

Geographic Information Systems Technologies in Crime Analysis and Crime Mapping

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Abstract

Social and geographic factors, such as location of schools or neighborhoods with different socioeconomic status within an area, can influence the patterns and rate of crime incidents in that area. Crime analysis and crime maps, achieved by GIS, have a major role in reducing crime and improving the effective police activities. Cankaya district includes significant concentrations of evening, late-night leisure and shopping opportunities in Ankara. Using information such as where and when crime occurs, this paper emphasizes what the inputs and outputs of crime analysis could be. In the first stage, the relationship between socioeconomic characteristics and crime rate for two police precincts of Cankaya was investigated. Then, spatial and non-spatial GIS analyses using Spatial Analyst, Buffer Analysis, and Hotspot Analysis were performed. The findings of this paper give the potential incident sites.

1. Introduction

The rate of crime incidents is increasing in all developing countries due to change of technology and materialistic way of life and also due to poor socio, political, economic and environmental conditions. The distribution of incidents across the landscape is not geographically random since incidents are human phenomena. For incidents to occur, offenders and their targets - the victims and/or property - be required to exist at the same location for a period of time. Several factors, including the lure of potential targets and simple geographic convenience for an offender, influence where people choose to break the law.

Naturally crime does not disappear on its own. Police departments are on the duty of protecting the citizen's safety and taking precautions to minimize the risk of crime. It has long been common practice for the police to identify locations and times that are more prone to criminal activity (Lab, 2000). To reduce or completely eliminate the crime, some actions, such as crime prevention methods, should be taken. Crime prevention can be signified as a set of ideas for combating incident and includes the activities taken by individuals and groups, both public and private.

The first step of crime prevention is to analyze the current status of incidents such as determining the density or pattern of the incidents. Lab (2000) claims that the finding that incident often concentrates in certain locations or at certain times may be an effective starting point for crime analysis. Ratcliffe and McCullagh (1999) define highest incident concentration areas as "hotspots". In this paper the identification of a hotspot is prompt analysis to uncover what factors make a location a good spot for crime.

Cohen and Felson (1979) outline three criteria that affect the occurrence of the incident. These are; a suitable target, a motivated offender and an absence of guardians. Besides these criteria the suitable landuse and appropriate time could be added into the reasons of incidents. Many authors like Lab (2000), Weisburd and McEwen (1998) mentioned the relationship between landuse, time and incidents in their studies. Particular areas may be devoted to different types of landuse (residential development, retailing, industry, leisure, open space) and based on its landuse type the activities and population profile of an area may vary considerably according to the day of the week or time of day.

The usage of Geographic Information Systems (GIS) in data storage, manipulation and display makes incident prevention process more manageable, more realistic and case specific. The results of GIS give an idea about the current status of incident pattern. Due to its spatial operation capability, GIS helps police and also other people who are interested in incidents, to visualize and analyze the spatial relationships between different data layers such as incidents and landuse, to forecast and take precautions for future incidents.

The knowledge derived through GIS provides a simple geographic inventory (e.g., indicate the location of all events that occurred within a certain time period in a specific location) or display different spatial patterns (e.g., the locations of burglaries may vary by the time of day – late-night incident locations may differ greatly from midday incident locations) or presents the results of more complex analyses (Wieczorek and Hanson, 1997).

Using information, which are recorded by the police in 2003, including the spatial and temporal information of incidents, this paper emphasizes the high-incident areas and the relationship between incidents and landuse for two important police precincts of Cankaya District of Ankara; Centre of Cankaya Police Station Zone and Bahcelievler Police Station Zone. The landuse data used in the study are the landuse types which are generated by digitizing IKONOS 1m resolution colored (Pansharpened) satellite imagery.

This study attempts to apply spatial data analysis integrated with GIS and analyze what landuses are prone to incident and why incident is higher in one area than another. Knowing even these two basic facts; time and place; show that many problems cluster in certain time and location.

2. Main Concept of Crime and Crime Incidents

Crime is a comprehensive concept that can be defined in legal and non-legal sense (web1). From a legal point of view, it refers to breaches of the criminal laws that govern particular geographic areas (jurisdictions) and are aimed at protecting the lives, property and rights of citizens within those jurisdictions. A crime is a criminal act against a person (for example, murder and sexual assault), or his/her property (for example, theft and property damage) and regulation (for example, traffic violations).

Non-legal point of view would define crime as acts that violate socially accepted rules of human ethical or moral behavior. As the moral principles that underpin the notion of crime are subject to gradual change over time, the types of behavior defined by the legal system as criminal may also change. Examples of behaviors that have been de-criminalized in some jurisdictions include prostitution, abortion, attempted suicide and homosexual intercourse. Other behaviors, such as tax evasion or credit card fraud, have been criminalized over time.

There are many reasons for occurring crime. Victim's real or perceived race, color, religion, nationality, country of origin, disability, economic status, gender or sexual orientation make the offender to break the criminal law. However incident is the act of violating an explicit or implied security policy (web2).

Investigating the causes or origins of crime requires many researches by various disciplines such as sociology, psychology, criminology or economy. Income level, unemployment, age, household size, female headed households, education, history of receiving public assistance are only few examples of the possible affects of crime. Some factors which have effects on the volume and type of crime occurring from place to place are given below (web3):

- Population density and degree of urbanization with size, locality and its surrounding area.
- Variations in composition of the population, particularly youth concentration.
- Stability of population with respect to residents' mobility, commuting patterns, and transient factors.
- Modes of transportation and highway system.
- Economic conditions, including median income, poverty level, and job availability.
- Cultural factors, educational, recreational and religious characteristics.
- Family conditions with respect to divorce and family cohesiveness.
- Climate.
- Effective strength of law enforcement agencies.
- Administrative and investigative emphases of law enforcement.
- Policies of other components of the criminal justice system (e.g. prosecutorial, judicial, correctional, and probational).
- Citizens' attitudes toward crime.
- Crime reporting practices of the citizens.

However the paper does not take in hand the causes of crime or socioeconomic status of the offender. It deals with the spatial and temporal pattern of incidents such as when and where incidents occur and how spatial factors effect crime locations determination.

3. The Relationship between Incidents and Landuse

An important characteristic for the geographic analysis of crime is the understanding that incident does not occur in random or unpredictable locations. Rather, criminal offences occur in observable structures that are influenced by

the landscape in which they occur, and the psychological factors that dictate the offender's movement. It is this maxim that makes geographic profiling as a powerful investigative tool.

Analyzing crime events using geography has long been a valuable resource for the criminal investigative process. With records dating back as far as the 1830s (web4), sociologists and criminologists have long understood the role of geography as a fundamental component of crime. By the early 1900s, people began to realize the advantage of using wall-sized pin-maps that detailed the distribution of crime events. By integrating these maps within their investigations, detectives were able to visualize and explore crime in relation to its surrounding landscape.

While building police beats the communities or census areas are generally divided according to boundaries of census zones or roadways. But the level of service needed, number of incidents and also the landuse are more important factors that should be looked at while locating the police beats (Chaffin, 2004). In addition dividing the beats based on only demographics, may result the resources being allocated improperly. Because there may be several areas where there are thousand inhabitants but they generate few calls for service, while there are less people that require much greater levels of service. For example parks do not have any inhabitants but they are more prone to incidents.

Many authors like Block (1998), mentioned the relationship between incident and landuse. Issues given below have an influence on the location, time, type and rate of the incident:

- Landuse data sets containing information on each parcel of land in the city (for example, vacant or not, abandoned or not, residential or commercial, state of repair, specific function such as tavern or convenience store, and so on)
- Public transit data sets (train or bus stops and routes)
- Schools (grammar, high schools, private)
- Community organizations (block clubs, religious centers, social service agencies)
- Parks and other open areas (with park roads, field houses, lagoons)
- Emergency locations (hospitals, fire houses, police stations)
- Public housing (by type, showing roads and play lots)
- Places holding liquor licences (by type of establishment and licence)
- Census data

In this case the following analysis may be generated in order to identify the incident pattern (Canter, 1998; Block 1998):

- identify areas that may likely be targeted by an offender;
- determine whether common attributes exist among a group of reported cases
- explore relationships between incident and other geographic features such as landuse and the built environment
- study the movement of offenders to predict the location of future targets to establish interdiction locations along escape routes
- detect whether the incident locations are clustered
- determine if incidents tend to be located close to a specific location such as taverns or gang territories or the periphery of a county or in the center

4. Geographic Information Systems in Incident Analysis

The location of an incident and any other geographic features associated with a criminal event are important attribute features. They can provide clues for identifying the suspects, assist in the design of prevention or apprehension strategies, aid in the evaluation of programs, and help gain a better understanding of environmental factors that may affect the incident.

Police analysts are particularly interested in identifying incident patterns and determining whether these patterns are randomly distributed due to chance, or if there is a tendency for a set of cases to statistically group or cluster. In this case they try to identify the areas of the highest incident concentration.

In order to examine the spatial distribution of incident locations, police places pushpins in wall maps (Canter, 1998). In the maps which contain all of the streets for an area of interest such as a police precinct or a municipality, incident

locations are usually represented by a pin. Thus the relationship between a particular point location such as street robbery to other geographic features such as bus stop or shopping center could be determined.

However because of the increase in the number of incidents the amount of effort for maintaining pin maps manually, become difficult and problematic. The limitations of the manual pin mapping compromise the geographic accuracy of the incident locations. Since the geographic location of an incident on a pin map is not quantifiable, analysts are not able to test hypotheses about the spatial distribution of incident. The maps need to be periodically updated for new roads or other geographic features. Thus it is unavoidable that police needs to use GIS to support incident mapping and analysis.

With GIS, police is able to produce more versatile electronic maps by combining their databases of reported incident locations with digitized maps of the areas they serve. GIS opens new opportunities for the use of digital mapping in incident control and prevention programs. GIS allows police personnel to make plans effectively for emergency response, determine mitigation priorities, analyze historical events, and predict future events; it helps crime officers to determine potential incident sites and facilitates to explore the relationship between incident and landuse.

5. Definition of the Study Area

The study area is comprised of two police precincts of Cankaya district, Centre of Cankaya Police Station Zone and Bahcelievler Police Station Zone. Centre of Cankaya Police Station Zone includes 15 neighborhoods and the second zone includes 4 neighborhoods.

District of Cankaya has significant concentrations of evening and late-night leisure areas. These properties of the district influence the rate and location of incidents. Especially Kizilay which is the city centre of Ankara, and surrounding neighborhoods have many entertainment functions and shopping opportunities. In addition, landuse type such as residential and income level make Bahcelievler neighborhood an attractive area for incidents. Therefore Centre of Cankaya Police Station Zone and Bahcelievler Police Station Zone were chosen as a case study area.

6. Data used in the Study

Data used in the study are compiled from government organizations and private companies in Ankara.

Spatial and temporal information regarding to incidents were obtained from Ankara Police Directorate. The data include the incidents that occurred in 2003 and recorded by the police stations in Ankara. The incident data are classified as murder, usurp, burglary, auto and pickpocket with their detail information as incident location address, occurrence time.

The other data that include the landuse types were obtained by digitizing the satellite images that were acquired in 2003. The image that was collected by IKONOS satellite was provided by INTA SpaceTurk. The data include the information of roads, landmarks, residential and commercial areas.

The socioeconomic data which were provided by State Institution of Statistics include population, income level, employed-unemployed rate, literacy and the size of households.

7. Exploring the Relationship between Socioeconomic Characteristics and Incident Rate

According to socioeconomic information and crime rates of the districts, thematic maps were prepared to see the relationship between them. Even though many studies have demonstrated that low socioeconomic status is a cause of crime, figures do not show a clear relationship between crime rate and socioeconomic conditions in the district of Cankaya. Since Cankaya has a dense population; the other socioeconomic values are accordingly higher in Cankaya, except education and household status which are the reverse. However highest crime rate is seen in Cankaya. Although relations are not very strong it can be said that, higher the population density, higher the crime rate; higher the income level, higher the crime rate (naturally burglars prefer rich places); higher the unemployment rate, higher the crime rate; lower the education level, higher the crime rate; larger the household size, higher the crime rate (Figure 1).

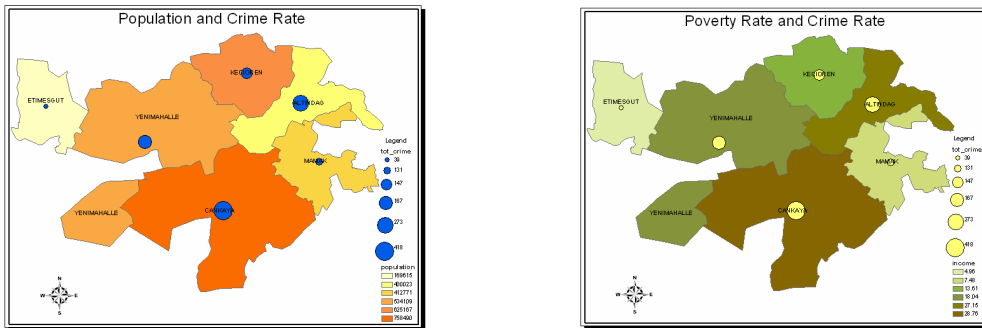


Figure 1. The Relationship between Socioeconomic Status and Crime Rate

In order to examine the socioeconomic characteristics of the main study area in Cankaya, thematic maps are generated for the neighborhoods. In the study area that includes the two important police precincts, left part which is mostly covered by residential areas is naturally denser than the right part which is mostly covered by commercial areas. According to the income level, the neighborhoods are generally in moderate level.

8. Temporal and Spatial Distribution of the Incidents

In the study area, mostly incidents of burglary occurred with a higher rate when compared to the other incident types (Table 1). Burglary from office and house are the most widely seen incidents in this type. Then pickpocket follows the auto incidents (auto theft or theft from auto). The incidents of usurp and murder have lower rates.

Incident Types	Number
Burglary	1041
Auto	377
Pick Pocket	360
Usurp	72
Murder	60

Table 1. Incident Types

The temporal pattern of the incidents was considered in terms of the day of the week and time of occurrence. Figure 2 reveals the specific days and the times of the day when the levels of incidents are at their greatest based on the incident types.

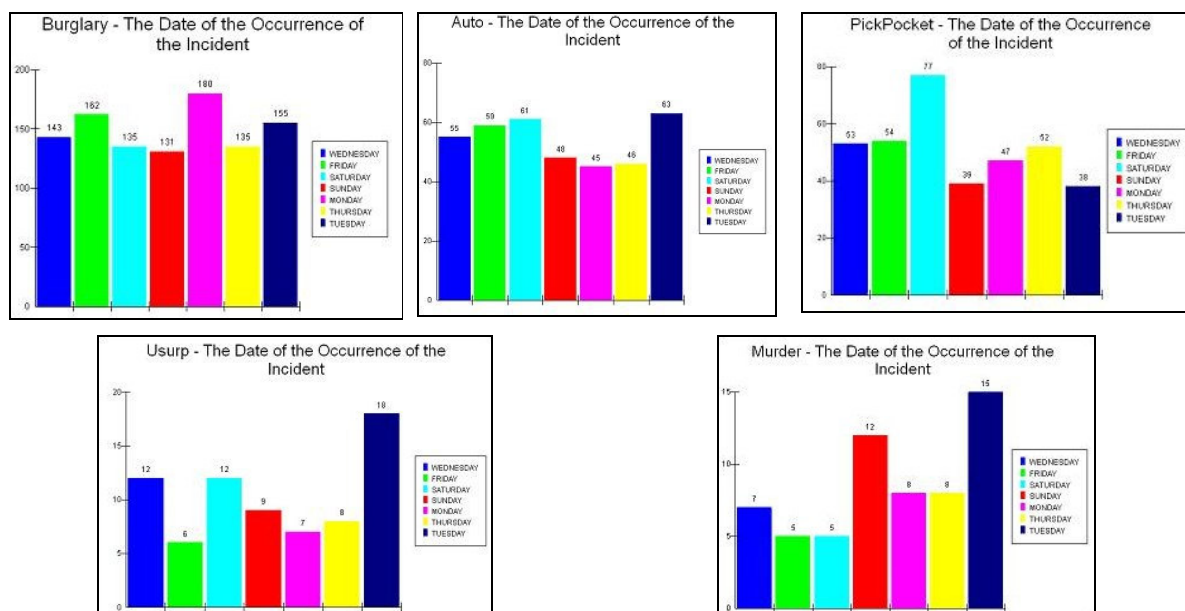


Figure 2. The Date of the Occurrence of the Incident

In order to analyze the hourly pattern of occurrence of incident, the time is investigated in 3 groups (Figure 3).

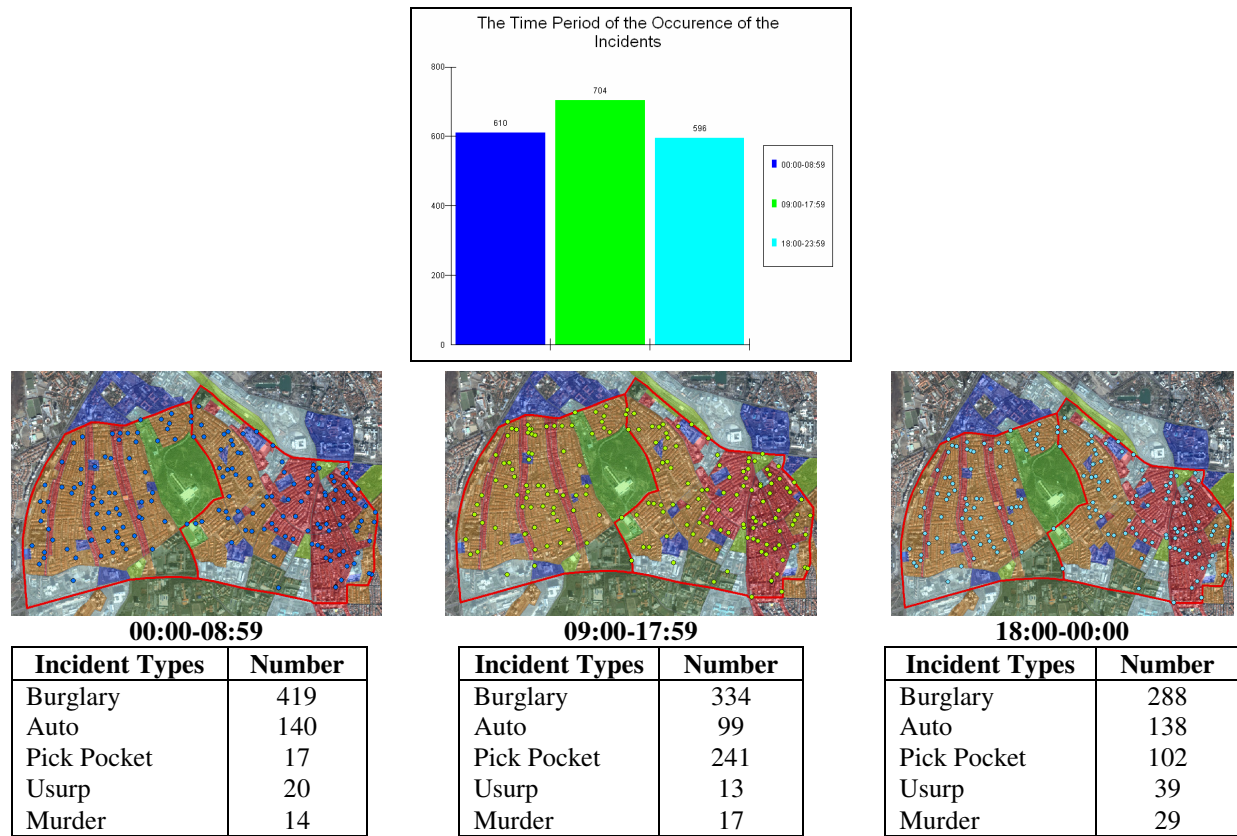


Figure 3. The Time Period of the Occurrence of the Incidents

In order to analyze the spatial distribution of incidents, in other words determine the hotspot areas, there are many methods using the capabilities of ArcGIS. One of them is generating thematic maps for neighborhoods by joining the incidents with the neighborhoods based on the spatial location (Figure 4).

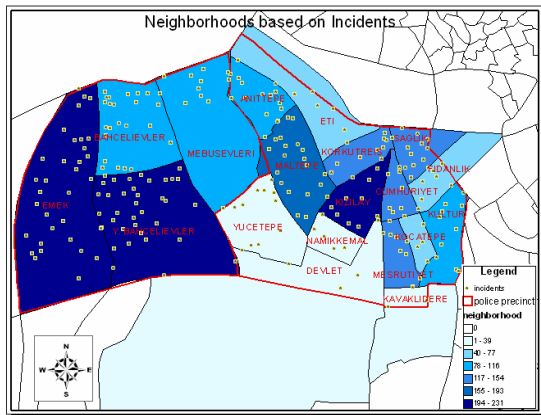


Figure 4. Thematic Map for the Neighborhoods based on Incidents

Another method for visualizing the spatial distribution of incidents based on the boundaries of neighborhood is interpolation. There are three methods for interpolation; Inverse Distance Weighted (IDW), Spline, Kriging. All of them were performed for neighborhoods, but the best result was obtained from Inverse Distance Weighted method (Figure 5).

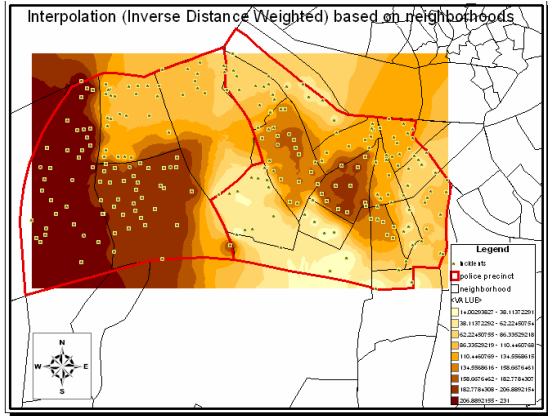


Figure 5. Interpolation Analysis

The other method used for determining the hotspot areas is kernel estimation which is performed by Density Analysis in ArcGIS (Figure 6). Kernel estimation was originally developed to obtain a smooth estimate of a univariate or multivariate probability density from an observed sample of observations (Bailey and Gatrell, 1995).

Kernel density estimation involves placing a symmetrical surface over each point, evaluating the distance from the point to reference location based on a mathematical function, and summing the value of all the surfaces for that reference location. This procedure is repeated for all reference locations (web5).

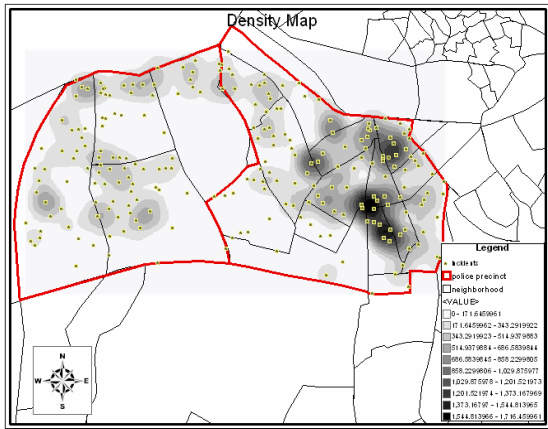


Figure 6. Density Analysis by Kernel Estimation

Most of the police analysts in developed countries identify a high-incidence area by the method of standard deviational ellipse. The standard deviational ellipse is computed using the Illinois Criminal Justice Authority's Spatial and Temporal Analysis of Crime (STAC) program (Figure 7). It is a spatial statistics program for the analysis of incident locations developed by Ned Levine and Associates under grants from National Institute of Justice, and has also a new version called Crime Stat II (web5).

CrimeStat is a spatial statistics package that can analyze crime incident location data and it is able to link to GIS software (web5). By using CrimeStat it is easy to detect the hotspot areas.

Generating hotspot areas is possible with an input that includes x, y coordinate pairs for each incident location, a search radius, and a set of parameters used to define the search area. For mapping, each of these dense clusters is bounded by the best-fitting standard deviational ellipse (ICJA, 1996).

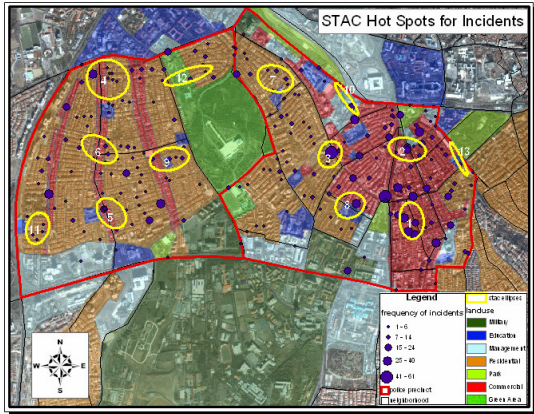


Figure 7. Hotspot Areas by STAC

There is an interesting comparison by overlaying the STAC ellipses on the kernel density result. As shown in Figure 8 there is some correspondence between some of the clusters and the higher elevation densities, but not at all. In part, this may due to the different densities in the clusters.

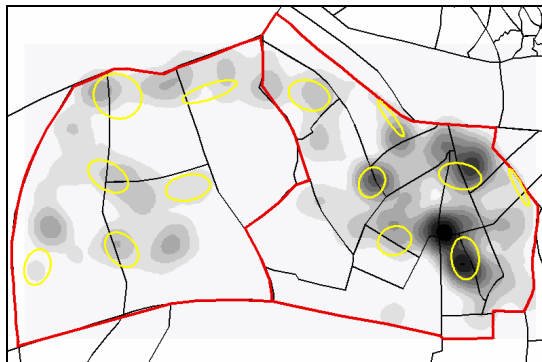


Figure 8. STAC ellipses with Density Map

9. Analyses Carried for Determining the Relationship between Landuse and Incidents

The rate of the incidents changes based on the type of the location – means landuse. Figure 9 indicates that the locations with more offices and houses have higher number of incidents. This is the result of most of the incidents’ being as burglary type. Then common usage places such as streets and roads are following, since the pick pocket type has also higher rate.

Category	Count
ATM	10
BANK	1
BAR	5
INSIDE BUILDING	19
ROAD	271
MOSQUE	2
WAREHOUSE	3
INSIDE HOUSE	518
CASINO	1
HOSPITAL	4
RESTAURANT WITH ALCOHOL	4
CONSTRUCTION	2
OFFICE	666
COFFEE HOUSE	4
LIBRARY	1
SHOPPING CENTER	2
SMALL MOSQUE	1
SUBWAY STATION	1
INSIDE SUBWAY	7
SCHOOL	1
OTEL	1
AUTO	7
CAR PARK	35
PARK	15
NIGHT CLUB	2
OPEN MARKET	3
OFFICIAL INSTITUTION	19
STREET	239
OPEN PLACE	6

Figure 9. The Place of the Occurrence of the Incident

Whether the incidents took place inside the buildings or on the streets, an examination of the specific location of incidents reveals that their overall distribution clearly reflects the location of residential and commercial areas. Also specific locations such as schools, major roads, police stations and the distance to these locations are the attracting places for the incidents. For this purpose, besides residential and commercial areas, these specific locations were selected to be examined in detail.

In addition to the number and type of incidents in the commercial and residential areas, the same information within 300 meter distance of schools were also determined by Buffer Analysis (Figure 10).

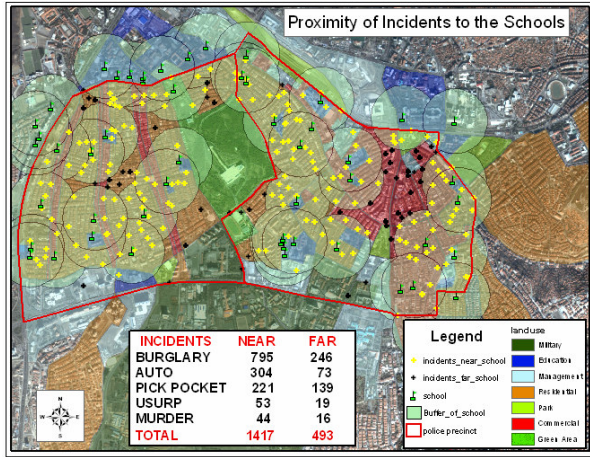


Figure 10. Proximity of Incidents

Similarly how many crimes and what types of crimes were occurring within 50 meter of major roads are determined. One reason for choosing major roads is when it is the main corridor, the escaping ways are limited compared to the interior street networks where there are lots of twists and turns which makes the escape an easier one. Also patrolling will be more in case of main roads.

Naturally incidents take place far from the police stations. To see the difference between the number of crimes far and near the police stations, same analysis were achieved (Table 2).

Landuse	Burglary		Auto		Pick Pocket		Usurp		Murder		Total	
	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Residential	499	542	204	173	70	290	25	47	15	45	813	1097
Commercial	486	555	138	239	262	98	36	36	39	21	961	949
Schools	795	246	304	73	221	139	53	19	44	16	1417	493
Major Roads	451	590	136	241	217	143	47	25	40	20	891	1019
Police Stations	92	949	19	358	28	332	15	57	3	57	157	1753

Table 2. The number of Incidents based on the distance to Locations

Based on these analyses, potential incident sites and thus suitable areas for a police station could be detected by using similar analyses in ArcGIS. Straight line in Distance Analysis, Reclassify and Raster Calculation are the tools which are used for detecting the potential incident areas. After straight line was obtained according to the buffers that were performed for schools, police stations and major roads, they were reclassified. In the reclassification higher values indicate that particular variable's value is risky for incidents. It means the criteria that have effect on incident rate and location were given 10, shown in dark colors and the others, which have fewer effects, were given gradual numbers, shown in lighter colors (Figure 11).

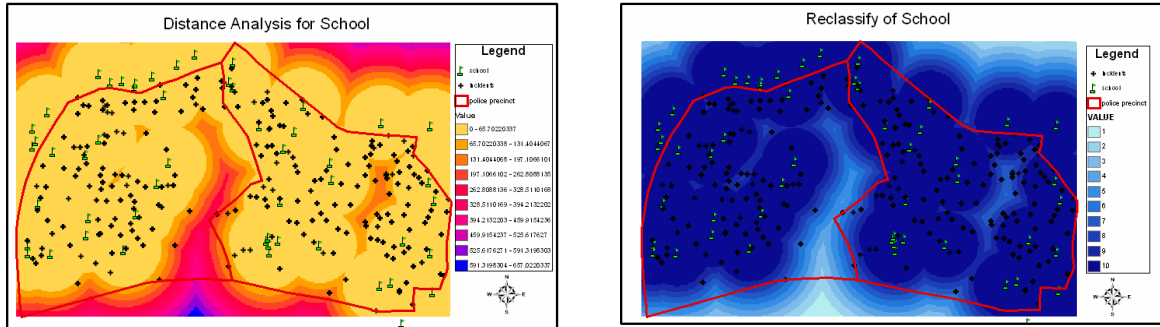


Figure 11. Distance Analysis and Reclassify of School

Additionally landuse, population and poverty information were converted into raster format and then reclassified according to their importance on incident rate. For landuse, their importance were decided based on the number of incidents that occurred in the related landuse (Table 3).

Residential	10
Commercial	9
Education	8
Park	7
Management	5
Green Area	3
Military	1

Table 3. Reclassify of Landuse

In addition hotspot areas that were obtained from density analysis were reclassified in order to join them into the final analyses which provide the potential incident sites.

For raster calculation, number of crimes occurred based on the distance to the police stations, major roads and schools were examined, and the weights were determined based on the number of occurred incidents. If the number of incidents is higher in the related variable it takes greater weight. The weights of other criteria as hotspot, landuse, population and poverty were given similarly. In the result of raster calculation dark areas show that these areas need more control. For instance establishment of new police stations, or police controlled zones should be relocated based on these dark places (Figure 12).

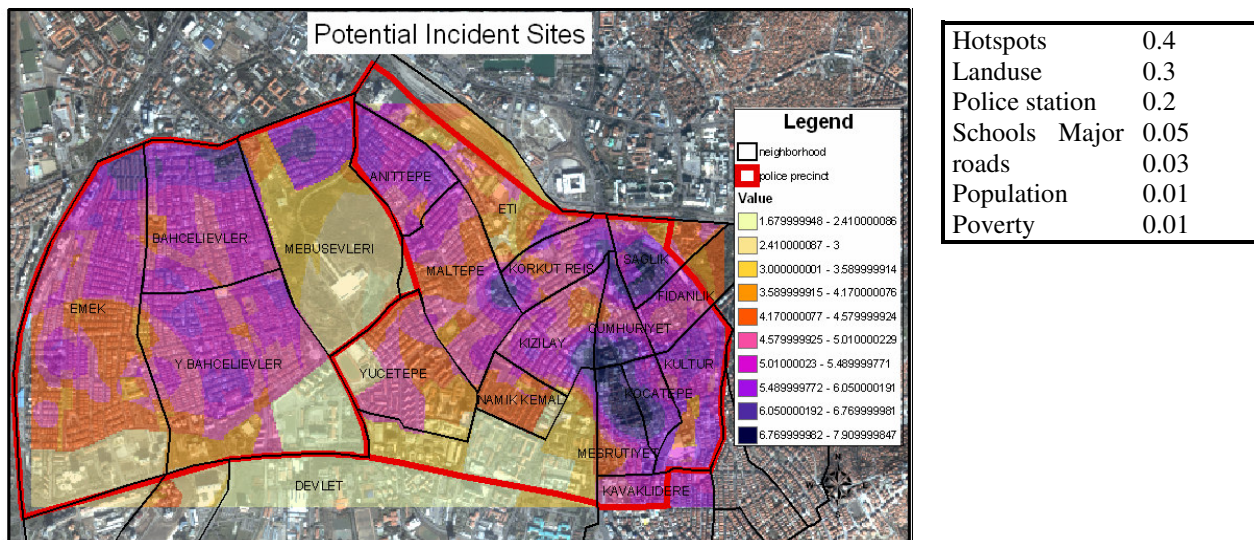


Figure 12. Potential Incident Sites

10. Conclusion

This study has emphasized the value of using a combination of different types of information in identifying the patterns of crime by analyzing a range of variables recorded by the police, relating to where and when incident occurs. For the two police precincts the locations of police stations should be reshaped according to the results of these analyses, which show that some areas are not controlled effectively.

Main findings of this paper can be classified into two themes. The first one is on the contributions of GIS - based methods in incident distribution analysis. The second one is on the relationship between incident locations and landuse.

In the process of determining the relationship between incident and landuse, hotspot areas are determined in some specific locations. This is why the relationship between incident and landuse is investigated.

Further studies may focus directly on physical design components of crime prevention. The physical characteristics of an area can influence the behavior of both residents and potential offenders. Increased lighting, use of surveillance equipment, access control, alarms and other physical changes are intended to bring about greater social cohesion, citizen concern and involvement, and ultimately, reduce crime and fear of crime.

It is also observed that the abilities of GIS such as managing data, organizing in different spatial units, providing quick and objective results and linking the spatial and other kind of information produce better results of incident analysis.

The findings of this study showed that using GIS is useful for incident analysis. GIS has many capabilities in incident mapping and analysis. It allows police personnel to plan effectively for emergency response, determine mitigation priorities, analyze historical events, and predict future events; it helps crime officers to determine potential incident sites.

As a conclusion an understanding of where and why crimes occur can improve attempts fighting crime. Mapping crime helps to reduce and prevent crime, reduce suffering by victims, punish guilty and identify crime ridden areas.

Acknowledgements

We wish to acknowledge the invaluable support of ESRI who provided the software to Middle East Technical University. We also thank Ankara Police Directorate, INTA SpaceTurk and State Institution of Statistics for their help in providing data used in the study. In addition we would like to thank Dr. Pinarcioglu for his comments during the study.

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web2 - <http://www.fedcirc.gov/incidentReporting/incidentDefinition.html> (visited on 23.12.2003)

web3 - <http://www.tempe.gov/cau/New%20Images/crimemap.html> (visited on 11.12.2003)

web4 - <http://www.ncjrs.org/html/nij/mapping/pdf.html> (visited on 28.02.2003)

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