VISUALIZING THE SPATIAL-TEMPORAL PATTERNS OF CRIME IN NAIROBI

BY

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university.

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Abstract

Crime in Kenya is a serious problem with high social and economic costs. Crime is neither unique nor random, but rather tends to be unevenly distributed and has a spatial-temporal pattern. Geographic Information Systems (GIS) and crime mapping have opened new opportunities in crime control and prevention. Unfortunately, many law enforcement agencies, especially in the developing world, are not aware of this technology and the strength it can bring to their work.

In this study, the spatial-temporal distribution of carjacking, robbery, burglary, murder and rape in Nairobi between November 2004 and April 2005 have been analyzed using: Point Pattern Mapping, Thematic Mapping, Spatial Ellipses, and Kernel Density Estimation. 3D visualization of crime density surfaces was employed to assist in the interpretation of these crime patterns. Changes in spatial distribution of crime during the hour of the day, day of the week and month of the year were also determined and results presented using graphs.

The results indicate that Buruburu and Kasarani police divisions have the highest concentration of crime hotspots. They also show that crime patterns in Nairobi vary with time, the highest concentration being between 6pm and 12 am, with peaks at 8pm to 9 pm.

The study concludes that although Kernel density estimation is a good method for identification of crime patterns, it is good to combine several methods to get the best results and to curb crime, an exhaustive strategy focusing on all areas of crime management is needed.

The study recommends increased reporting of crime, adoption of GIS techniques in analysing crime patterns, capacity building in the Police Force and finally cooperation and sharing of information between security organs, researchers, international organizations and a regional approach in managing crime.
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Finally I thank God, from whom all wisdom and knowledge comes.
DEDICATION

In memory of my late Father, Mr. Musembi Mani, for teaching me that education is the key to a bright future.
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DEFINITION OF TERMS AND LIST OF ABREVIATIONS

DEFINITIONS OF TERMS

For the sake of clarity and ease of reading, this section gives concise definitions of terms used. Credence is given to the contextual as opposed to the literal meanings.

**Crime**: Crime is a complex, multidimensional event that occurs when the law, offenders and target (refers to a person in personal crimes and an object in property crimes) converge in time and place (such as a street corner, building or street segment).

**Robbery**: The concept robbery refers to the taking, or attempting to take anything of value from the care, custody, or control of another person or persons by force or threat of force or violence and/or scaring the victim.

**Carjacking**: Carjacking is the deliberate action of seizing control of a vehicle in transit by use of force for the purposes of either robbing or harming the occupants, or using the vehicle to accomplish other missions without the consent of the motorist(s) in charge.

**Murder**: Murder is the criminal act of deliberately terminating the life of a person either by use of a weapon that causes severe bodily harm leading to death or using any other means that interferes with the functional operation of the person’s system so as to kill without necessarily having the intention of stealing anything.

**Rape**: Rape is a crime wherein the victim is forced into sexual activity against his or her will. Effectively, it co-opts the victim’s own sexual anatomy as a weapon of domination. It is considered, by most societies, to be among the most severe of crimes.

**Geographic Information System (GIS)**: GIS is a computer based information system that enables the input, management (storage, retrieval, updating), analysis, output and
dissemination of geospatial data (data referenced to a spatial location in geographic space) and information, information being what one gets on processing data.

**Global Positioning System (GPS):** GPS is a system initially set up for navigation and positioning, on a programme that started in 1969 by the US department of Defence. It comprises of a constellation of 30 (as of April 2007) satellites orbiting the earth at a nominal altitude of roughly 20,200km above the earth. GPS permits accurate positioning to less than a cm. Global Navigation Satellite System (GNSS) is a satellite system that is used to pinpoint the geographic location of a user's receiver anywhere in the world. Two GNSS systems are currently in operation: the United States' Global Positioning System (GPS) and the Russian Federation's Global Orbiting Navigation Satellite System (GLONASS). A third, Europe's Galileo, is slated to reach full operational capacity in 2008. Each of the GNSS systems employs a constellation of orbiting satellites working in conjunction with a network of ground stations.

**Hotspot:** A crime hotspot is generally defined as an area containing dense clusters of crime incidents. Identification of hotspots helps public safety institutions allocate resources for crime prevention activities.

**Crime Analysis:** Crime analysis is a set of systematic, analytical processes directed at providing timely and pertinent information relative to crime patterns and trends.

**Spatial Analysis:** Spatial analysis refers to the examination of the geographic aspects of events through analytic querying of the geographic database, e.g which police division has the highest concentration of carjacking cases.
Temporal Analysis: Temporal analysis refers to examination of the time component of events, through construction of histograms or graphs to show distributions by weekday, hour etc.

ABBREVIATIONS

GIS: Geographic Information System

GPS: Global Positioning System

STAC: Spatial And Temporal Analysis of Crime

POL DIV: Police Division

POL STN: Police Station

NOV 04: November 2004

APRIL 04: April 2004

RD: Road

ST: Street
CHAPTER ONE: INTRODUCTION

1.1 Background

One of the biggest challenges facing Kenya as a nation is insecurity (The East African, 2004), with Kenyans wondering what the police are doing about it.

As Nairobi grows larger in terms of population, it has become increasingly necessary for the law enforcement department to utilise Information Technology to fight crime and to increase the effectiveness of the available resources. If analysts can be able to predict the time and place of hotspots, or high crime areas, law enforcement personnel will be better prepared to either reduce the intensity of the hotspots or be able to move quickly and mobilize officers to handle the increased crime rate. Obvious high crime areas have long been identified based on location, but with changes in the way urban residents live and work, a temporal dimension must also be considered.

Crime is a human phenomenon; therefore its distribution in space is not random (National Institute of Justice (NIJ) website, 1999). It is a complex, multidimensional event that occurs when the law, offenders and target (refers to a person in personal crimes and an object in property crimes) converge in time and place (such as a street corner, building or street segment (Brantingham et al, 1981). Today, with the rapid advancement of technology, a computer-based technique for exploring, visualising and examining the occurrences of criminal activity is essential. One of the more useful tools facilitating exploration of the spatial distribution of crime is a Geographic Information System (GIS). GIS is a Computer based information system that enables the input, management (storage, retrieval, updating), analysis, output and dissemination of geospatial data (data referenced to a spatial location in geographic space) and information, information being
what one gets on processing data (Aronoff, 1989). The fundamental strengths of a GIS over traditional crime analytical tools and methods is the ability to visualize, analyse, store large volumes of data, process the data at high speeds, allow data sharing and explain the criminal activity in a spatial context.

1.2 Problem Statement

Government expenditure on public order and safety increased from 1.8% of GDP in 1999/2000 to 2.5% in 2003/2004. The Kenyan Taxpayer contributes Ksh 5 billion annually to the Police budget (The East African, 2004). However, insecurity still continues to rise with the number of reported cases of crime rising from 77,340 in 2003 to 83,841 in 2004 (Kenya Police Website, 2006). Most of these cases have been reported in the major urban centres.

Nairobi, the capital city of Kenya with a population of about 3 million people, (Central Bureau of Statistics, 2000) continues to be less safe as its population grows. This can be attributed to the fact that, crime prevention resources (personnel and equipment) do not always increase with increase in population and also the resources available in most cases, are not effectively managed. Unemployment rate is also very high and many people turn to crime when they lack job opportunities.

Crime patterns in Nairobi are inherently complex and uncertain. They develop over time due to an intricate interaction between the target of crime and the offender over space. If the behaviour of offenders is to be better understood, then models that incorporate both space and time are needed. The traditional and age-old system of criminal record
maintenance has failed to live up to the requirements of today’s crime resolution needs. Current trends indicate that criminal activities have become more brutal and sophisticated. This calls for new ways of dealing with crime (Muraya, 2004). GIS is well suited for presenting the spatial and temporal aspects of crime events and discovering spatial correlation, yet most police officers in Kenya and similar countries in Africa are not aware of the technology. Similarly, in Kenya, little has been done on crime mapping (Muraya, 2004) and maps are not used much.

The problem this study seeks to address therefore is the need to develop modern techniques of crime mapping and analysis using GIS to:

(i) Identify distinct spatial-temporal characteristics (patterns) of various crimes in Nairobi.

(ii) Analyse events within specific spatial hotspots to identify peak times of criminal activity.

The resulting information about space and time of hotspots can then be used as a decision support tool in policing resource allocation and in modelling relationships between crime events and geographical areas.

1.3 Study Area

Nairobi lies between latitudes 1° 10’ S and 1° 25’ S and longitudes 36° 40’ E and 37° 10’ E. It is neighboured by Kiambu to the North, Thika to the East, Kajiado to the South and Machakos to the South East. Figure 1.1 shows the location of Nairobi Province.

Nairobi city is the capital city of Kenya and headquarters of both Government and the majority of private sector corporations.
Figure 1.1: Location of Nairobi
Visualizing the spatial-temporal patterns of crime in Nairobi

It is the largest city in Kenya, with a population of approximately 3 million people (Central Bureau of Statistics, 2000). It covers an area of 696 square kilometres with an estimated population density of 49 persons per square kilometre. Nairobi has eight police divisions namely: Kasarani, Buruburu, Central, Kilimani, Kayole, Langata, Gigiri and Embakasi and a total of twenty-six gazetted Police stations and thirty eight police posts. Figure 1.2 shows location of various police stations within the city. In Kenya the Police Force is territorially subdivided based on provincial boundaries. The province is headed by a Provincial Police Officer (PPO). Each province is divided into divisions based on district boundaries. Nairobi city is divided into police divisions whose boundaries may differ from the administrative division boundaries. Divisional Police Commanders heads the police divisions. Within the police divisions there are police stations and police posts. A police station is a law enforcement base in a particular area. It has among other facilities; offices, holding cells and interview/interrogation rooms. A police post is a law enforcement base set up in the estates and villages to ensure law enforcement services are close to the consumer. Station Commanders and Post Commanders head police stations and police posts respectively.

Nairobi, like many cities in the developing world, is characterized by a majority of the population (estimated at 60%) living in non-formal settlements (Starvou, 2000). Poverty among the city population is rampant, reflecting the country’s absolute poverty levels where approximately 50% of the population lives below the absolute poverty line of less than one US dollar a day. According to the 1997 Welfare Monitoring Survey (KIPPRA, 2004), about 50% of the population of Nairobi fell below the absolute poverty line of Ksh 2,648 monthly income.
LOCATION OF POLICE STATIONS

Figure 1.2: Nairobi Estates, Road network and various police stations.
Nairobi was purposely selected for this study because of its role as a commercial hub in Kenya and in the East African region and also because it has a high crime prevalence. Nairobi has all the characteristics of urban populations in other urban centres and provides a strategic entry point for raising security issues for follow up.

1.4 Study Objectives

The general objective of the research is to conduct an exploratory spatial data analysis study of the patterns of specific crime (Carjacking, Robbery, Burglary, Rape and Murder) in Nairobi using a database of crime records for 2004/2005.

The specific objectives are:

1. To collect crime data
2. To geocode the spatial location of crime incidents in Nairobi.
3. To determine overall crime hotspot by density analysis of the point pattern of the particular crime being studied.
4. To visualize the spatial –temporal distribution of crime in Nairobi according to the time of the day, day of the week and time of the year.
5. To demonstrate the superiority of GIS in crime analysis and visualization over traditional approaches.

1.5 Scope of the Research

The research focuses on Carjacking, Robbery, Burglary, Rape and Murder incidents for the period November 2004 to April 2005. The crime data includes reported cases in
various police stations in Nairobi. The crime data contains details on time of the day, the
date, day of the week, month, the location of the incident and name of the victim.

1.6 Structure of The Thesis

Chapter 1 of the thesis provides an introduction to the subject, states the problem and
outlines the study area. Chapter 2 provides a literature review on visualizing spatial-
temporal patterns of crime. Chapter 3 sets out the methodology followed during the
research while chapter 4 sets out the results obtained and their analysis. Chapter 5 gives
conclusions and some recommendations for future work and finally references for my
study.
CHAPTER TWO: LITERATURE REVIEW

2.1 Crime and Crime mapping

2.1.1 Crime Definition

Crime is a multifaceted concept that can be defined in a legal or non-legal sense. From the legal point of view it refers to breaches of the criminal laws that govern particular geographic areas and are aimed at protecting the lives, property and rights of citizens within those areas. Most of the crimes with which the criminal justice system is concerned involve breaches of State legislation that cover most offences relating to persons (for example, murder and rape), property (for example, theft and property damage) and regulation (for example, traffic violations). Other types of crime include what are commonly referred to as “white collar crimes”. They include corruption, cyber crimes, terrorism, drug trafficking and human trafficking (National Criminal Justice Statistical Framework, website, 2003). The non-legal point of view would define crime as acts that violate socially accepted rules of human ethical or moral behaviour. As the moral principles that underpin the notion of crime are subject to gradual change over time, the types of behaviour defined by the legal system as criminal may also change. Examples of behaviours that have been de-criminalized in some countries especially in the west include abortion, attempted suicide and homosexuality. Other behaviours, such as tax evasion or credit card fraud, have been criminalized (National Criminal Justice Statistical Framework website, 2003).

Crime events occur both in both space and time. Crime occurs when the law, offenders and target (refers to a person in personal crimes and an object in property crimes)
converge in time and place (such as a street corner, building or street segment (Brantingham and Jeffery, 1981).

2.1.2 Automated Crime Mapping

Analysis of the spatial dimension of crime has had a long history and has traditionally taken the form of pin maps of crime locations, traffic accidents and other police events (Lee and Egan 1972; Ekblom 1988). Automated Crime Mapping refers to the mapping and spatial analysis of crime using computer based methods. Automated Crime Mapping has been common since the mid 1970s in the developed countries (Mc Ewen and Taxman, 1995).

Automated Crime Mapping applications can be classified into Crime Analysis of Patterns (CAP) and Crime Pattern Analysis (CPA), which have quite different objectives and meet different operational requirements (Hirschfield et al, 1995). CAP operations are used mainly in tactical analysis, to show the occurrence of crimes in certain areas such as police beats. The search for patterns is manual through the structuring of spatial queries and inspection of Pin Maps. CPA applications use spatial tools such as GIS to analyse Crime distribution, for significant patterns that transcend administrative boundaries and require minimum user intervention. Some types of CPA include hotspot analysis and geographic profiling – a technique used to determine the likely home base of a serial offender based on the spatial behaviour of offenders (Grescoe, 1996). This study is an example of Crime Pattern Analysis and Spatial data visualization techniques to identify certain crime patterns in Nairobi, Kenya.
2.2 Overview of GIS in Law Enforcement in developed countries

Arguably, the most powerful weapon in law enforcement is information technology (Nelson, 1999). GIS not only allows integration and analysis of data to identify, apprehend and prosecute suspects, but also aids more proactive behaviour through effective allocation of resources. Over the past decade, there were more police departments using GIS for their individual needs especially in the west.

A wide variety of crime analysis tasks benefit from use of GIS. They include:

- **Creating briefing maps**

  The creation of briefing maps for beat-level patrol officers is the primary method of disseminating information to the front line of law enforcement. The strategic view of the analyst and managers must be translated to the tactical level if GIS and crime analysis is going to support the officer in the field.

- **Mapping for decision-making**

  Beat, sector, district, and citywide level maps may be used routinely for strategic decision-making meetings in law enforcement. Two types of analysis for these include: (1) pattern analysis to understand where crime was located and where it was going spatially and (2) temporal location analysis of the crimes as a tool for guiding the deployment of officers at times when crime is most likely to happen.

- **Mapping for pattern detection**

  Pattern detection maps detect specific, repeating patterns of particular types of crime for purposes of allocating patrol resources. Criminals exhibit repeating sets of patterns or "MO's" (modus operandi) that can be as distinctive as a signature. Identifying a criminal's MO and matching it to a pattern of crime often leads to a successful arrest.
• Mapping recovery operations
This involves overlaying the locations of theft and recovery of stolen vehicles or other property; law enforcement officers can then know in which areas suspects frequently dump stolen vehicles, and focus on these specific areas.

• Resource allocation
Resource allocation involves using spatial analysis to create service zones or patrol areas, or using network analysis to establish emergency response routes or patrol routes.

• Proximity mapping
Proximity mapping is the creation of spatial buffer zones around an area of interest such as a school, the address of an offender or even a crime incident.

• Integrating interagency data
As crime mapping matures in an agency, data from other agencies may be integrated into the crime mapping process (e.g., property ownership from tax databases, demographic information from the Census, street light information from public works, alcohol sales information from the zoning department, etc.).

Some examples of law enforcement agencies using GIS include, the Dallas Police Department in the US, which uses GIS in identification of crime hotspots (Janis, 2004), the Vancouver Police Department in Canada, uses GIS for constructing accurate and timely models of crime, including areal concentrations of crime (Murray, 1995), Jefferson County in Colorado is developing a GIS Crime Analysis Program and Event Reporting System (Stuart et al, 1999), South African police Service has carried out tactical crime mapping and analysis using GIS (Cooper et al, 2003) and the New York
City Police Department which uses GIS to analyse and display geographic concentrations or hotspots of crime events (Dough et al, 1999), among others.

2.2.1 Other applications of GIS in crime

- **Geographic profiling**

Geographic profiling is an investigative methodology that uses the locations of a connected series of crime to determine the most probable area that an offender lives in. Although it is generally applied in serial murder, rape, arson, robbery, and bombing cases, geographic profiling also can be used in single crimes that involve multiple scenes or other significant geographic characteristics. This methodology is based on a model that describes the hunting behaviour of the offender (Brantingham and Brantingham, 1981). A computerized geographic profiling workstation incorporates an analytic engine, GIS capability, database management and powerful visualization tools. Crime locations which are broken down by type (e.g., victim encounter, murder and body dump sites for a murder) are entered by address.

- **High Resolution GIS**

Most crime analysis is conducted on what could be labelled medium scale, typically representing a city or neighbourhoods within a city. Rengert et al, 1998 have reported on GIS applied to individual buildings or other small areas, such as street segments, terming this approach as high resolution GIS. Orthophotos can be linked with GIS to enable the analysis of crime at extremely specific locations.
• **Early Warning System for Street Gang Violence**

An early warning system for street gang violence, a joint project of the Chicago Police Department and the Illinois Criminal Justice Information Authority is underway in Chicago’s Police Area Four, an area containing some of the riskiest neighbourhoods for street gang violence in the city. The purpose of the project is to develop an automated early warning for law enforcement, which would identify potential neighbourhood crisis areas, areas that are at high risk for suffering a recurring serious street gang, related violence and homicide. It is based on a statistical model, which consolidates spatial information obtained from a variety of community and law enforcement sources.

The Early Warning System project is founded on the premise that, since street gang violence is spatially anchored and occurs as the culmination of escalating incidents of revenge and retaliation, information compiled by community and neighbourhood organizations, as well as by law enforcement, could be used to develop an “early warning system” of neighbourhoods in crisis (Spergel and Curry, 1990). Continuing escalation would then be prevented by crisis intervention and dispute mediation, using both internal community influences and external police support. The project has shown success in the two pilot projects in Chicago’s Humboldt Park and in Philadelphia (Spergel and Irving, 1984), but requires the strong support of neighbourhood agencies, churches, community groups, and the police department.

**2.3 Crime Place Theories**

Over the years, many theories have been presented in attempts to define and explain criminal activity. Some of these have focused on individual criminals while others
examine the aggregate crime within an area. Although the public perception may be that crime is randomly distributed in space, extensive evidence now suggests that it is not (Guo et al, 2003). Theories on crime that seek to explain this non-random spatio-temporal distribution can be classified as neighbourhood theories and crime place theories.

Neighbourhood theories focus on the motivation of the offender and use of socio-economic factors to explain the distribution of crime. Crime Place Theories focus on the location of crime and its characteristics, the movement paths that bring the offenders and victims together at the location, and the offender’s perceptions of crime locations that make it attractive or unattractive (Brantingham and Jeffery, 1981). Three Crime Place Theories are described below and their relevance to crime analysis is discussed.

2.3.1 The Rational Choice Perspective

From the rational choice perspective, offenders are seen as rational decision makers-making tradeoffs and choosing targets that fulfil their goals. The offender’s choice of the place and time to offend is based on the attractiveness of the place for such crimes which includes such factors as the presence or absence of security personnel, the convenience of public transport to the place and the presence of car types (in case of motor vehicle theft) that satisfy the required goals. Based on this perspective, crime incidents will tend to cluster spatially if offenders make their choices consistently.
2.3.2 Routine Activity Approach
As people perform their routine activities, crime opportunities present themselves to motivated offenders who are able to steal the desired object in the absence of capable guardians (e.g. parents) or place managers (e.g. security guards) whose presence might have prevented the crime from happening. Thus, the spatial distribution of crime depends on the distribution of targets, offenders and capable place managers (Felson and Clarke, 1998).

2.3.3 Crime Pattern Theory
As offenders move through routine activities of home, school, work, entertainment (shopping and recreation), they develop knowledge of the paths, then their routine activities as well as areas around routine activities (Personal awareness space). Different offenders may have different awareness spaces, which may overlap. Generally motivated offenders will discover potentially good target areas that offer a good choice of targets and low risk within their awareness space. Consequently areas within the general urban space that are not part of most individuals’ selective target areas will have the most numerous crimes (Brantingham and Jeffrey, 1981).

2.4 Crime Place Theories and Analysis of Crime
The non-random spatio-temporal distribution of crime suggests existence of clusters or hotspots of crime in space and time. (Sherman, 1996) found that in Minneapolis State, USA, of the 323,000 service calls to police in 1986, a small number of hotspots produced most of the crime in the city (50% of the calls came from only 3% of the locations). Opportunities for crime tend to shift by the hour of the day and day of the week as
changes occur in the risk of offending and the availability of attractive targets (Felson and Clarke 1998). The day of the week dictates the set of routine activities undertaken. For example, on weekdays people engage in a limited number of routine activities by following routine paths to routine locations, while on weekends people have a different set of movements as the weekend (even vacations or holidays) represent a break from the weekday routine (LeBeau and Langworthy, 1986). According to Routine Activities theory, this change in routines may affect the spatio-temporal distribution of crime as offenders and targets flux based on trips to work, school, and leisure settings. In addition, crime has been found to vary with the time of the year (Cheatwood, 1988).

2.4.1 Types of Crime Analysis

Crime analysis is a set of systematic, analytical processes directed at providing timely and pertinent information relative to crime patterns and trend correlations to assist the operational and administrative personnel in planning the deployment of resources for the prevention and suppression of criminal activities, aiding the investigative process, and increasing apprehensions and the clearance of cases. It supports a number of police departmental functions including patrol deployment, special operations, tactical units, investigations, planning and research, crime prevention, and administrative services.

Types of crime analysis include:

(i) Tactical Crime Analysis

This is an analytical process that provides information used to assist operations personnel (patrol and investigative officers) in identifying specific and immediate crime trends, series, patterns, sprees and hotspots, providing investigative leads and clearing cases.
Analysis includes associating criminal activity by method of crime, time, date, location, suspect, vehicle, and any other type of information. (Johnson, 2000)

(i) Strategic Crime Analysis

This is study of crime and law enforcement information integrated with socio-demographic and spatial factors to determine long term patterns of activity, to assist in problem solving, as well as to research and evaluate response and procedures. (Johnson, 2000)

Used for:
- Identification of unusual activity levels by time or location
- Forecasting potential crime events/concentrations

2.4.2 Hotspot Analysis

GIS can be used to analyse and display geographic concentrations or hotspots of crime. The term hotspot has become part of crime analysis lexicon and has received a lot of attention.

A hotspot is a condition indicating some form of clustering in a spatial distribution. However, not all clusters are hotspots because the environments that help generate crime – the places where people are – also tend to be clusters. So any definition of hotspots has to be qualified. Sherman (1996) defined hotspots as “small places in which the occurrence of crime is so frequent that it is highly predictable at least over a one year period”. According to Sherman, crime is approximately six times more concentrated among places than it is among individuals.
2.4.3 Hotspots and Scale

Are hotspots purely a function of scale? Brantingham and Brantingham (1995) argue that any set of points in geographic space can be a hotspot if the scale is modified enough. At an extremely small scale all the crime incidents in an entire city area may appear to be a hotspot. As scale increases, points become more dispersed until, at the largest scale, individual points can be isolated.

Generally, the hotspot concept is applied to street crime rather than white-collar crime, organized crime or terrorist crime. That a few white-collar crimes might overwhelm street crime in their economic impact tends to be ignored. This may be because white-collar crime does not cause the same kind of community fear and anxiety as street crime. Similarly, if a city experienced several terrorist bombings or school shootings within one year, it is considered a hotspot that defies the normal hotspot definition. There is a qualitative aspect to hotspots; which refer only to limited crime types.

2.4.4 Hotspots in time

Just as hotspots can be described geographically, they can also be defined using time-related criteria. An important question is; how long is a hotspot “hot”? The answer requires defining an incident accrual rate within the hotspot, based on units of time. Related decisions are needed to determine whether the hotspots’ “temperature” is measured according to all confirmed crimes, all calls for service, specific crimes or other conditions. In a GIS framework, hotspots (and/or incidents within hotspots) can be colour coded or otherwise symbolized according to their age. For the purposes of my thesis the hotspots identified are “hot” within the six-month study period.
2.4.5 Hotspot Identification Using GIS

Before recent technological advances, law enforcement agencies typically placed colored pushpins in wall maps to visualize individual crime events and examine the spatial distribution of crime locations. This was a popular approach for detection of crime hotspots, which is still being practiced in many third world countries, Kenya being one of them. Nowadays visualization can be more effectively done using GIS, which permits analysers not only to draw the hotspots but also allows the analysis of hotspots over a period of time. Geo-coding is necessary for generating the GIS based hotspot maps, it assigns X and Y coordinates to an event or address, so that it can be placed on the map. This allows fast and accurate visualization of data on the map.

2.5 Crime mapping techniques

2.5.1. Point mapping

The most common approach for displaying geographic patterns of crime is point mapping (Jefferis, 1999). Point mapping is popular mainly because it is a simple digital version of a familiar and traditional method of placing pins representing crime events onto a wall map. In a digital application, if these individual geographic point objects are suitably attributed with information, such as codes describing the type, date, and time of offense, sets of points meeting particular conditions can be simply and quickly selected. These selections can then be displayed using suitable symbology representing the crime category displayed. However, trying to interpret spatial patterns and hotspots in the crime point data can be difficult, particularly if the data sets are large. Also, at certain locations, what appears to be a single crime point may be more than one crime point. These points at coincident locations are impossible to identify in a point map. However they do have
their applications such as mapping individual events of crime, small volumes of crime, and repeat locations through the use of graduating symbol sizes but they can become less effective for identifying hotspots of crime, particularly from large data volumes.

2.5.2 Thematic mapping of geographic boundaries

A popular technique for representing any spatial distribution is geographic boundary thematic mapping. These geographic boundaries usually are defined administrative or political areas such as wards, sub-location, location or division boundaries. Crime events mapped as points can be aggregated to these geographic regions. These counts of events by their geographic areas can then be thematically mapped to display the spatial pattern of crime across the area of interest.

Boundary thematic maps are important map outputs, as the areas they represent often are geographic regions used for political and administrative purposes. For example, a police inspector may have management responsibility for combating crime in a group of geographic areas; this inspector will be interested in the general information contained in a crime thematic map. The inspector will also most likely be interested in receiving summarized information of patterns that exist in neighboring geographic areas (e.g., a geographic boundary thematic map, with a table of crime counts by categories for these areas of interest). These methods do, therefore, have an important application for providing summarized management information across areas of accountability, but may mislead focused crime prevention targeting because of failing to reveal patterns within and across the geographic division of boundary areas. Due to the varying size and shape of most geographic boundaries, thematic shading can mislead the users in identifying
where the spatial cluster of crime may exist. A division may contain an area with a cluster of crime events. These crime events, however, may be evenly spread across the whole area of this large division. Thus an actual hotspot in this area may not exist. If this was the case, the map may misinform any targeting initiative to hotspots of crime identified by this method. An additional problem with mapping by defined boundaries is that presented by the Modifiable Area Unit Problem (MAUP) (Bailey and Gatrell, 1995; Openshaw, 1984), in which changes in the geographic boundary areas used to thematically represent the distribution of crime can affect and further mislead map interpretation.

2.5.3. Spatial Ellipses

The application of spatial ellipses for attempting to identify crime hotspots has a long tradition in crime mapping. These methods depend on the proximity of incident points (Harries, 1999). In order to more formally assess the extent to which a point pattern shows clustering or dispersion, two main classes of techniques may be applied:

(i) Nearest Neighbour distance statistic

This uses the magnitude and/or distribution of inter-point distances, or the distances between the points and reference locations as an indicator (distance based tests).

The distance-based statistic uses the distribution of the distance to the nearest neighbour as a measure. If this distance tends to be smaller than what it would be under complete spatial randomness, this suggests clustering. If, on the other hand, it tends to be larger, then dispersion is the suggested alternative. The Nearest Neighbour Index (NNI) is calculated using the following steps:
• For each point, calculate the distance to the nearest neighbour point.
• Sum the nearest neighbor distance for all points and divide by the number of points in the data. This value is the observed average nearest neighbour distance.
• Create a random distribution of the same number of crime points covering the same geographic area, and for each point calculate the distance to each nearest neighbour point.
• Calculate the sum of the nearest neighbour distances for all these randomly distributed points and divide by the number of points in the data. This value is the average random nearest neighbour distance.
• The NNI is then the ratio of the observed average nearest neighbour distance against the average random nearest neighbour distance.

\[ NNI = \frac{Average \ distance \ of \ the \ nearest \ other \ point \ (nearest \ neighbour)}{Average \ random \ nearest \ distance}. \]

If the result generated from the NNI test is 1 then the crime data is randomly distributed.
If the NNI result is less than 1 then the crime data shows evidence of clustering and therefore hotspots, in the point data.

(ii) The Spatial and Temporal Analysis of Crime (STAC)

(a) The Concept
This method uses the number of points within a given area as the basis for test statistics. It assesses the presence of clusters by comparing the number of events (points) within a given region to the number expected under complete spatial randomness. STAC performs
the functions of a radial search and identification of events concentrated in a given area (Levine, 1996). The results are visualized as a standard deviational ellipse computed for the points identified to be a “cluster” or “hotspot.”

(b) STAC Parameters

The main STAC parameters are the search radius and the minimum number of points. The search radius is the distance within which the STAC routine searches. The default is 800m. A 20 x 20 grid is overlaid on the study area. At each intersection of a row and a column, the routine counts all points that are closer than the search radius. Overlapping circles are combined to form variable-size clusters. The smaller the search radius that is selected, the fewer points will be selected. On the other hand, choosing a larger search area, the more points will be selected. However, the larger the search area, the greater the likelihood that clusters could be chance groupings.

The minimum number of points required for each cluster allows the user to specify a minimum number of points for each cluster. The default is 5 points. If there are too few points allowed, then there will be many very small clusters. By increasing the number of required points, the number of clusters will be reduced.

(c) How STAC identifies Hotspots Areas

The following procedure identifies hot spots in STAC. The program implements a search algorithm, looking for Hot Spot Areas.
Visualizing the spatial-temporal patterns of crime in Nairobi

• STAC lays out a 20 x 20 grid structure (triangular or rectangular, defined by the user) on the plane defined by the area boundary (defined by the user).

• STAC places a circle on every node of the grid, with a radius equal to 1.414 (the square root of 2) times the specified search radius. Thus, the circles overlap.

• STAC counts the number of points falling within each circle, and ranks the circles in descending order.

• For a maximum of 25 circles, STAC records all circles with at least two data points along with the number of points within each circle. The X and Y coordinates of any node with at least two incidents within the search radius are recorded, along with the number of data points found for each node.

• These circles are then ranked according to the number of points and the top 25 search areas are selected.

• If a point belongs to two different circles, the points within the circles are combined. This process is repeated until there are no overlapping circles. This routine avoids the problem of data points belonging to more than one cluster, and the additional problem of different cluster arrangements being possible with the same points. The result is called hot clusters.

• Using the data points in each hot cluster, the program calculates the best-fitting standard deviational ellipses, which are called hotspot areas. The standard deviational ellipse is a statistical summary of the hot cluster points.
2.5.4 Kernel Density Estimation

(a) The Concept

The goal of Kernel Estimating is to estimate how the density of events varies across a study area based on a point pattern. Kernel Estimation was originally developed to obtain a smooth estimate of univariate or multivariate probability density from an observed sample. (Bailey et al, 1995). In the spatial case, Kernel Estimation creates a smooth map of density values in which the density at each location reflects the concentration of points in the surrounding area (Dough et al, 1999).

In Kernel Estimation, a three-dimensional floating-function visits every cell on a fine grid that has been overlaid on the study area. Distances are measured from the centre of the grid cell to each observation that falls within a predefined region of influence known as a bandwidth. Each observation contributes to the density value of the grid cell based on its distance from the centre. Nearby observations are given more weight in the density calculation than those further away.

Kernel Estimation has two advantages for displaying crime patterns:

- It clearly shows complex spatial point patterns in a smooth image that can also be used to create other data sets e.g. 3D Images for further visualization
- It can be used for quantitative comparisons over time.

First, this method helps make sense of complex point patterns; the result, a smooth raster image of densities, can be used in conjunction with the point map. This means no information is lost in the analysis. From this raster image users can quickly identify hotspots, either by eyeballing (visually inspecting) them, which is subjective and very judgemental, or by defining hotspots based on statistical significance. The product of
Kernel Estimation method is a simple, aesthetically pleasing raster image from which users can derive other data sets, specifically contours of density. These contour loops can be displayed independently of hotspot areas that can be analysed separately. Hotspots are often irregular in shape.

Kernel estimation can also be used to analyse change over time. Raster images of crime density can be used as input into correlation analysis or time series analysis. The correlation analysis can be performed either by comparing two consecutive time periods (i.e., one month to the next) or by comparing one time period to a similar one (i.e., June of the current year to the June of the previous year). Either way, the user would expect to see high values in the same area for the other period. Time series/change analysis can use multiple density images to monitor change over time.

One weakness in using the Kernel Estimation is the arbitrary nature of selecting a radius for the region of influence or bandwidth. There is no hard and fast rule for determining this distance, as discussed in (b) below. Ideally, this distance should represent the actual distances between points in the distribution.

(b) Estimating Bandwidth

Selecting an appropriate bandwidth is a critical step in Kernel estimation. The bandwidth determines the amount of smoothing of the point pattern. The bandwidth defines the radius of the circle centred on each grid cell, containing the points contributing to the density calculation. In general, a large bandwidth will result in a large amount of smoothing and low density values, producing a map that is generalized in appearance. In
contrast using a small bandwidth will result in less smoothing, producing a map that depicts local variation in point densities. Using a very small bandwidth, the map approximates the original point pattern and is spiky in appearance.

Several rules of thumb have been suggested for estimating bandwidth. Arcview GIS software uses a measure based on the areal extent of the point pattern as the default bandwidth. Specifically, the bandwidth is determined as the minimum dimension (X or Y) of the extent of the point theme divided by 30.

Bailey and Gatrell (1995) suggest a bandwidth defined as 0.68 times the number of points raised to the 0.2 power scaled to the areal extent of the study area, or $0.68(n)^{0.2}$, where n is the number of points. This can be adjusted depending on the size of the study area by multiplying by the square root of the study area. The problem with the first two methods for estimating bandwidth is that neither takes into account the spatial distribution of the points. Bailey and Gatrell (1995)’s estimate is based on point density, but this is limited at best. Large sample sizes will result in large bandwidths, while small sample sizes will result in small bandwidths. No consideration is given to the relative spacing of the points. The arbitrary nature of combination would yield similar results. The Arcview GIS default method is useful if the study area is large but not if the study area is small.

The best method is the one based on the interpoint distances of the point pattern. Thus the bandwidth will reflect the spacing of points rather than the size of the study area or the number of points. Dough Williamson, a doctoral candidate at the City University of New York is developing the K-nearest neighbour method, which bases the bandwidth on the spatial distribution of the point pattern. (Dough et al, 1999)
CHAPTER THREE: METHODOLOGY

3.1 Data Sources and Format

There are two important components of geographic data:

- **Spatial data:**
  Geographic position specifies the location of a feature or phenomenon by using a coordinate system, which is used for representing geographical features e.g. cities, rivers and lakes.

- **Attribute data**
  Attribute data refer to the properties of spatial entities, which describe the characteristics of the geographic features, e.g. population, length, and area.

Spatial features in a GIS database are stored in either vector or raster format.

(a) Vector data

Vector data represents the shapes of features precisely and compactly as an ordered set of coordinates with associated attributes. (Zeiller, 1999). GIS data structure adhering to a vector format store the position of map features as pairs of X, Y (and sometimes Z) coordinates. A point is described by a single X-Y coordinate pair and by its label. A line is described by a set of coordinate pairs and by its name (or label). An area, also called polygon, is described by a set of coordinate pairs and by its name or label with the difference that the coordinate pairs at the beginning and at the end are the same.
(b) Raster data

The raster or grid-based format represents map features as cell or pixels in a grid matrix. The space is defined by matrix of points or cells organized into rows and columns. Each cell has a value that represents the characteristics of the feature.

In this study vector data was used. A base map of Nairobi Province was obtained from Geomaps International. It comprised of various layers amongst them; buildings, roads, rivers, parks, area and building names. The attribute data consisted of the crime data. Table 3.1 shows the sources of various data sets.

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Source of Data</th>
<th>Location of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Divisional</td>
<td>Nairobi Police Division Map 2005, scale 1:2500</td>
<td>Nairobi Provincial Police Headquarters</td>
</tr>
<tr>
<td>Boundaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nairobi Province</td>
<td>Aerial Photographs of February 2000, Scale 1:10000</td>
<td>Geomaps International</td>
</tr>
<tr>
<td>base map</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crime data</td>
<td>Kenya Police crime records</td>
<td>Nairobi Provincial Police Headquarters</td>
</tr>
</tbody>
</table>

Table 3.1: Data Sources for the study.

3.2. Data Collection

The crime data was obtained from Nairobi Provincial Police Headquarters from the Occurrence Book. This included carjacking, robbery, murder, burglary and rape cases covering a period of six months, from November 2004 to April 2005. Each record identified the name of the victim, the Police division in which the crime occurred, the Police station where the crime was reported, type of crime, description of incident
location, time and date of occurrence. Rape records were very few due to low reporting rate of rape incidents. This later hindered any meaningful analysis of rape hotspots. A hand held GPS receiver (GARMIN GPS 12) was used to pick coordinates of crime incident locations and Police stations. Population data was obtained from the Population Studies and Research Institute (PSRI), Library at the University of Nairobi.

During the study, attempts to obtain crime data from the private security companies were futile as several companies approached were not cooperative. These included Wells Fargo, Securicor etc.

3.3 Preparation of base map

The base map data for Nairobi was in the form of ten Blocks. Each block contained the following layers all in DGN format, a MICROSTATION 95 format: Roads, buildings, rivers, parks, place and building names. These were then imported into ARCVIEW 3.2 and converted into shape files. All similar features in various blocks were merged together so as to have only one data layer representing a particular feature. Editing was carried out to correct for overshoot and undershoot errors. Additional fields were created to allow for more attribute information to be added for each data layer. The data layers were then labelled appropriately. Table 3.2 shows the various data layers, their spatial type and their format while Table 3.3 shows the attribute information of various features.
## Data Layer

<table>
<thead>
<tr>
<th>Data Layer</th>
<th>Spatial Type</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police divisional boundary</td>
<td>Polygon</td>
<td>Shape file</td>
</tr>
<tr>
<td>Population</td>
<td>Polygon</td>
<td>Shape file</td>
</tr>
<tr>
<td>Building</td>
<td>Polygon</td>
<td>Shape file</td>
</tr>
<tr>
<td>Road</td>
<td>Line</td>
<td>Shape file</td>
</tr>
<tr>
<td>River</td>
<td>Line</td>
<td>Shape file</td>
</tr>
<tr>
<td>Police Station</td>
<td>Point</td>
<td>Shape file</td>
</tr>
<tr>
<td>Police Post</td>
<td>Point</td>
<td>Shape file</td>
</tr>
<tr>
<td>Crime Incident location</td>
<td>Point</td>
<td>Shape file</td>
</tr>
</tbody>
</table>

Table 3.2: Data layers and their format.

## Feature

<table>
<thead>
<tr>
<th>Feature</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>Road Name, Classification</td>
</tr>
<tr>
<td>Nairobi Police Division</td>
<td>Division Name, Total population, Carjacking cases, Robbery cases, Burglary cases, Murder cases, and Rape cases</td>
</tr>
<tr>
<td>Building</td>
<td>Building names</td>
</tr>
<tr>
<td>Crime Incident Location</td>
<td>Police Station, Police Division, Victim, Incident Location, Date, Time, Crime Type, Coordinates</td>
</tr>
<tr>
<td>Police Station</td>
<td>Name</td>
</tr>
<tr>
<td>Police Post</td>
<td>Name</td>
</tr>
</tbody>
</table>

Table 3.3: Attribute Schema.
3.4 Database Creation

The crime data was entered into a Microsoft EXCEL database. Before any spatial analyses could be performed on the crime data these records had to be geocoded. In other words, the address information attached to crime records had to be converted to point locations so as to be useful in a GIS database. The data was recorded as road junctions, building name, shopping center name, estate name or street name. A GPS receiver was used to position the incident location. The X and Y coordinates of these incident locations were then entered into the excel database. However, not all the incidences had exact locations (a street name, a building name or shopping center name), and therefore could not be used in hotspot analysis but were used for general analysis such as; analyzing the total number of murder incidents in a particular police division. Figure 3.1 is a sample of the Microsoft Excel database. Microsoft Excel is not compatible with ArcView 3.2 and therefore the database was converted to a DBASE IV format and then imported into ArcView as an event theme (Events enable one to map data that contain geographic locations but which are not in a spatial data format). The theme was then converted to shape file format to allow analysis in ArcView.
3.5 Spatial-Temporal Analysis and Visualization

3.5.1 Spatial analysis tools for identifying Crime hotspots

Three tools were used to identify crime hotspots: ArcView, ArcView Spatial Analyst, and CrimeStat.

In ArcView, views were created containing the various data layers (themes), which were used for subsequent analyses as shown below:

Table 3.4: Sample of Crime database
(i) **Point Pattern Mapping**

This view contained Police Divisional boundary theme, Police Station theme, Police Post theme, and crime incident location theme. This enabled the visualization of crime distribution relative to the location of Police Stations and Police Posts in Nairobi.

(ii) **Thematic Mapping of Individual Crimes**

This view contained the following themes; Police divisional boundary, Police Station, Police Post. Thematic mapping of individual crime was based on Police Divisional boundary. The attribute table for the Police Division contained the total number of individual crimes (carjacking, robbery, burglary, murder and rape) and this was used to analyze the spatial distribution of the crime in Nairobi. Symbolization was done by Graduated Color method, in which the distribution of individual crimes was classified according to the number of cases per division and the classes were represented with a color ramp going from lowest to highest. Rape cases reported were very few in all the divisions and therefore no credible analysis was possible for rape.

(iii) **Spatial Ellipses - Hotspot detection in CRIME STAT**

**Nearest Neighbor distance statistic**

A Nearest Neighbor statistic was implemented in **CrimeStat** in the Distance Analysis menu of Spatial Description. The Carjacking.shp file for Kasarani Division was used as the primary file and Coordinate System and data units set to Projected and Meters respectively as shown in Figure 3.1
In the **Distance Analysis** dialog, the box next to Nearest Neighbor Analysis (NNA) was checked as shown in Figure 3.2 and analysis was done automatically after clicking on the compute button. The resulting ellipses were then loaded into ArcView for visualization.
Visualizing the spatial-temporal patterns of crime in Nairobi

Figure 3.2: Nearest Neighbour Analysis

Spatial And Temporal Analysis Of Crime (STAC)

STAC was implemented in CrimeStat under the Hotspot Analysis II tab of the Spatial Description tab. The Carjacking.shp file for Kasarani Division was set as the Primary File. The Data Units were set to kilometers. The box next to STAC on the interface was checked, and the Output Units set to kilometers, as in Figure 3.3. The STAC parameters i.e, the search radius (STAC uses a circle with a fixed radius in the scan operation) and
the minimum number of points to consider a cluster were set. In Figure 3.3, the settings are 5 km for search radius and 5 for the minimum number of points. After computation the resulting ellipses that had been saved as shape files, were then loaded into ArcView for visualization.

![Diagram showing STAC ellipse parameters](image)

**Figure 3.3:** Computation of STAC ellipses

(iv) **Hotspot Detection by Kernel Density Estimation in ArcView Spatial Analyst**

A Kernel Estimation method was used within the Spatial Analyst Extension in ArcView GIS to calculate the density of various crime incidents across the study area based on the point patterns.
Visualizing the spatial-temporal patterns of crime in Nairobi

The view for carjacking density contained the following themes; Police Divisional boundaries, carjacking incidents, Police Station, Police Posts and the calculated carjacking density in Nairobi.

To create a carjacking density map with Spatial Analyst, first a density grid was calculated from the carjacking point theme containing locations of individual crime incidents. This was done in the Analysis menu of Spatial Analyst, where Calculate density option was chosen. As with any interpolation technique, two parameters needed to be set which were critical to the outcome. The first was the underlying cell size, which determined the output resolution. The second was the search radius of a circular window (or bandwidth) that stepped across the grid cells. ArcView Spatial Analyst provided default values for these parameters based on the size of area of the point theme and number of points to be processed. Thus each cell in the grid was automatically assigned a specific size of 152.148 m and had a circular search radius of 676.266 m applied to it.

The search radius is the distance used to search from each cell in the output grid theme for points to be used in the density calculation. ArcView Spatial Analyst sets the default search radius as the smaller distance of the width and length of the extent of the input point theme (or the extent of the selection) divided by 30. In this case the width of the carjacking point theme was 20.287 km, dividing this figure by 30 gave a search radius of 676.266m. Cell size determined how coarse or smooth the patterns would appear. The smaller the cell size, the smoother the density surface. However, very small cells also required considerably more processing time and computer storage space. The size of the search radius determined how generalized the density patterns would appear. A smaller
search radius showed more local variation, while a larger search radius showed broader patterns in the data.

Kernel density calculations were done and these gave more weight to points near the center of the search area than to those near the perimeter. This resulted in a density surface showing the spatial distribution of carjacking hotspots in Nairobi.

A similar procedure was carried out to calculate the density of robbery incidents in Nairobi. To show the spatial distribution of particular crime incidents in a Police Division, Kernel Density surfaces for robbery hotspots in Buruburu and Kasarani Divisions were created. Overlaying the density surfaces with the road network and buildings layers then zooming in to particular hotspot area enabled better visualization of the hotspot.

3.5.2 3D Visualization

3D visualization was carried out in ARCVIEW 3D Analyst Extension. After a density surface was created in ArcView Spatial Analyst, it was converted to Grid Format and then to TIN format. The TIN was to be added as a theme in a 3D Scene. Figure 3.4 is a view showing a TIN surface of murder hotspots in Nairobi.
In ArcView’s table of contents, “3D Scenes” was selected. The new Scene was then renamed appropriately and a TIN surface added as a theme. On the 3D Scene menu, 3D Scene properties, which included background colour, vertical exaggeration and map units, were set. Zooming in and out was done to achieve a good 3D view. The Nairobi Police Division theme was added in the background so that when one clicked on a particular point on the 3D surface, he/she could tell in which Division it lies.
3.5.3 Spatio-Temporal Patterns of Crime

**Daily, Weekly and Yearly Spatial Patterns of Crime**

The period during which particular crime occurred is captured in the database as the date and time it was reported to the law enforcement authorities.

The daily spatio-temporal patterns of all crimes were determined by first identifying five distinct time periods, (Between 12am and 6am, between 6am and 12pm, between 12pm and 6pm, between 6pm and 9pm; and between 9pm and 12 am), then the frequency was graphed against the distinct time periods. Different colours were used to symbolize the crimes.

To determine the weekly spatio-temporal distribution, the total incidents of carjacking, robbery, murder and burglary for each day of week were graphed.

Spatio-temporal distribution for the six month period of study (November, 2004 to April, 2006) was determined by graphing the crime incidents per month. Different colours were used to symbolize different crimes.
CHAPTER FOUR: RESULTS AND ANALYSIS RESULTS

The results of this spatio-temporal data analysis reveal that the distribution of crime in Nairobi between November 2004 and April 2005 was not uniform but displays distinct patterns in space and over time. This distribution is presented and discussed below.

4.1 RESULTS AND ANALYSIS RESULTS

4.1.1 Point Pattern Maps

Figure 4.1 is a Point Pattern Map of Nairobi. Incident locations of all the crimes studied are represented as dots and the position of Police stations and Police posts in various Police divisions are shown. A point pattern map is good for mapping individual events of crime, small volumes of crime, and repeat locations through the use of graduating symbol sizes.

Figure 4.2 shows a point pattern map for carjacking cases in Buruburu division. Since the area of coverage is small and number of points fewer compared to those in Figure 4.1 this map is easier to interpret. The large volume of points shown on the map in Figure 4.1 makes it difficult to feel completely confident in identifying the hotspots of the crime incidents. Also, at certain locations, what appears to be a single crime point may be more than one crime point. These points at coincident locations are impossible to identify in a point map with a large number of points such as Figure 4.1.
Figure 4.1: Nairobi Point Pattern Crime Map
Figure 4.2 Buruburu Point Pattern Map of Carjacking incidents
4.1.2. Thematic Mapping Of Individual Crimes

Carjacking, Robbery, Burglary and Murder analysis

Figures 4.3, 4.4, 4.5 and 4.6 show Carjacking, Robbery, Murder and Burglary incidents respectively in Nairobi thematically mapped based on police division as the boundary. For carjacking and robbery, Kasarani and Buruburu divisions have the highest number incidents while Kayole Division has the least. For Murder, Kilimani has the highest number of incidents, which is due to its proximity to the Kibera slum, where most murders seem to have been committed during the study period. This method has an important application for providing summarized management information across areas of accountability such as police divisions, but may mislead focused crime prevention targeting because of failing to reveal patterns within and across the geographic division of boundary areas.
Figure 4.3: Carjacking Distribution in Nairobi
Figure 4.4: Robbery Distribution in Nairobi
Figure 4.5: Distribution of murder incidences in Nairobi
Figure 4.6: Burglary Distribution in Nairobi
4.1.3 Spatial Ellipses

(i) Hotspot detection in CRIME STAT

Figure 4.7 is a Map of carjacking cases in Kasarani division. Spatial Ellipses have been used to identify clusters. The pink ellipse is a Nearest Neighbour Hierachical (NNH) clustering. It was generated by CRIME STAT in a constant –distance clustering that groups points together on basis of spatial proximity. It identified carjacking hotspot areas in Kasarani as the area along Thika Road. The blue ellipses are STAC ellipses (uses circle with fixed radius in the scan operation). The minimum radius for the STAC was 5 km and the minimum number of points was 4. The minimum number of points was chosen to be 4 because this was the maximum number of carjacking incidents found in one particular location and represented by a single point on the map. The carjacking incidents were first displayed on the map and physical examination was done to determine the distribution, which was found to be uneven. The search radius was context specific and required some trial and error. Initially a larger radius of 25 km was chosen, and then smaller radii of 10 km, 5km, 2.5 km and 1km were re-analyzed respectively within the large radius. The smaller the search radius that was selected, the fewer the points that were selected and subsequently very many small clusters. On the other hand, the larger the search radius, the more points were selected and subsequently fewer clusters. After several trials 5km was found to be appropriate.
Four Hotspot areas were identified using this method. Figures 4.8, 4.9, 4.10, 4.11 and 4.12 show these areas at a larger scale.

Figure 4.8: A STAC Ellipse of Hotspot area around Pangani and Eastleigh areas.

Thika Road and Park Road junction is a repeat place hotspot area as shown in the “identify results” dialog box, three cases at this junction were reported during the study period.
Figure 4.9: STAC Ellipse of hotspot area along Thika Road.

The junction of Outer Ring and Thika Road is a repeat place hotspot area i.e three carjacking cases have been reported to have occurred at this junction/round about. Further investigation shows that all the carjacking cases here, happened at night.
Visually inspecting the ellipse shows only two crime incidents as represented by the green dots. However Thika Road and Garden Estate Road junction is a repeat hotspot place with four carjacking cases being reported during the study period. Further investigation shows that all the carjacking cases happened after five thirty in the evening.

Figure 4.10: STAC ellipse of Hotspot area along Thika Road, near Roasters Inn.
Figure 4.11: STAC ellipse of hotspot area near Safari Park Hotel.

The Safari Park Matatu Stage along Thika Road is a repeat hotspot area with six cases of carjacking reported during the study period. Further analysis shows that of the six cases, four were reported during the day between 1000 hours and 1330 hours, while two cases were reported in the night. The incidents happened on Thursdays and Fridays.
Figure 4.12: STAC Ellipse of Hotspot area near Kenyatta University.

Kenyatta University Stage is a repeat hotspot place as four carjacking cases were reported during the study period. Results 1 to 4 in the Identify Results dialog box represent the stage while results 5 and 6 represent Thika Road and Kahawa Wendani junction which is also a repeat hotspot area.

Figures 4.7, 4.8, 4.9, 4.10, 4.11 and 4.12, demonstrate how spatial ellipse techniques are useful for grouping crime point clusters and revealing areas for closer inspection. However, the ellipse outputs also demonstrate certain weaknesses if an analyst is trying
to accurately identify the location of crime hotspots. Crime hotspots do not naturally form spatial ellipses. These methods, therefore, do not represent the actual spatial distribution of crime and can often mislead the analyst to focus on areas of low crime importance within an ellipse. Only specific areas within the ellipse form a crime hotspot. Also, these techniques require a number of parameters to be entered, such as search radius and minimum number of points to form a cluster. For example, setting the search radius too large or too small may not yield any cluster. Usage of different parameters by different analysts can introduce ambiguity and variability in the final output. For example, different crime analysts investigating crime hotspots from the same data may produce different results because of the different parameters they have chosen to enter into the routine. Grouping events into elliptical clusters also excludes from any visual result those events that do not belong to a cluster.

4.1.4. Kernel Density Estimation

A Kernel Estimation method was used within the Spatial Analyst Extension in Arcview GIS to calculate the density of various crime incidents across the study area based on the point patterns.

Figure 4.13, is a density surface of carjacking incidents in Nairobi. The dark areas represent areas of high crime concentration -carjacking hotspots. The density pattern of carjacking incidents indicates that some areas were more prone to carjacking than others and had higher risks. Carjacking hotspots were found in the central business district as well as in the suburbs. Kasarani had the highest number of carjacking cases followed by Buruburu Division. Buruburu and Central divisions had the highest concentration along
Jogoo Road, Mbotela area and along River road and Tom Mboya Street, and Globe Cinema round about respectively. River Road and Tom Mboya are highly prone to crime because of dark alleys and overcrowding. For Kasarani, several hotspot areas were spread along Thika road.
Figure 4.13: Carjacking density in Nairobi
Figure 4.14, is a density surface of robbery hotspots in Nairobi relative to the location of police Stations and Police Posts. The dark areas represent high concentrations of robbery cases. Kasarani, Buruburu and Central division have more robbery hotspots as compared to the rest of the divisions. Langata division has only one hotspot, which is not very concentrated.

Overlaying both the carjacking and robbery density surfaces for particular divisions with road network and building layers enables clear identification of the hotspot area.
Figure 4.14: Robbery Density in Nairobi
Figure 4.15 is a robbery density surface for Buruburu division. Robbery hotspots are found in the following areas; Mbotela, Makongeni, Jerusalem, Maringo, Donholm, Umoja and Dandora. There is only one Police Post in this Division i.e Dandora Police Post, although there are several Police Stations including; Shauri Moyo, Jogoo, Makongeni and Buruburu Police Stations. More Police Posts should be set up especially in Donholm and Umoja areas.
Figure 4.15: Robbery Hot Spots in Buruburu
Figure 4.16 is a robbery density surface for Kasarani Division. Robbery hotspots are found in Pumwani, Mathare, Eastleigh, Huruma, Kariobangi, Zimmerman, Githurai, Kahawa West and Kahawa Sukari. The Division has several Police Posts distributed throughout the division and four Police Stations. Despite this, it has many robbery cases, since most of the Police Stations and Police Posts lack manpower and equipment to curb crime.

Poor allocation of resources has also contributed to rising number of robbery cases and GIS analysis can assist the law enforcement officers in knowing which areas to allocate more resources such as Police Patrol. Zooming into the map, shown in Figure 4.16 gives a better view of specific location of robbery incidents over a section of Kasarani Division. The incidents are represented by blue dots Figure 4.17. This is good for patrol purposes by the Police Officers as it shows the specific area to focus on, for example the street corners and road junctions.
Figure 4.16: Robbery Hot spots in Kasarani
Visualizing the spatial-temporal patterns of crime in Nairobi

Figure 4.17: A section of Kasarani Division, showing the robbery hotspots.

Figure 4.18 is a murder density surface for Nairobi. There are murder hotspots in Central, Buruburu, Kasarani, Kayole and Kilimani Divisions. Amongst these Kasarani has the highest number of murder cases followed by Buruburu division.
Figure 4.18: Murder Density in Nairobi
Figure 4.19 shows a murder hotspot area around Globe Cinema round about, Tom Mboya Street and River Road in Central Division. This represents a sample of a possible briefing map for beat-level patrol officers. Briefing maps are a primary method of disseminating information to the front line of law enforcement.

Figure 4.19: Murder hotspot in City Centre
4.1.5 3D Visualization

Figures 4.20, 4.21, 4.22 and 4.23 are 3D surfaces of Murder, Carjacking and Robbery Hotspots in Nairobi. These were derived from the Murder, Carjacking and Robbery density surfaces in ARCVIEW 3D Analyst. Overlaying the surfaces with the Nairobi Police Division theme enables one to know in which Division a point represented as hotspot on the map lies. Figure 4.20 shows a murder hotspot on 3D surface being identified to be in Kasarani Division.

Figure 4.20: 3D view of Murder hotspots in Nairobi.
In Figure 4.21 the highest point on the surface represents a carjacking hotspot area in Buruburu Division while in Figure 4.22 a carjacking hotspot in Kasarani has been identified.

**Figure 4.21:** 3D view of carjacking hotspots
Figure 4.22: 3D view of carjacking Hotspots

Figures 4.23 and 4.24 visualize robbery hotspots, with hotspots in Kasarani and Buruburu being identified.
Figure 4.23: 3D view of robbery Hotspots
4.1.6. Temporal Distribution of crime in Nairobi

(i) Temporal Distribution during the day

Five distinct time periods of occurrence of various crimes were identified: Between 12am and 6am, between 6am and 12pm, between 12pm and 6pm, between 6pm and 9pm; and between 9pm and 12 am. All crimes peaked between 6pm and 9pm and between 9pm and 12 am as shown in Figure 4.25.
Figure 4.25: Crime Incidences by hour of the day

Figure 4.26 shows the pattern of carjacking incidences during the day with the peak time being between 8pm and 9pm.

Figure 4.26: Pattern of carjacking incidences during the day
Distinct spatial variation is evident when the density of all crimes is visualized for the five time periods (Figures 4.27, 4.28, 4.29, 4.30 and 4.31). Between 12am and 6am a number of incidences occurred throughout Nairobi with hotspots occurring in most of the divisions. Kayole and Embakasi had the least number of hotspots. Between 6am and 12pm the crime was moderately high. There was a high hotspots concentration in Kasarani, Buruburu and Central divisions. Between 12 pm and 6pm, there were crime hotspots in Buruburu, Central, Kasarani and Embakasi. For Embakasi the hotspots were found in the area bordering the central division. Between 6pm and 9pm there were many hotspots in Buruburu, Kasarani, Central and moderate cases in Gigiri, Kilimani, Embakasi and Kayole. From 9pm to 12 am crime hotspots were spread in most of the divisions with Buruburu and Kasarani having higher concentration. Thus the spatial distribution of crime varied with time of the day as the risk for offending and availability of attractive targets changed also with time of the day, with night-time being the most attractive time for offenders in most of the divisions. Higher concentration of crime hotspots in Buruburu and Kasarani between 9 pm and 12 am can be attributed to presence of many unemployed youth who during the day are idling waiting for darkness to set in for them to get involved in criminal activities.
Visualizing the spatial-temporal patterns of crime in Nairobi

Figure 4.27: Crime Density in Nairobi for the period between 12am and 6am

Figure 4.28: Crime Density in Nairobi for the period between 6am and 12pm
Visualizing the spatial-temporal patterns of crime in Nairobi

Figure 4.29: Crime Density in Nairobi for the period between 12pm and 6pm

Figure 4.30: Crime Density in Nairobi for the period between 6pm and 9pm
(i) Temporal Distribution During the Week.

Analysis of the distribution of the crimes for each day of the week revealed the following:

**Carjacking**

Figure 4.32 shows that Carjacking incidences peaked on Wednesdays and Friday. This can be explained by the routine activity theory where many people in Nairobi are known to go for recreational activities (especially social drinking) during midweek-Wednesday and end of the week-Friday. The thieves target these days for their operations.
Figure 4.32: Carjacking incidences by day of the week.

Robbery

Figure 4.33 shows that robbery incidences peaked during Wednesdays and Thursday while Tuesday had the least incidences.
**Murder, Burglary and Rape**

Figures 4.34 and 4.35 indicate that murder incidences peaked on Wednesday and Friday, while Burglary incidences peaked on Tuesday and Wednesdays. Rape incidences reported throughout the study period were only eight in number and therefore no meaningful analysis could be derived from these few cases. Few cases of rape could be attributed to a low level of reporting rape cases. There is still a general reluctance by victims to report rape due to stigma and the police department is yet to develop capacity for dealing appropriately with rape victims.
Figure 4.34: Murder incidences by day of the week.

Figure 4.35: Burglary incidences by day of the week.
Temporal distribution during the six months

December had the highest number of robbery cases while carjacking was more uniformly distributed through the six-month period with slightly more cases in November. Large number of crime incidences in December could be attributed to the fact there are many holidays in December with people moving from the city to the rural areas leaving their property unguarded.

**SIX - MONTH SPATIAL DISTRIBUTION OF CRIME IN NAIROBI**

![Bar chart showing spatial distribution of crime in Nairobi over the six-month period.]

**Figure 4.36:** Spatial Distribution of crime in Nairobi over the study period.
4.2 DISCUSSION

Traditionally crime was displayed in graphs and tables (Muraya, 2004). The use of maps was previously neglected. However, this has changed and current mapping technologies have significantly improved the ability of crime analysts and researchers to understand crime patterns and victimization. Four methods of analysing crime patterns have been used in the study. They include; Point pattern mapping, Thematic mapping of geographical boundaries, Spatial Ellipses and Kernel Density estimation. Each of these methods has both strong and weak points as indicated in Table 4.1

The Kernel density estimation method in particular has been demonstrated as being more than just a method that presents an attractive map of crime, but a more robust technique suited for understanding the spatial patterns of crime hotspots. However, identifying hotspots requires multiple techniques; no single method is sufficient to analyse all types of crime.

The visual display of a crime pattern on a map should be consistent with the type of hotspot and possible police action. For example, when hotspots are at specific addresses, a point pattern map is more appropriate than a thematic area map, which would be too imprecise. It directs their attention to large areas where little effort needs to be expended and away from the places where attention is needed. On the other extreme, focusing attention on point locations when the problem is at the area level focuses attention on too precise an area and suggests action that is too focused.

Combining several methods therefore leads to better interpretation of crime patterns.
<table>
<thead>
<tr>
<th>METHOD</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
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<tbody>
<tr>
<td>Point Pattern Mapping</td>
<td>Simple method that acts as a gateway to the other crime mapping functions in part because the ability to implement good pin maps implies the analyst has successfully addressed his/her data needs and has reliable base street maps.</td>
<td>Has the problem of overlaying dots at the same location, obscuring the true distribution.</td>
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<tr>
<td></td>
<td></td>
<td>In areas with a large amount of criminal activity, however, identifying which locations have higher concentrations than others may be difficult.</td>
</tr>
<tr>
<td>Thematic Boundary Mapping</td>
<td>Provides summarized management information across areas of accountability, which can be used for political and administrative purposes.</td>
<td>Involves the aggregation of data within statistical or administrative areas that may not correspond to the actual underlying spatial distribution of the data Can mislead focussed crime prevention targeting because of failing to reveal patterns within and across geographic boundaries.</td>
</tr>
<tr>
<td>Spatial Ellipses</td>
<td>Good for grouping crime point clusters and revealing areas for closer inspection</td>
<td>Can mislead analysts to focus on areas of low crime importance within the ellipse.</td>
</tr>
<tr>
<td>Kernel Density Estimation</td>
<td>It clearly shows complex spatial point patterns in a smooth image that can also be used to create other data sets It can be used for quantitative comparisons over time.</td>
<td>The arbitrary nature of selecting a radius for the region of influence or bandwidth may result in inconsistent results.</td>
</tr>
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**Table 4.1**: Advantages and disadvantages of the crime mapping methods used.
The study revealed that Buruburu and Kasarani divisions had the highest concentrations of crime hotspots. Specific areas in Buruburu division where the crime hotspots were found included Mbotela, Makongeni, Maringo, Jericho, Jerusalem, Uhuru, Donholm, Umoja and Dandora. In these areas there are very many unemployed youth who have resorted to crime. It was also established that policemen in some of these areas also collude with the criminals by renting out their guns and sharing out the stolen properties and these complicates the fight against crime. In Kasarani division apart from high rates of unemployment amongst the youth, some of the most notorious militia/hitsquad gangs operate from this division. They include Mungiki and Taliban gangs who area found in areas like Githurai, Zimmerman, Mathare and Kariobangi where crime hotspots are also concentrated. The proliferation of sophisticated arms and ammunition at minimum costs in Eastleigh area brought into the country by illegal Somali immigrants and even citizens has complicated police efforts in fighting crime, leading to a high concentration of crime in Kasarani division.

The escalating growth in urban as a consequence of rural urban migration in search of employment has culminated in mushrooming of slums and other non-formal settlements. Crime hotspots are found in most of these slums, for example Kibera slum was found to have very many cases of murder. Over crowding, poor living conditions and general sense of hopelessness characterize the slum areas. High population in the slums puts a strain on the available crime prevention resources.

In the Central division roundabouts such as Globe Cinema and Haile Selassie are crime-hotspots. Globe Cinema roundabout is close to Nairobi River that acts as a gateway for
fleeing after a crime has been committed near the roundabout. As the crime pattern theory suggests crime occurs when the awareness space of offenders coincide with high availability of targets and thus criminals take advantage of overcrowding and little police presence in bus stops such as Kencom and in other crowded areas such as Tom Mboya street and River road area to commit crime.

Although most crimes in the city were found to occur any time, the peak times for crime incidents were found to be mostly at night. Poor lighting along the major roads, highways and in estates makes it conducive for criminals to execute their plans more precisely.

The study focused on analysis of crimes of violence or property crimes perpetrated by individuals but not organized crime or the white-collar crimes such as cyber crimes. The rise in computer crimes, particularly those committed over the Internet, has spawned interest in the extension of existing methods to the mapping and analysis of computer crime (Brown et al, 2004). Currently studies are being done on how to use crime-mapping methods to develop preferences or profiles of computer criminals based on incident data.

The study did not factor in the crime incidents against people who work in Nairobi but live outside Nairobi in areas such as Ongata Rongai, Ngong, Athi River etc. Ongata Rongai Ngong, and parts of Athi River have already been included in Nairobi as far Police Administration is concerned. Therefore in future crime data used for this kind of studies should cover these other areas forming the "greater Nairobi".
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The objectives of this study were:

1. To collect crime data.

2. To geocode the spatial location of crime incidents (Carjacking, Robbery, Burglary, Rape and Murder) in Nairobi.

3. To determine overall crime hotspots by density analysis of the point pattern of specific crime being studied.

4. To visualize the spatial-temporal distribution of crime in Nairobi according to the time of the day, day of the week and time of the year.

5. To demonstrate the superiority of GIS in crime analysis and visualization over traditional approaches.

All the above objectives have been achieved.

Spatial-temporal analysis of crime patterns in Nairobi revealed that crime in Nairobi does not occur randomly over space but rather was concentrated in hotspots in various parts of Nairobi. Buruburu and Kasarani divisions had the highest concentrations of crime hotspots. These Divisions have the highest population in Nairobi of 624854 and 640575 (Central Bureau of Statistics, 2000) respectively. Thus there is a relationship between population and crime. The study also revealed that crime patterns in Nairobi varies with time, the highest concentration being between 6pm and 12 am, with peaks at 8pm to 9 pm.
The findings of this study support crime place theories such as routine activity theory that explain why crime often is concentrated in certain days of the week and certain times of the day, crime pattern theory that explains why crime is concentrated at specific places and rational choice theory that explains why offenders make rational choices regarding the decision to commit a crime.

The study also emphasises the fundamental strengths of a GIS over traditional crime analytical tools and methods being the ability to visualize, analyse and explain the criminal activity in a spatial context. The 3-Dimensional surface visualization techniques enable communication of more detailed information about the density of crime incidences. Crime maps produced in a GIS can be linked to real time reporting system to enable quick response to crime. Different layers of information have been integrated together in the analysis, this ability to access and process data from a variety of sources quickly while displaying it in a spatial and visual medium allows law enforcement agencies to allocate resources quickly and more effectively. Traditionally law enforcement agencies have relied on paper maps and pins for their operational activity, with GIS, they have the ability to generate maps directly relevant to the situation at hand. Mapping functions can also be distributed through the internet/intranet to enable officers to generate customized maps. The Kenya Police department, realizing the importance of GIS in crime analysis, has embarked on a pilot study of application of GIS in crime analysis for Kilimani Division.

Observations made during the research indicate that apart from adoption of modern techniques such as GIS in crime analysis, an exhaustive strategy in managing crime is
seen as the best solution to managing crime. Such a strategy would focus on virtually all aspects of crime management and preservation of security and safety. This would include boosting economic growth so that poverty is reduced and employment is generated, adequately equipping security personnel, sustaining their motivation to work, and reforming the enforcement of justice. It also requires the state machinery to play its role efficiently and effectively. For example, the local authorities are expected to contribute indirectly to the management of crime by providing core services such as lighting the streets, ensuring proper planning to create space for police mobility, and opening up a liaison office to provide immediate response.
5.2. RECOMMENDATIONS

- **There should be public education and sensitization.** This is vital in changing the passive public attitude about crime reporting, especially rape cases to allay fears and feeling of apathy and resignation among the public, and to create a proactive and security conscious public.

- **There should be a crime management policy.** This is important in providing a framework for cooperation and collaboration among the different stakeholders including the Security agencies in the public and private sectors, other government agencies, researchers, community and international organizations such as UN-HABITAT, UNDP. Such a policy could have elicited much cooperation from the private sector.

- The study focused on six months of Carjacking, robbery, burglary, murder and rape. Future research should provide similar assessments for longer periods of time to allow for comparison between same months say in two consecutive years that would enable identification of inherent temporal patterns, such as “are carjacking incidents more frequent this December than they were last month or the year before, compared to time, month of the year?”

- Further studies could use animation of the changes in crime distributions over time and to relate these changes to crime prevention interventions. The animation would work well with crime density maps generated by kernel density and make the density maps more visually appealing.

The law enforcement agencies need to:

- Adopt a proactive approach to crime and security.
• Revise the police boundaries to harmonize the police operations. Well-revised boundaries will be able to make the management units responsible for their areas of operation.

• Crime incidences, distribution, frequency and crime density and population of a particular area should be the basis for determining the allocation of resources in the police department and for setting up new Police Posts and Police Stations.

• Introduce digital crime mapping and analysis and use this as the basis for police planning, management and research for result-based service delivery. This calls for extensive exposure and facilitation of the crime and intelligence units to modern crime analysis and mapping technologies, while incorporating into the Police Force various professionals such as GIS Experts, IT specialists, Lawyers, Journalists, etc for effective management of police services.

• Finally, with globalization, crime has also become global. Therefore a regional approach to analyzing crimes would enable law enforcement officers to detect patterns and to cooperate in the apprehension of highly mobile criminals. Regionalization may be a means of sharing costs, experience, and expertise among countries for example in the East African Community (EAC).
REFERENCES


