importance of dispersed systems to maximize the search is evident.

Discovering which crime incidents belong to a series is an essential and important step in serial crime investigation (Rossmo 2006). Link analysis, also known as comparative case analysis, is the process used to tie a series of crimes together based on three main methods: (I) physical evidence, (2) offender description, and (3) crime scene behavior (Rossmo 2000). A forensic GIS can be used to establish such links and display the locations where the potentially linked incidents occurred. Using a forensic GIS to link similar crimes or suspected offenders within a limited geographic area provides further associative evidence of a relationship. One of the benefits of linking cases is that it informs an investigator of a potential serial criminal, which permits the focus of the investigation to shift from multiple unrelated incidents to identifying a single suspect responsible for many incidents. As such, apprehension of one individual would have the potential of solving numerous linked cases. Once a suspect is apprehended, the link analysis informs the investigators to question the suspect about each of the linked cases and seek to prove guilt through a confession, physical evidence, or witnesses (Rossmo 2006). In contract to establishing links between multiple incidents and a single offender, using a forensic GIS in the link analysis process may also inform investigators of potential multiple offenders for similar incidents based on geographic location.

1.5.4 Stage IV: Analyzing Information

Whether investigating a major crime or a crime series, vast amounts of data are generated, and the sheer volume of these data invariably obscures possible underlying relationships and linkages (Adderley and Musgrove 2001). Nelson (1999) stated without analysis that data is useless. A GIS allows a database and a map to be linked for the purpose of data analysis and visualization. Markovic et al. (2006) described such GIS maps as "heuristic devices, or effective tools for stimulating investigatory processes, exploration, and reexamination" with the advantage of being able to empirically validate hypotheses generated through discussion and an interactive discovery process performed by patrol officers, detectives, and crime analysts. While collected information alone is useful within an investigation, further analysis can allow investigators to confirm or reject identified links. Within a forensic GIS, the analysis is centered on spatial information to inform the investigative process. Longley et al. (2005) suggest six generalized types of spatial analysis common to GIS: (1) queries, (2) measurements, (3) transformations, (4) descriptive summaries, (5) optimization, and (6) hypothesis testing. A detailed discussion on the various types of spatial analysis remains outside the scope of this paper; suffice it to say there is a wide range of spatial analysis techniques available to investigators, and the choice of which types of analysis to use would depend upon each unique investigation case.

1.5.5 Stage V: Using Information

GIS technology allows the analysis of data to identify, apprehend, and prosecute suspects (Nelson 1999). Suggs et al. (2002) discussed the benefit of link analysis as a widely accepted tool for criminal and environmental investigations which assists in providing an understanding of complex relationships during trial presentations. Wilson et al. (1997) described computer-generated evidence from GIS as being highly reliable. One of the most common applications of GIS in criminal prosecution cases is in validating distance measurements. For example, when a drug sale occurs near a school, a GIS map clearly marking whether the location of the suspect's arrest falls within a GIS-measured drug-free buffer zone often suffices to enact enhanced penalties. In an investigation of high-crime areas, Leipnik and Albert (2003} discussed the application of (ilS to prove significant relationships between the location of crime and certain establishments, such as liquor stores. In these cases, civil enforcement actions and license revocation were actions taken in lieu of proving criminal activity on the part of the establishments, although the GIS provided both graphic and geographic proof of localized crime when taken to court or liquor control board proceedings.

1.6 Summary

The management of the large amounts of raw data and derived information generated during criminal investigations call for new approaches using spatial information technology (Adderley and Musgrove 2001). In order to perform meaningful analysis, practitioners are finding an increasing need for the transfer of new knowledge and technologies from other disciplines (Haggerty 2004). Many of these new technologies have proven to he improvements over existing forensic technologies for the purposes of demonstrating compelling evidence in lawsuits (Jacobson 2004). Different types of geospatial technology have been used to investigate crime, prosecute and convict offenders, and exonerate suspects. Common examples of geospatial technologies include GIS, remote sensing, ground-penetrating radar, high-definition 3-D laser scanning. Light Detection and Ranging (LiDAR), thermal imagery, radar, sonar, magnetic resonance imaging. X-ray, GPS-related tracking, and radiofrequency identification. The applications, acceptability relevance, and procedural legality of each technology vary substantially, leading to a number of considerations still being addressed by the court system, ranging from the rules of evidence lo the protection of privacy and constitutional liberties. Although considerable precedent exists for the use of geospatial technology, new issues and challenges are emerging as the technology evolves, generating new legal considerations.

The main utility of geospatial technology has been to provide associative evidence to assist in proving or disproving links between people, places, and objects as they relate to the court of law. Spatial data, inherent to geospatial technologies, are a valuable and versatile resource when used to investigate and establish facts in a court of law. Forensic GIS, defined here for the first time, is the application of geographic and spatial tools, principles, and methodologies to investigate and establish facts within the boundaries of forensics. The main utility of forensic GIS is to provide correlated evidence, which assists in either proving or disproving geographic, spatial, or temporal links between people, places, and objects as they relate to the court of law.

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