Land Use and Opportunities for Crime: Using GIS as an Analysis Tool

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(ABSTRACT)

It is important to identify the link between land use and opportunities for crime in order to create safer living environments in cities. Changes in land use change urban form and this leads to changes in the routine activities of people, which in turn creates new opportunities or changes existing opportunities to commit crime. This link is supported by theories in the field of environmental criminology. There is a need for data and information in order to understand this link and to make decisions on strategies that are to be implemented for reducing opportunities for crime. GIS has emerged as a powerful analysis tool to support the decision-making process involved in crime prevention. This paper tries to identify the informational needs for crime prevention through law enforcement and planning and the use of GIS to support efficient decision-making.

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TABLE OF CONTENTS

SECTION 1
INTRODUCTION

The growth of a city is directly influenced by its population growth. Growth and change ultimately impact quality of life in communities both positively as well as negatively. The positive effects are seen through the creation of new spaces to live, work and shop. However, the negative effects such as an increase in demand for public facilities and services and an increase in crime are undesirable. As a city grows, law enforcement and crime prevention are among the services that often do not receive adequate attention.

This research paper will focus on how decisions about land use and urban form ultimately influence the growth and future of cities. The research examines whether it is possible, through careful consideration of land use, urban form and building design, to reduce opportunities for crime and thereby minimize the additional demand for law enforcement services that will be experienced because of growth of cities. This is also an attempt to understand and analyze the importance of criminology and its relationship with factors affecting the development of cities such as land use, zoning and infrastructure.

GIS and spatial analysis tools have been used in two ways in relation to variables affecting growth of cities:

- Law enforcement agencies use GIS to map and to analyze patterns and trends of crime in order to allocate policing resources.
- Planning departments use GIS tools as a part of comprehensive planning and zoning to evaluate existing development and to consider potential new development or redevelopment opportunities.

The above-mentioned information is rarely combined into a single analysis. This research paper examines the potential for more effective use of GIS and spatial analysis tools to become more proactive in addressing opportunities for crime and in responding to existing crime hot spots.

The foundation for this approach comes from research in environmental criminology, which has shown that there is a relationship between land use, urban form, routine activities and crime.

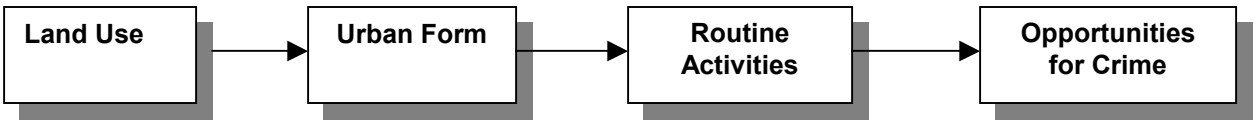

Figure 1.1: Relationship between Land Use and Opportunities for Crime

Figure 1.1 helps us to identify the strong link between issues of land use planning and opportunities for crime through two other important factors namely routine activities and urban form, which will be discussed in detail in the next section.

The goal is to be able to identify those specific places where specific types of crime are most likely to occur (both now and in the future), based on information about existing patterns of crime, as well as the other variables that factor into the crime equation as per the above model. Examples of such variables are activities and schedules, existing and future land use, zoning and land development regulations, etc. Thus, this paper uses research in environmental criminology to structure the discussion and to understand the various types of information that would be necessary to create safer communities.

The next section of this paper discusses research in environmental criminology and examines the relationship of land use with opportunities for crime in the light of these theories, which have lessons for both law enforcement agencies as well as planning departments.

SECTION 2
ENVIRONMENTAL CRIMINOLOGY AND THE LINK BETWEEN LAND USE AND CRIME

Interest in the link between the physical environment and crime first emerged in the 1920s at the University of Chicago. Researchers there studied a number of American cities and tried to understand the relationships among the city's urban form, the distribution of delinquency and other factors, such as social events. These studies of delinquency by School of Sociology researchers Clifford Shaw and Henry McKay shaped the future of criminology in the U.S. and marked the beginning of our understanding of spatial patterns of crime. Others, such as Park, (Park et al., 1925) focused on the two components of social ecology. The first component, urban form and structure, suggests that land use is guided by economic segregation and the economic competition for space and resources (Brantinghams, 1981). The second component of social ecology is social psychology, which predicts the nature and quality of community interaction and social organization, as well as the community character within different naturally evolving areas.

Jane Jacob's book *The Death and Life of Great American Cities* (1961) was the first contemporary piece to show how an active street life could considerably reduce opportunities for crime. This was followed by C. Ray Jeffery's book *Crime Prevention through Environmental Design* (1971, 1977). Jeffery considered a broad array of environmental factors that influence offenders, including the physical environment (urban form and design), the legal environment (reinforcing rules and regulations), the economic environment and social structures and social organization. His work stimulated researchers such as the Brantinghams, Felson and Clarke, as well as professionals such as planners, geographers, sociologists, psychologists and architects to study crime in relation to environmental factors. The results of their work are summarized in Figure 2.1.

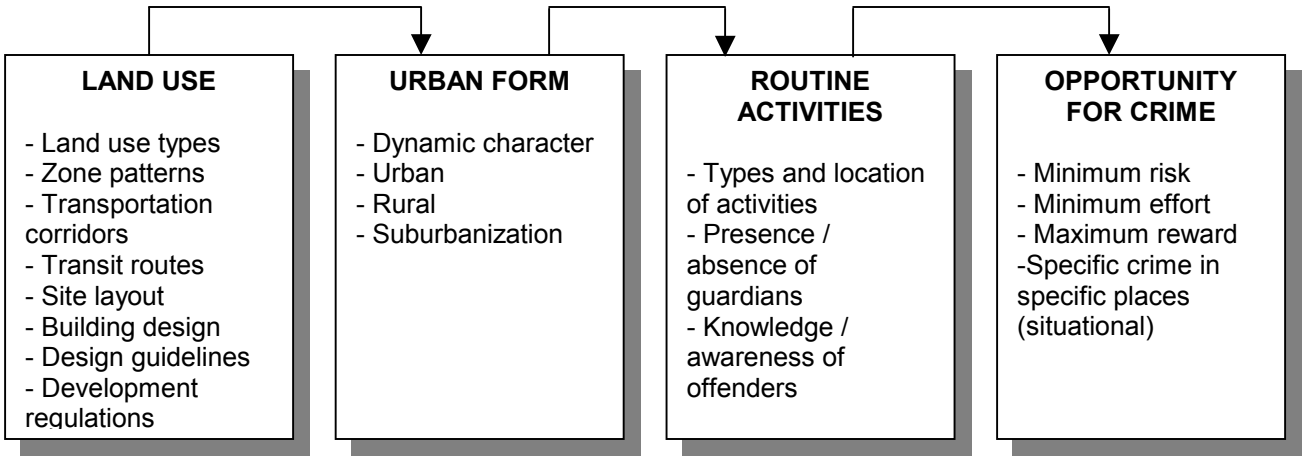

Figure 2.1: Theoretical Foundations for the link between Land Use and Opportunities for Crime

This figure shows that land use, i.e., development patterns (zoning), transportation corridors or transit systems, site layout, building designs, and development regulations and design guidelines play a key role in influencing the urban form. Changing land use therefore

changes the activities that take place in a city and these change the opportunities for crime that are available.

Studies in environmental criminology have also indicated that there is a strong relationship between the patterns of crime in a city and the urban form. In 1978, Paul and Patricia Brantingham studied how crime locations scatter themselves into specific patterns in relation to the variables that govern growth of cities. Older cities with concentric zonal forms have crime-locations concentrated towards the dense core of the city (Brantinghams, 1981). The cities with mosaic patterns that are relatively newer seemed to have a scattered pattern of crime spots.

The patterns of roads in a city also have a relation with the patterns of crime because the roads determine the accessibility to potential crime spots in a city. Cities built on gridiron patterns are known to have higher crime rates when compared to cities with naturally developed street layouts.

The different types of crimes that are committed are related to the different land uses that exist in a city, as shown in Table 2.1. The table indicates that residential plots showed the highest frequency followed by streets and public channels, parking lots and commercial areas. The other facilities such as educational institutions and recreational areas are moderate in their frequencies while medical facilities have shown the lowest frequency.

Table 2.1: Crime Frequencies by Land Use, 1984

Land Use	**Frequency**
Residential (Private residences)	68,513
Public Channels (Street)	43,090
Storage nodes (Parking lots)	33,979
Retail and Trade (Commercial)	26,288
Educational Facilities (School / College)	7,202
Urban Recreation (Bar / Tavern)	4,317
Industrial (Construction sites)	2,522
Other	2,332
Rustic Recreation	1,677
Office Buildings	1,202
Rural Industrial	1,106
Medical Facilities	724

Source: Illinois Law Enforcement Commission, 1984

Even more important is the combination of land uses and the impact this has on opportunities for crime. Chances of property crime occurring are higher at places where there are dispersed shopping and strip commercial developments. Commercial areas in cities have been found to be prone to burglaries and thefts while residential areas are conducive to crimes such as sexual offence and murders. Studies have also indicated the possibility of child-sex offences and juvenile crimes occurring are much higher near areas where high schools are located.

As land use changes through new development and redevelopment, the structure of urban form changes as well (Brantinghams, 1981 & Felson, 1987). (See Figure 2.1) Urban form is dynamic in character. Take for instance, a case in which a new school is built in a relatively unpopulated area on the outskirts of a city where vacant land is available. This change in land use might bring other changes nearby, such as the development of bus stops, other community facilities like stores, etc., which would eventually change the original rural image of the place. This means that the change in land use in one part of a city can lead to development of other necessary land uses nearby which leads to the creation of a new urban form.

In 1987, Felson developed his routine activities theory for understanding crime in relation to the studies conducted by the Brantinghams. Routine activities are the day-to-day activities of people: shopping, using parks or recreation facilities, or commuting from home to work. Changes in land use bring about changes in urban form, which change routines and provide new opportunities for crime. According to Felson, routine activities deliver easy crime opportunities to the offender. The occurrences of most criminal acts require the convergence in space and time of potential offenders having sufficient awareness about the space, suitable targets or victims and the absence of guardianship (Cohen & Felson, 1979).

Ronald V. Clarke is well noted for his research in situational crime prevention, which examines the relationship between routine activities and rational choice in order to evolve strategies for crime prevention. He argued that specific types of crime are committed at specific locations depending upon the situations. In rational choice theory, the focus is on the idea that potential offenders commit crimes in places they know well and when they get opportunities, involving least risk and effort and maximum benefits (Cornish & Clarke, 1986). Thus, the opportunities for committing crime are directly influenced by routine activities that are involved in the everyday lives of people living in cities and the routine activities in turn are influenced by urban form and structure (Brantinghams, 1981, 1984; Clarke, 1986; Felson, 1987).

The literature in environmental criminology supports the idea that a link exists between land use and opportunities for crime. As a matter of summary of this section of the paper, we can state that change in land use changes urban form and this leads to new routine activities, which in turn change the opportunities for crime as shown in Figure 2.1. The City of Sarasota, FL (see case study in box, below), is a good example in which law enforcement officers and planners identified the link between land use and opportunities for crime.

Analysis of research theories in the field of environmental criminology can aid in promoting urban safety because it helps us to identify the factors that are crucial in determining the crime rates and their distribution in a city. A thorough analysis of the crime rates, crime-patterns and the types of crime that could be committed by offenders in different zones having

Case Study: City of Sarasota, FL

The North (Tamiami) Trail in Sarasota, Florida, had several motels and deteriorating structures with poor maintenance built prior to the 1960's. When the city decided to update its comprehensive plan, a detailed study of this area was conducted which indicated the existence of illegal activities such as prostitution and drug dealing. An initiative was undertaken to study crime in this area and a citywide administrative task force was formed for this purpose.

The task force conducted a detailed analysis of the North Trail Area in terms of existing land use, demographics and the distribution of businesses and residents. Analysis of a citizen survey revealed that street prostitution was the most visible crime indicator. Poor lighting and landscaping had created negative perceptions of the area, which also created an environment conducive to illegal activities like prostitution and drug dealing.

The task force next analyzed crime data for the North Trail Area. Crime statistics for the area supported the survey results. They showed that prostitution and drug dealing had been increasing while property values and maintenance were declining.

A review of zoning regulations in the area showed that the area was full of motels and hotels built in the 1940's to 1960's, before the latest Zoning Code was enacted in 1974. Most of them were not in conformance with zoning regulations including setback requirements and parking requirements. Their inability to redevelop the area had encouraged the building owners to rent them to prostitutes and drug dealers. The area therefore continued to have a bad image and negative publicity, which led to ever-pervasive presence of prostitutes in the area.

As a result, the City of Sarasota created as new zoning district, which allowed for creative redevelopment, as long as property owners would implement the design recommendations of the task force. Specifically, these requirements were meant to reduce crime opportunities in the area. The City of Sarasota, Florida, is a classic example of how urban planners and law enforcement agencies can participate together in order to identify the link between land use and opportunities for crime and to support crime prevention.

different land uses can be a good step toward reduction of crime rates in urban areas and promotion of safer living environments. It is therefore extremely important to have the right kind of data in order to make such decisions on crime prevention. The next section of this paper therefore discusses the information needs and possible sources of information for this analysis.

SECTION 3
INFORMATION NEEDS AND INFORMATION SOURCES

The identification of the link between land use and opportunities for crime as explained earlier lays the foundation for the discussion on what types of information may be required in order to make better land use decisions and ultimately to reduce opportunities for crime. Information about land use, urban form, routine activities and opportunities for crime is obtained from different data sources.

Land Use Information

Planners have to store and manage different kinds of data such as data about land use in order to make correct decisions regarding comprehensive plan updates and also regarding the revision or creation of zoning ordinances which determine land use patterns, and in turn opportunities for crime. Some of the different kinds of data that planners store and use are listed below:

- Existing land use data and maps
- Future land use data and maps
- Zoning ordinances and data
- Land parcel information
- Building footprint details
- Assessed values of properties
- Property ownership (tenure)

Urban Form Information

Information about urban form is obtained from departments such as transportation, engineering and public works. For examples, details of road networks and patterns including transit routes and stops can be obtained from the transportation department while water supply and utility network data can be obtained from engineering and public works departments. Planning departments can provide us with information on suburbanization and potential new developments in the city, which can substantially alter urban form and structure.

Information on Routine Activities

Demographic data (census data like age, gender, race, salaries, etc), information about the level of satisfaction of citizens and details about the routine activities of people can be directly obtained through citizen surveys and community input through public hearings. For example, contacting personnel in the mass transit management departments could help us get information on commuting patterns of people in the city. Similarly, information on routine activities such as recreation and shopping can be obtained by contacting managers and other staffing personnel involved in the operation of recreational and commercial complexes.

Information on Opportunities for Crime

Law enforcement agencies store and manage data about crime occurrences and data about potential opportunities for crime. Law enforcement agencies maintain information on offenders and criminal records, arrests, crime incidents (crime-type and crime locations), law enforcement resource data such as patrol beats as well as community resource data. Crime data stored in the information system can be analyzed in different ways. Some of the different approaches of crime data analyses are by:

- Total crime
- Crime rate
- Type of crime
- Location of offense
- Time of day
- Day of week
- Month or season of year
- Characteristics of crime event
- Victim or target characteristics

Information Sources and Information Sharing

It is clear from the above discussion that different kinds of data and information have different sources which gives rise to the need for efficient data sharing amongst all the different departments in the city in order to ensure easy and efficient accessibility to information that can be used for decision making. Information can be best shared amongst different departments when collaborative efforts are organized with cooperation from the citizens to solve community problems such as high crime rates.

For example, in order to conduct a crime analysis, we might be interested in obtaining details about routine activities of school children in a city which involves collecting data concerning the functioning of the school, activity-schedules of school children, their playing areas and playing times, etc. Another example of routine activity data could be details concerning the operation of a convenience store, the number of clerks operating the store, hours of operation, etc. Such data about routine activities can be obtained directly through interaction with the convenience store owners, managers, employees and customers in order to study them in relation to urban form.

Details concerning opportunities for crime can be obtained from law enforcement agencies that keep track of crime locations, crime-event characteristics, etc. The data stored in all these different departments might have been collected through different means such as observations, surveys, citizen input and feedback through public hearings, input from social forums and non-profit organizations involved in providing education and information on crime prevention through collaborative initiatives, etc. At this point, it must be emphasized that this data needs to be shared amongst all the different departments (planning, law enforcement, public works, engineering, transportation, etc) and with the citizens so that there is collaboration between the different departments to collect and share data to make decisions. This facilitates easy accessibility to required information for making decisions that fall within the purview of each department. The data collection and sharing process has been greatly improved through the developments in information technology in the recent years.

Rapid improvements in networking and Internet technologies have facilitated easy information sharing between planning departments and other agencies and between planners and citizens. Developments in the field of information technology such as web based GIS have emerged as powerful tools in implementing the planning process starting with the community input and feedback. The web enables planners to host all information concerning changing polices, zoning ordinances, update of comprehensive plans and other possible future evolutions or changes in the city. This would thus act as an additional tool that can support the objectives of public hearings and public participation, which makes it easier to address community concerns.

It can therefore be understood from the above discussion that the link between land use and opportunities for crime has a variety of data sources, which can provide us with different kinds of information we need in order to promote safety through crime prevention. This necessitates information sharing between the different departments. This can be best achieved through collaborative efforts of different departments in the city in order to fight crime. When different departments coordinate with each other in a collective effort to tackle crime problems, easy flow of information from one department to another occurs facilitating the identification of the factors that could be modified to promote safety. The City of Boston is a very good example of how information needs can be satisfied through collaborative efforts between different departments within a city through information sharing.

Case Study: City of Boston, MA

In 1995, the Boston Police Department prepared a strategic plan to improve communication between the police and citizens. The police department solicited input and feedback from the people to get information for crime assessment and safety promotion. This improved the collaboration with stakeholders and local accountability for police commanding officers. The collaboration efforts of the police department with the community led to a better feeling amongst the people regarding neighborhood safety in the City of Boston.

The Boston Police Department undertook a major collaborative effort called Safe Neighborhood Action Plan (SNAP). The department collaborated with the U.S Department of Housing and Urban Development (HUD), U.S Conference of Mayors and the National Assisted Housing Management Association to improve crime prevention efforts in residential neighborhoods. The program was successful because the department was involved in cooperative efforts among key stakeholders such as governments, property owners, residents, managers, businesses and neighborhood leaders, etc. They also took the initiatives to make the communities express the problems they faced and to help them to be able to use the existing crime prevention resources effectively. This was aimed at stabilizing neighborhoods at risk and to help the neighborhoods already in distress.

The above-explained approaches helped the Boston Police Department reduce the city's crime rate by 44% from 1992 to 1997. The city identified the community problems directly through encouragement of public participation. The city facilitated easy access to information sources and effective information sharing through collaborative efforts with other departments. The departments of other cities have lessons to learn from the City of Boston regarding information access, sharing and management.

SECTION 4
GIS: AN ANALYSIS TOOL

GIS: A Solution for Information Needs

We have learned from theories that land use and opportunities of crime are strongly related. In order to analyze and understand this link better, a wide array of information from different sources is needed. GIS has emerged as powerful tool to support analysis of information as a means for understanding the relationships of variables affecting the link between land use and opportunities for crime.

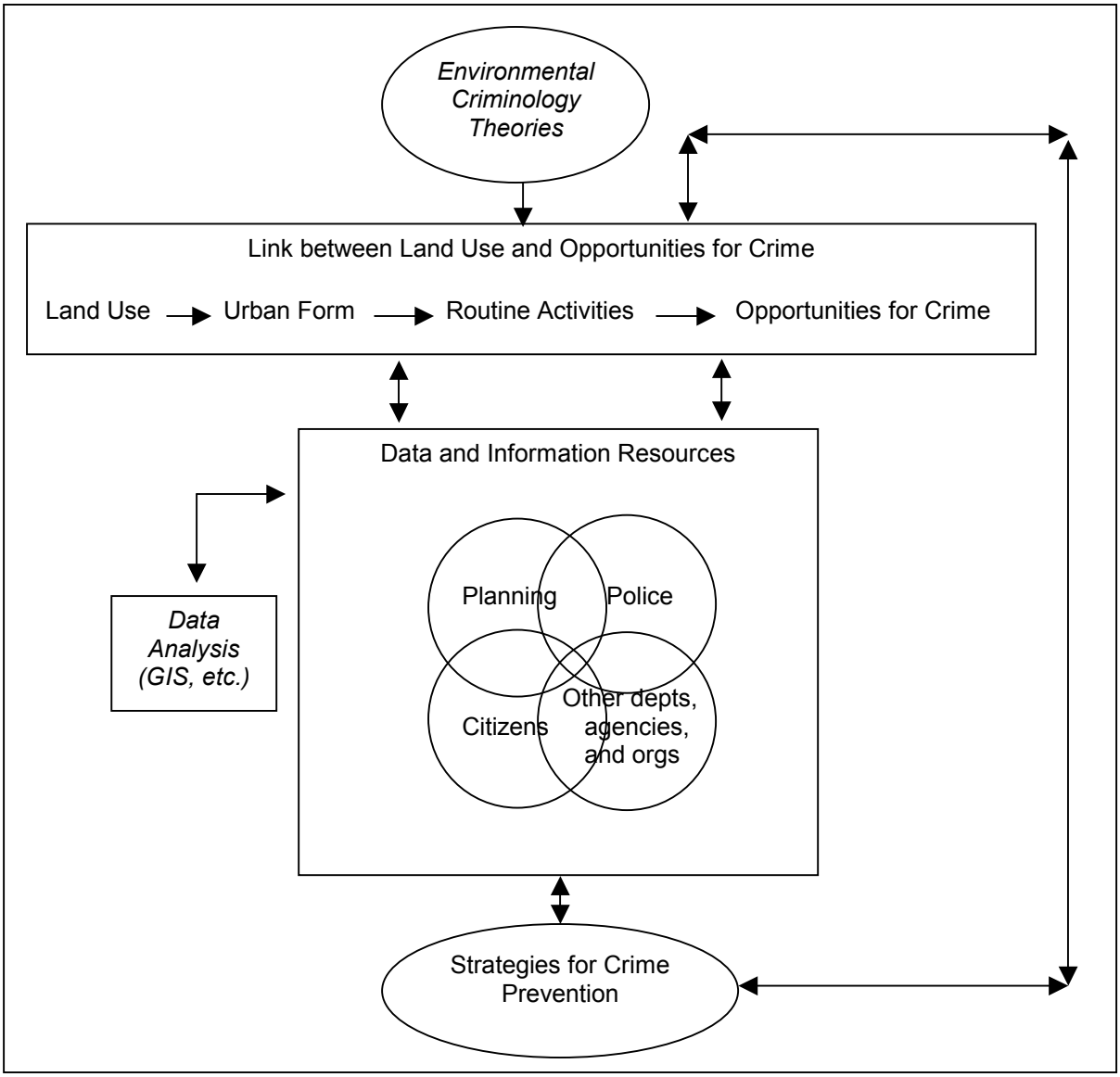

Figure 4.1 Role of data analysis and GIS in decision making on crime prevention

A Geographic Information System (GIS) is a special kind of database management system that supports analysis, organization and visualization of demographic and spatial (geographic) data as well as creation of new datasets. GIS is also a system of inter-related functions that can achieve several goals such as data entry and storage, data-analysis and display. What makes a GIS unique when compared to other database management systems is its ability to handle spatial data. When the database is queried with preset conditions about the data, it provides us with information with which we can make decisions. It is important to understand the role of GIS in the decision making process as shown in Figure 4.1.

Hot Spot Analysis

GIS tools allow integration of crime information systems with spatial data and assist in the production of accurate and high quality maps that clearly show the locations of different kinds of crimes as crime-spots. The concentration and distribution of such crime-spots can be visually studied to identify crime patterns. A "hot spot" is a location or a small area within an identifiable boundary showing concentration of criminal incidents (Anselin, et al., 2000). Hot spot analysis is an important contribution to policing because it helps law enforcement agencies to understand how best to allocate resources and planning departments to decide on land use or zoning modifications to promote crime prevention.

Different strategies can be used to identify and map hotspots. Various statistical algorithms can be used for clustering the crime spots. GIS software programs extensively use methods such as areal analysis (analysis in terms of area) and pin-map analysis (analysis in terms of points) in order to determine the correct hot spot areas. A set of grid cells with a definite number of crime occurrences in each cell can also be used as a basis for hot spot demarcation. However, this would require us to set rules and standards concerning threshold values and grouping of cells into newer hot spots as crime patterns and trends change over time. The choice of boundaries selected to represent hot spots can be of particular interest. The boundaries can be fixed or can be variable depending upon the kind of hot spot analysis that one chooses to do.

Density surface analysis can be used to identify areas that could represent potential crime hot spots. Crime location data are discrete data (points). In order to generate the density surface, we have to transform the discrete crime spots data into a continuous surface with interpolation techniques which can take into consideration tolerance limits or buffers for areas of high densities.

There is a definite relationship between place and crime. In order to understand this relationship, we have to understand the dynamics of hot-spot development both spatially and temporally (See Appendix A). Special attention must be given to a location's facilities and utilization that can contribute to criminal behavior. Two different kinds of models namely, descriptive models and predictive models have been used in hot-spot analysis. These research models are respectively based on spatial statistical theories from descriptive statistics and inferential statistics.

GIS for Proactive Decisions

Consider a hypothetical case in which GIS is used for studying robberies in neighborhood convenience stores. The first step would be to identify all possible occurrences of crime in

convenience stores in the recent past in order to conduct hot spot analysis. Once this analysis is complete, we can identify areas with high concentrations of convenience store robberies according to which patrolling services can be distributed by law enforcement agencies as a reactive measure. However, it to be emphasized that GIS is not just used for such reactive decision making but it can also be used for proactive decisions concerning crime prevention.

At this point, it is worth recalling the link between land use and opportunities for crime. The next step is to examine urban form in relation to the hot spots in order to identify factors such as proximity of the hot spot to highways, the levels of accessibility through street networks, etc. Next, the routine activities of the convenience store must be examined in relation to the hot spots by taking into consideration details such as hours of operation, number of personnel operating the store, lighting conditions near the store, etc. Study of convenience store hot spots in relation to these factors with the use of GIS enables us to identify a deeper cause that might be crucial for the occurrences of convenience store robberies.

Once the deeper cause for the opportunity for crime in relation to land use or urban form or routine activities is identified, we can make a proactive proposition involving manipulation of one of the identified factors, which is changeable such that it promotes crime prevention. For example, residential land use cannot be changed easily because it already exists. Urban form in terms of accessibility of roads is fixed and cannot be changed. The only thing that can be changed is the routine activity in terms of improving guardianship and this could be a valid proactive decision. Another proactive decision would be to emphasize on good lighting conditions to ensure clear visibility in the areas near convenience stores.

The role of GIS in this context of proactive decision-making is very important because it helps us to study hot spots in relation to data layers from planning departments to identify deeper causes that are beyond the purview of law enforcement services. Such deeper causes might actually be a planning problem as we saw in the case study of the City of Sarasota, FL. We can therefore say that GIS is not just used for reactive decision making but is also used for making proactive decisions to study crime hot spots in relation to other crucial variables which form a part of the vital link between land use and opportunities for crime.

Planners can use GIS to study the interrelationships between different variables that govern the development and future of cities in relation to crime. This can help them to make correct decisions concerning redevelopment of existing areas as well as new developments in cities. They can take decisions about changing zoning laws in cities with a goal of reducing crime.

The distribution of crime-locations can be compared with other kinds of data such as demographic data from census such as population densities, economic levels of population residing in an area, etc. In some of the analyses done in cities, there has been a higher probability of crime occurring in very highly populated areas as well as the least populated areas. This might be due to the higher probability of finding criminals in densely populated areas and the areas with very low population could be serving as crime pockets for criminals. (Crime pockets are places in cities that are conducive to the occurrence of crime). Further, the crime mapping analysis can also help us to hypothesize a relationship between economic levels and standards of

living of different categories of people living in different parts of the cities. The hypotheses that are formed from crime mapping of data from different sources using GIS can be subjected to a rigorous statistical analysis to verify the formulated hypotheses.

Layers of GIS data such as land parcels, crime spots, land use, topography of land, etc can be studied in relation to each other. This data can be used to make forecasts and decisions concerning future land use and it's impact on other variables, which supports the decision making process in land use planning. GIS can also be used to consider redevelopment of areas in cities to modify the existing land use based on the analysis of interrelationships between variables with respect to distribution and concentration of crime.

Thus, we see that GIS is a powerful analysis tool that assists both law enforcement officers as well as planners to make decisions. The next section of this paper makes recommendations for examining the link between land use and opportunities for crime and for reducing potential crime opportunities.

SECTION 5
RECOMMENDATIONS AND CONCLUSION

The identification of the link between land use and opportunities for crime with theoretical foundations from environmental criminology helps us to learn that crime prevention can be actively implemented by both police departments as well as urban planners. Further, we have lessons to learn from the case studies of the City of Sarasota, FL, and the City of Boston, MA. We have also learned that GIS analyses help us in the decision making process. Some of the lessons that we have learned can be summarized in the form of recommendations.

Recommendations for Data and Information Collection

- Encourage all departments in the city such as engineering department, law enforcement agencies, public works department, etc. to work in coordination with each other to share information that is required through collaborative efforts for crime prevention.
- Promote collaborative efforts and coordination amongst teams and organizations such as local, State and Federal governments, social and non-profit organizations in order to support crime prevention through partnership efforts.
- Promote effective information sharing strategies with all departments in the city in order to facilitate efficient and easy accessibility to information to each department to make decisions.
- Encourage public participation (community involvement) in crime prevention through citizen surveys and public hearings to promote a safer living environment.
- Use the web for posting online information and surveys as an additional tool for obtaining community feedback and to encourage public participation.

Recommendations for GIS Development and Analysis

- Use computer-aided simulation techniques to model crime patterns and to make accurate forecasts about possible crime occurrences.
- Use GIS to study interrelationships of variables affecting growth of cities with respect to crime and to make accurate forecasts on crime occurrences and decisions on allocation of safety resources.
- Understand the factors affecting opportunities for crime through the link between land use and opportunities for crime by using GIS as an analysis tool in order to make proactive decisions concerning crime prevention.
- Develop custom GIS applications and programs that can analyze variables such as land use, zoning, building codes, neighborhood safety and housing conditions.
- Use GIS to conduct spatial and temporal statistical analyses of crime data in order to study crime patterns and trends in relation to urban form.

Recommendations for Land Use Planning and Policy-making

- Analyze and identify the root cause for concentration of different types of crime in different areas in relation to land use and routine activities.
- Create a special task force of professionals such as planners, architects, urban designers, landscape designers, etc for investigation into specific land use and zoning issues related to crime occurrences.

- Take appropriate land use decisions on location of services for education, recreation and commercial activities based on possibilities of different kinds of crimes occurring in different types of areas.
- Review and update zoning ordinances and crime prevention policies regularly to adapt policies as per changing trends and rates of crimes in different geographic areas.
- Frame appropriate development requirements for parcels based on possible evolution of crime opportunities due to loopholes in existing ordinances.
- Make changes to zoning ordinances based on changes in socio-economic conditions in the city such that the modifications support crime prevention.
- Use analyses of crime patterns to make decisions on land use and zoning while updating the comprehensive plan.

Conclusion

Land use and opportunities for crime are related to each other through routine activities and the shape of urban form. This link between land use and opportunities for crime and several other environmental factors is supported by research theories in the field of environmental criminology. In order to create a safe living environment in cities to provide good quality of life, we must make every possible effort to reduce crime. This means we need information to make decisions on crime prevention. Information can be obtained from various sources and this requires agencies to share the data and information with one another in the city in order to facilitate coordination and collaborative efforts for crime prevention. GIS is an analytical tool that can facilitate analyses and visualization of crime-data as well as planning-data in order to make decisions on law enforcement and planning. The relationship between various variables that influence the growth and future of cities can be studied in relation to the important link between land use and opportunities for crime using GIS to satisfy the information needs that are involved in making objective decisions in policing as well as planning in order to create safer communities.

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APPENDIX A
USING GIS FOR CRIME ANALYSIS

The purpose of this appendix is to give an insight into how GIS can be used for analyzing crime data. Different analysis approaches can be used with GIS to understand the crime patterns are described below:

1. Temporal Analysis (Time Based)

Temporal Analysis of crime is the study of crime patterns over a specified period. Patterns of variation, such as day-to-day, month-to-month or seasons-to-seasons and with respect to times of day are studied. This particularly useful in assessing crime trends with respect to time and to make forecasts about possible future crime occurrences.

2. Spatial Analysis (Geographic Distribution Based)

Analysis of spatial data (spatial statistics), which is the study of variation in datasets with respect to geographic areas, is a powerful tool for taking decisions concerning law enforcement and urban policies. GIS maps with geocoded datasets and research theories form the input for analysis of spatial data (geographical datasets), which leads to statistical hypotheses and tests. The results of these statistical tests can help police officers to take decision about law enforcement and its applicability over a specified geographic area. It can help urban planners to make policy decisions that are tailor made to different zones in the cities.

Spatial Analysis of crime involves a study of distribution of crime spots (locations) geographically. Point data are plotted on maps to identify crime spots and such an analysis is based on absolute locations. On the other hand, the analysis can be based on relative locations with due considerations given to center of mass of the crime spots and to the nearest neighboring crime spots occurring with a specified range distance from a crime spot under consideration. Spatial statistical models coupled with crime-spot mapping provide valuable information about crime patterns and trends. Further, the spatial theories that can be used can be one of the following three categories namely Macroanalysis, Mesoanalysis or Microanalysis. For example, Crime patterns occurring between closely located cities and near transportation, arteries are studied to obtain information about inter-urban crime patterns.

3. Trend Surface Analysis

This is a standard statistical research method that identifies the pattern and intensity of crime at various spatial locations and their variation across a wide spread geographical area. The method typically involves fitting a polynomial surface using three-dimensional regression to different spatial locations depending upon the intensity of crime at the location. This means that the trend surface tends to be much more elevated at the areas where hot spots are located and they tend to be least elevated where the probability of crime occurring is minimum.

4. Cluster Analysis

This is another statistical research method that allows groping up of different crime locations (crime-spots) into clusters. The algorithm used for grouping can be either hierarchical or can be based on proximity (nearness in terms of distances). The identified groups (or clusters)

reveal the possibility of the location of hot spots and help in prediction of the probable locations of residences of criminals. Several software programs are available in the market that can help us in crime analysis. STAC (Spatial and Temporal Analysis of Crime) is a software program that can used to identify and characterize the hot spot ellipses. The cluster analysis techniques are vital in the methodology that is used by the program to identify the crime patterns. For example, Hot Spot Area analysis was conducted using STAC in Chicago in order to study violence in gang-violence crisis areas.

5. Hypothesis Formulation and Testing

Crime maps are the best sources for formulation of hypothesis about crime patterns and trends. The geocoded datasets and the crime databases can help us determine the measures of variance and elements of inferential statistics that can lead to several hypotheses and predictions about possible crime patterns and locations in future. These hypotheses can be tested using standard statistical tests such as t-test, chi-square test and f-test and thus their validity can be determined with a definite confidence interval. Law enforcement officers, urban planners and public policy makers can use the results of these hypothesis tests to assess the projected (extrapolated) trends and to support their decisions regarding new laws and policies that they wish to introduce. They can also be used to inform public and to improve the safety measures for protection thereby promoting the creation of a safe living environment.

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