Evolution of Micro, Macro, Me so Level Simulations for Spatial Analysis of Burglary in Metropolis using Crime Mapping and GIS

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Abstract-Crime is a long overwhelmed issue of human society. Especially, with the expansion of cities and population aggregation in recent years, crime problems have become a great challenge in urbanization process. Both urban policy-makers and police departments have realized the importance of a better understanding of the dynamics of crime. This study explores the spatial characteristic of crime in Chennai using Geographical Information System (GIS) and police call data of the metropolis in 2008. In the research, the combination of both applied and theoretical methods is used to analyze the characteristics of Chennai crime. To find out the crime pattern of the city, three spatial levels (i.e. macro level, me so level and micro level) are adopted. In this paper the crime is divided into two categories: violent crime and property crime. The spatial distribution of the two kinds of crimes is analyzed on a comparative basis of different properties in terms of land use type and population features, and the relevant factors of the crime pattern are investigated. The results reveal that there are some hotspots in downtown, transportation hubs, where population density is relatively high and the crime density decreases gradually away from the center. The analytical and theoretical result will undoubtedly lead to enhanced crime prevention strategies of Chennai in the future.

Keywords: Crime, Spatial Pattern, GIS, Police Records; Chennai.

I. INTRODUCTION

Crime is one of the major problems in the development of modern society [1], and Chennai is obviously not an exception. Pre-reform INDIA had only five to six criminal cases per 100,000 inhabitants annually during the 1950s and 1960s, which makes it earned a reputation of being a "crime free" society at that time [2]. However, since INDIA implemented economic reform and an open-door policy in the late 1970s, crime has been increased approximately 50 times the rates observed in the 1950s and 1960s [3] . Besides, in many of the world's industrialized countries, the crime rate recorded by the police is two or three times higher than those of 30 years ago [4]. Conclusions drawn from the International Crime Victim Survey show that high crime rates is a statistically normal characteristic of nations all over the world [5].

Traditionally, most criminological theories tried to find out what motivates people to commit criminal acts [6]. From the viewpoint of environmental criminology [7], situational crime prevention [8], and routine activity theory [9, 10], crime was spatially concentrated in specific places in urban areas, and extremely high incidence areas or "crime hot spots" existed in cities of both developed and developing countries where people's activities concentrated [1, 11-13].

Geographical or spatial analysis of crime using GIS has played an important role in both criminal justice practices and criminological research [14]. Boba [16] introduced the concepts of crime analysis and crime mapping through the discussion of related theories, data, practices and analysis techniques, particularly the advantages of using GIS in crime study. With the help of GIS, Ackerman and Murray [1] conducted a multi-level spatial pattern assessment of crime in Lima, Ohio. They found that trouble high incidence area existed in the city and GIS could be used to provide a better evaluation of crime and specific socio-economic, demographic, land use and environmental characteristics associated with these trouble spots.

Early in 1970s, conventional geographical approaches were employed to study the spatial pattern of urban crime, and criminal geography has now become a sub discipline of geography [17]. The study of "crime places" has appeared as an important focus of crime prevention and practice [18]. Recent longitudinal analysis has suggested that macro level crime trends are caused by changes in specific types of crime places, and relatively small places measuring at micro units of geography account for the majority of crime [19].Spatial analysis has now been recognized as an important tool in crime study and control [16]. With the development of environmental criminology and other related theories, geographical information system (GIS) has been increasingly used in crime research and practice [20-22]. In recent years, there are a great number of studies on city crime over the world [1, 15, 16, 23-27]. Findings on these studies can be summarized as follows. First, crime rate varies in different geographical areas and can be observed as aggregation in region, city or county level. Second, a further variation of crime pattern has been found when property and violent crime are separated, and usually property crime is more than violent in number. Third, spatial patterns of crime are useful for policymakers, because it is very easy to compare the spatially arrayed crime data with spatially arrayed of data about inhabitant areas. Fourth, environmental factors, such as economy situation, population and land use type also play an important role in spatial crime patterns.

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For example, crime is more likely to happen in shopping centers, and the number of property crime occurring in residential area is larger than that in other regions.

As one of the most influential fast-developing cities in INDIA, Chennai has recently witnessed the rapid urban development over the past 30 years due to the government's strategy of "the reform and opening-up policy". In particular, since the 1990s, the city has experienced unprecedented economic growth during the process of shaping a globalizing metropolis with an excellent investment environment and international competition. Different from other cities in INDIA, Chennai is the largest commercial and financial center in mainland INDIA, and is also regarded as one of the best cargo port. With the floating population accounting for about one third of the total, Chennai has been described as the "showpiece" of the world's fastest-growing major economy.

The existent studies have conducted only exploratory analyses of crime pattern in local level variability. They failed to discuss whether spatial crime pattern of Chennai shares the same tracts with other cities that undergo great transition, or cities in countries that transfer from planed to market economy, or any other cities in western developed nations. For example, is there any significant variation of Chennai crime concentration in macro scale, or within neighborhoods (i.e., from block to block) Or do we find an overall similar micro crime pattern within larger geographical units? Can environmental factors, such as land use type, and population also explain the crime pattern of Chennai?

To answer these questions, we divide the crime into violent and property category, and analyze the spatial pattern of crime in Chennai by using police records from January 1, 2007 to December 31, 2007. Data is very important in criminal research and crime mapping [20]. A distinctive feature of our dataset is that each record has x, y coordinates, making it very convenient to conduct spatial analysis in GIS. With the help of ArcGIS, we aim to find the specific areas which involve more crime, and provide a useful reference for the police or policy-makers. The main objectives of this study include: (1) spatial (macro-, meso- and micro-level) analysis of Chennai crime; (2) spatio-temporal analysis of Chennai crime in urban centre; (3) relationship between crime concentration and environmental factors; and (4) implications for practice.

II. CASE STUDY AREA AND DATA SOURCE

A. Study area

South Chennai is Tamil Nadu eighth largest Town, and is second largest Town in North Chennai with a total population of 1125 463 residents on 31 December 2006.North Chennai one of the largest and most Historical modern Baltic Sea ports. In Figure 1 the area within Middle Ring represents urban district and the part within Inner Ring indicates the center of urban area; Outside Middle Ring is the outskirts of the city and those places beyond the Outer Ring are referred to as outer suburbs.

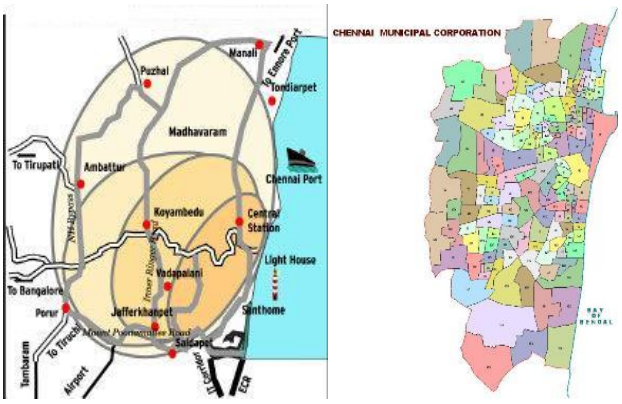

Fig1. Chennai Map With inner, middle, outer Rings

Total Residential Burglary Count: 1,225

- One Time Addresses for Residential Burglary: 514
- Repeat Residential Burglaries Count: 703 (56.71%)
- Number of Properties affected by Residential Burglary: 767
- Number of Properties Revictimized: 226 (29.90% from the total reported residential burglary offences in South Chennai Promoter Apartments are revictimized more than one).

B. Data source

All crime related data used in this paper comes from Chennai 100 Police unit centers. The database records the information of case number, occurring time, case type, occurring location and other brief description of crime. In Chennai, there were totally 3,706,34 crime records in 2008. According to the police crime discrimination framework, these crime records can be classified into 75 types. However, as many categories rarely happen here we just focus on those types that frequently occur (e.g. murder, attempted murder, wounding and assault, rape, indecent assault and robbery, property, fraud burglary, pick-pocketing, and stealing automobiles, electro-mobiles, motorcycles, or bikes). After eliminating unqualified data (repeating call or incomplete and invalid records), and traffic accidents which are beyond the scope of this research, the total number of remaining crime records was, 106,104.

Chennai population data of 2008 used in the research comes from "Chennai statistics yearbook" and the fifth population census Chennai community.

III. METHODS

A. Data collection and editing

The original crime data of 2008 is stored in oracle 9i, which contains much confidential information, such as the caller's name, identification number and telephone number. As such information is not related to our investigation, we exclude these "sensitive" data by replacing the item with some special characters in PL/SQL Developer. We design certain SQL sentences to get the types (as presents in chapter 2.1) of crime records according to the "case category" field. Those cases that happened in a certain period can also be selected according to the "happening time" field. Each type of records containing x, y coordinates is exported to text or .txt format.

B. Crime mapping

Crime mapping refers to the process of conducting spatial analysis within the range of activities of crime analysis [16]. In order to examine the spatial patterns, the process of crime mapping is conducted using ArcMap 9.3. By adding the .txt format data into ArcMap, Using the "Display XY data" tool, the crime data can then be mapped to Chennai administrative map.

C. Analytical approach

Spatial analysis is now recognized as a tool for the study and control of crime [20]. The analysis of spatial patterns of crime comes from the concepts advanced in the field of environmental criminology [33]. This approach seeks to explore the emerging patterns of crime by focusing on the nature of the environment in which crimes occur. In our spatial analysis framework, crime records are firstly mapped to a digital map. Fortunately, the data can be mapped to Chennai map quiet well due to the X, Y coordinates. We then analyze the crime pattern at three spatial levels of Simulations (macro-level, me so-level and micro-level).

At macro-level, the density of both violent and Burglary crime are calculated using kernel density [34, 35] in ArcGIS, because of its advantages over other methods in searching highly crime-infested area, including its ability of allowing irregular shaped hot spots [36]. To have a more clear check of crime aggregation in Chennai city center, "Multiple Buffer Ring" tool in ArcGIS spatial analysis modular is used. At Meso-level, crime rates per 100,000 persons of both violent and property crime of each district are calculated, and are further displayed on Chennai administrative map. Spatial-temporal pattern of crime in Chennai downtown is also analyzed using kernel density method. At the micro-level, crime distribution is explored at block level using geo-statistic tool in ArcGIS 9.3 software. And statistical methods are employed to study the relationship between crime concentration and environmental or social factors.

D. Computer Simulation

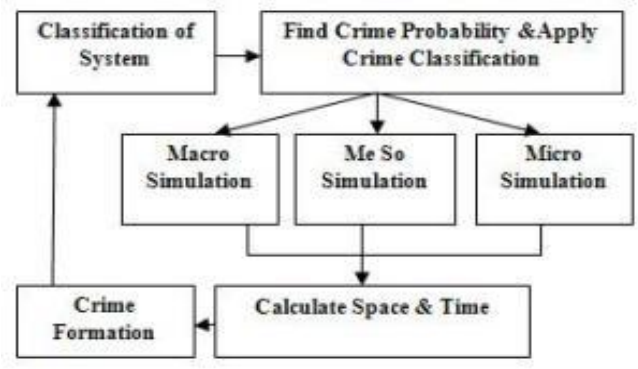

Fig 2: Flow Chart of Computer Simulations

IV. EXPLORATORY ANALYSIS OF CRIME

The pattern of particular crime types are reflected by the spatial distribution of recorded crime data [15]. On the basis of police classification standard, there are many types of crime in the police data, and we only concentrate on categories of crime, as declared in chapter 2.2. We further categorize these cases into two classes (see Table 1): violent crime (murder, attempted murder, wounding and assault, rape, indecent assault and robbery [15]), and property or non-violent crime.

Table1. Crime type classification

Violent crime	Property or non-violent crime
Rape	Fraud
Murder	Burglary
Attempted murder	Pick-pocketing
Wounding and assault	Stealing
Indecent assault and robbery	automobiles, electro-mobiles

A. Macro-Level Simulation

Kernel Density calculates the density of features in a neighborhood around those features. It can be calculated for both point and line features. Possible uses include finding density of houses, crime reports or density of roads or utility lines influencing a town or nature habitat. The population field could be used to weigh some features more heavily than others, depending on their meaning, or to allow one point to represent several observations. The kernel density function is implemented in ArcGIS. The spatial pattern of crime at macro-scale is conducted using kernel density tool in "spatial analyst module" in ArcMap 9.3, with search radius and output cell size set to 2000 meter and 200 meter respectively [37]. According to the statistical analysis result (see Figure 3(a)) it is obvious that crime concentrated in every county center, and there were more Burglary cases inside the Outer Ring of Chennai than other places. Moreover, the hard-hit of the crime was in the center area of the city.

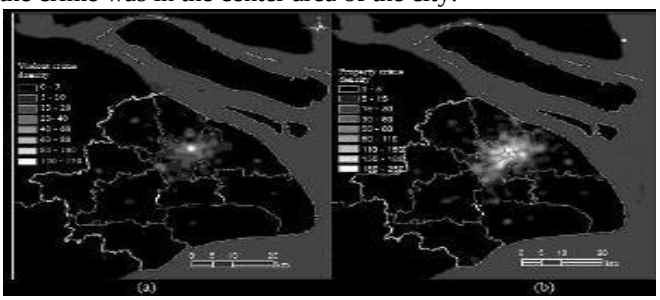

Figure3. Distribution of Chennai crime.(a) Violent crime. (b) Property crime

The results of "crime hot spots" of property crime in macro-Simulation analysis are shown in Figure 3(b). It illustrates that there was more property crime in the urban area of Chennai, especially in the downtown. More specifically, South Chennai Areas share most property cases of the city. In addition, property crime clusters almost in every district center.

Multiple ring buffering creates a new feature class of buffer features by using a set of buffer distances. The new features may be dissolved using the distance values, or as a set of individual features. To find a more exact regulation between crime incidents and the distance from center, Multiple Ring Buffer tool in ArcGIS is used. The People's Square, the center of Chennai, is taken as the center and a total of 20 concentric zones (i.e. circular buffers) with a width of 1 kilometer are created. The R2 of the fitting curve in Figure 3 is rather high, and there is generally a logarithmic relationship between the number of crime cases in every square kilometer and the distance from the city center.

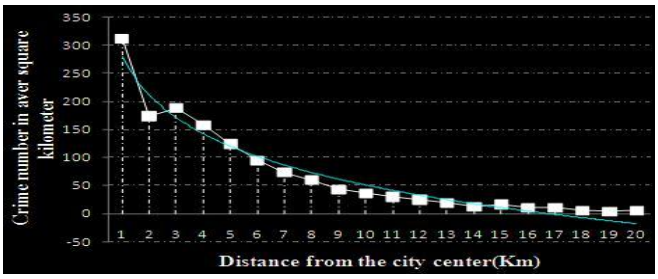

Figure4. Crime density decrease gradually away from city center

Building area and many tour sites are concentrated in the city center. Office-people account for the most part of the population in these areas and the relatively wealthy people attract perpetrators attention. This may increase the incidence of violent and property crime in the downtown of Chennai. As suggested by Figure 3, the number of property crime was larger than violent crime. However, as the distance away from the city center increases, shopping centre and office block were relatively less centralized, making crime density decrease gradually away from city center. The spatial crime pattern of Chennai is quite identical to many western cities in developed countries.

B. Me so-Level Simulation

Table 2. Crime rate and density in each Area of Chennai

Area Name	Crime in every 100,000 persons		Crime number in every square kilometer	
	Violent crime	Property crime	Violent crime	Property crime
Alwar Tirunagar	1.67077	2.11902	0.06942	0.0880
Besent Nagar	3.01338	7.11051	0.19307	0.4555
Choolai	4.14575	10.39530	0.28601	0.7171
Egmore	3.81480	7.56086	0.32006	0.6343
Ganesh Nagar	5.72108	8.04105	0.37564	0.5279
Indra Nagar	8.11021	13.15910	0.58696	0.9523
Korattur	11.35975	19.68740	1.16107	2.0122
Aminnijikar	14.57729	40.07690	1.58759	4.3647
Bharathipur	13.87511	69.49549	2.17627	10.900
Chromepet	21.31143	69.50830	3.25486	10.615
Ennur	36.08998	191.53600	7.36880	39.107
GreamsRoa	29.09787	175.08000	7.92690	47.695
JawaharNag	30.28928	236.88300	8.60282	67.279
Puttur	44.44771	311.13400	15.0920	105.64
Saidhai	48.58091	178.64500	15.4417	56.783
villivakam	46.43982	295.68301	16.0006	101.87
R.K.V.Stree	55.57730	398.04300	18.7036	133.95
Mambalam	47.64907	327.05399	20.6804	141.94
Thirnagar	98.48268	245.06200	35.3441	87.949

As stated in chapter 2.1, there are 19 Areas in Chennai. We investigate crimes at Area level and calculate crime quantity in 100,000 persons in each county. The area of each areas varies greatly, so crime density (crime quantity in every square kilometer), as another important crime evaluation index in our study, is computed (See table 2). Six areas (Indra Nagar , Korattur, Aminnijikari, Bharathipuram, Chromepet, Ennur) suffered a high crime rate per 100,000 people, which experienced 40 to 100 violent crimes and 180 to 320 property crimes. According to the crime density, it is also found that the six areas still rank the top six. So it is advisable that the police need to pay more attention to these areas while making tactics to struggle against crime. All the six districts are located within the Inner Ring and crime aggregates in these areas, which is the most developed business area of Chennai.

C. Micro-level investigation

From chapter 4.1 and 4.2 we find Chennai crime is spatially clustered in the city center. To study the spatial pattern of the city at a smaller level, both violent and burglary crime happened in each block is calculated and displayed according to crime density in each block (See Figure 5). The observation reveals their overall similarities with each other: the city center area suffered relatively high crime than other places. The geographical distribution of areas with higher estimated incidence densities appeared to be almost identical. A closer examination, however, reveals that some differences do exist between the two maps:(1) downtown suffered more property crime than violent crime; (2) the number of property crime was higher than violent crime in total blocks, and some blocks far away from the city center of Chennai had relatively high property crime.

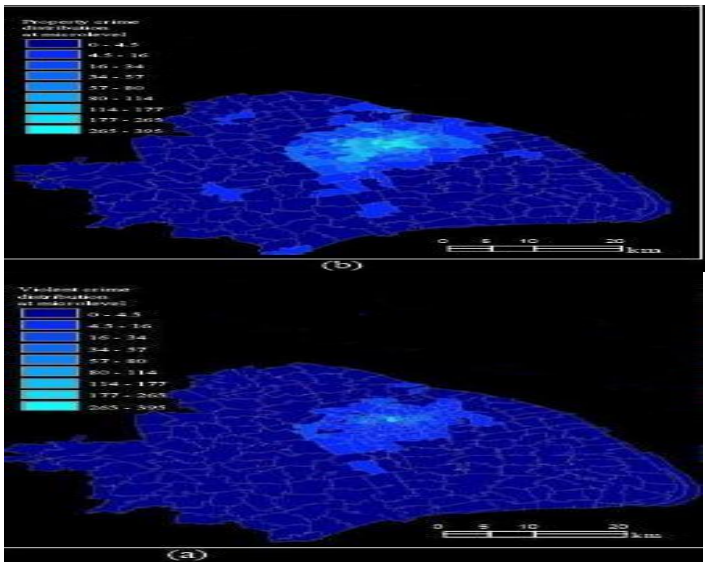

Figure5. Micro level distribution of Chennai crime.(a) Violent crime (b) Property crime.

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Figure 5 (a) and (b), we can find six towns (Indra Nagar, Korattur, Aminnijikari, Bharathipuram, Chrome pet and Ennur) underwent the top highest density of property crime. More than three-fourths of these blocks which suffered relatively high crime incidence are located in center of the city.

D. Spatial-temporal analysis of crime in Chennai

As depicted in chapter 4.1, the study obviously demonstrates the clustering characteristic of crime in city center. Spatial-temporal distribution of crime in downtown of Chennai is listed in Table 3. It is clear that the vast majority (85.2%) of crime happened in the city center (within the outer ring area). Furthermore, 44.5% of the crime in Chennai occurred between the outer ring and the middle ring, while there was relatively less crime incident in the city core (within the inner ring). More precise problem identification and exploration is clearly the first step in finding out the spatial-temporal pattern of Chennai crime in a smaller scope. This section specifically studies crime incidents happening in 4 seasons in the downtown of Chennai, using kernel density estimation method. We roughly draw an envelope of Chennai Outer Ring, and limit our study area to this region. Here the search radius is still set to 2000 meter and output raster size set to 200*200m, and the result is shown in Figure 5.

Table 3. Chennai crime distribution in downtown of South Chennai

	Crime Number in total	Within Inner Ring	Between Middle Ring and Inner Ring	Between Outer Ring and Middle Ring	Outside Outer Ring
January	7106	2008	3160	5932	1065
February	5977	1313	2662	2575	631
March	5833	1335	3564	3038	931
April	4661	1043	3628	3199	811
May	6428	1333	2188	2908	910
June	5548	1081	7798	2404	874
July	6256	1233	2152	2765	938
August	6643	3403	2105	3908	1009
September	5842	1252	2017	2597	937
October	6121	1225	2107	2791	946
November	5941	1206	2025	2602	937
December	4537	955	1538	2044	926
Percentage of total crime		21.3%	14.2%	44.5%	14.8%

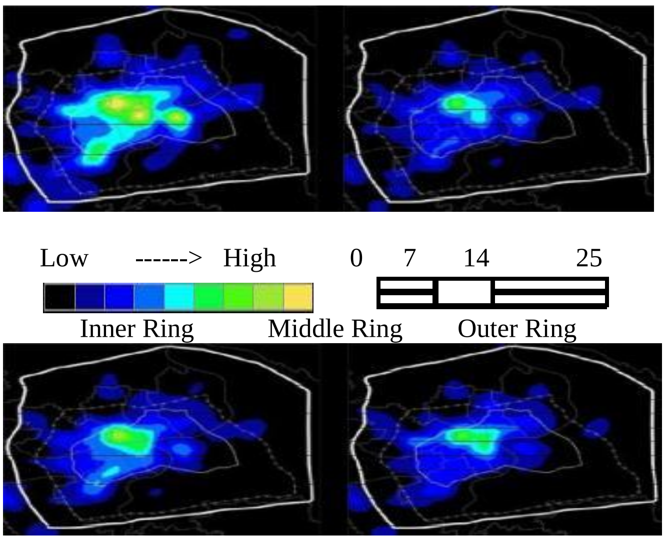

Figure6. Spatial-temporal distribution of Chennai crime in downtown.

From Figure 6 we can find that the overall similarity of Chennai crime in each month of 2008. The general geographical distribution of city center area was identical (crimes concentrated in public traffic areas such as Chennai Railway Station and South Railway Station, and commercial area such as the Anna Nagar Financial Area. See Fig 1), however aggregation of the crime in 12 month differed from one another in terms of higher estimated incidence densities.

It can be easily seen that in spring, there were three evident crime "hot spots" within the Inner Ring area, also crimes in this season were the most of the whole year. The cluster of crimes in the city was the most obvious in geographical distribution, while there was only one distinct hot spot in other three seasons.

V. CRIME PATTERN AND RELATED FACTORS

A. Relationship between Chennai crime and its types

From the viewpoint of environmental criminologists, crime is closely related to the society, economy, population, and so on [20]. The land use type, which is the best illustration of social-economic activity, is employed to identify where violent or property crime risk is the greatest. To cope with this problem, a 4-class classification system is used here, taking the Crime distributions properties of the city into consideration. They are industrial warehouse land, traffic land, public building land, residential land, land use for greening, land for municipal utilizes, agricultural land, water area and unutilized land. Land use datasets of 2008 is derived and classified by manual visual interpreting from aerial photographs (1m horizontal resolution). Figure 6 shows the distribution of Chennai crime in different kinds of land use.

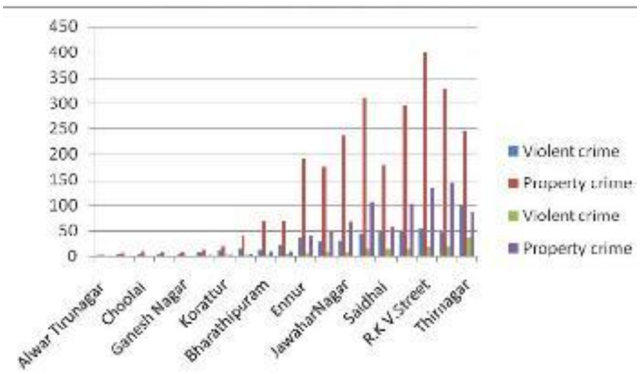

Figure7. Crime distributions in different areas

The result reveals that 92.8% of violent crime and 95.3% of property crime occurred in industrial warehouse land, traffic land, public land for construction and residential areas. Both types of crimes were more likely to take place in public traffic areas, especially the property crime. Security environment of residential area is the most important to our daily life, however, the number of either violent or property crimes in the residential area ranks the second highest among the nine land use types. Examination of the crime dataset shows the distribution of Chennai crime in residential areas by house type (see Table 4)

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Table 4. Occurrence of crime in residential area

Residential area type	Old houses	New houses	Apartments	Natural villages
Violent crime	319	1342	17	266
Burglary crime	666	6315	36	388
% of violent crime total	11.9%	72.8%	0.9%	14.4%
% of burglary crime total	9.0%	85.1%	0.8%	5.2%

Firstly, the majority of both recorded violent and property crime (72.1% of violent crime and 85.6% of property crime) took place in new houses, and the minority of both crimes occurred in Apartments. Secondly, violent crime was more likely to happen in natural villages than old houses, while the situation of property crime was just the opposite. If one focuses on the density of crime (crime number/sq km) in different residential area, both property and violent crimes happened frequently in old or new houses (see Table 5), and the former occurred more in new houses.

Table 5. Density of crime in different residential area

Residential area type	Old houses	New houses	Apartments	Natural villages
Violent crime density (crime number/sq km)	6.535	4.806	0.455	1.051
Property crime density (crime number/sq km)	19.875	22.615	1.531	1.533

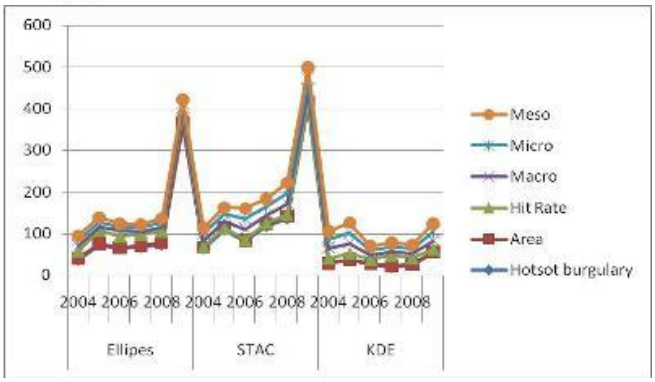

Figure 8: Simulation results comparison from Various Mapping Techniques

B. Suggestions for allocating resource

Nearly all the policing strategies require identifying and understanding the spatial patterns of crime, and the results of this study have guiding opinions to both Chennai police practice and related crime prevention policies. Policing strategies can be strengthened based on investigation on crime pattern in macro-Simulation, and overall security assessment of each Area in Chennai can be achieved using the result of me so-Simulation crime pattern study. In addition, crime prevention strategies can become more effective by providing the police with better information on locations where more police efforts are needed in the perspective of crime pattern at block scale. Additionally, based on the characteristics of the spatial-temporal pattern of Chennai crime, police force can be effectively allocated.

VI. CONCLUSIONS

Crime is an increasingly serious problem in cities all over the world, especially in developing countries or counties in transition. However, the study of crime is still inadequate. The use of GIS in crime research has established its advantage for a long time, and city officials and policy makers have also recognized the importance of a better understanding of the spatial pattern of crime. However, the lack of spatial awareness and thinking (especially in management) result in an un-urgent sense of developing GIS analysis in police practice.

In this research, crime of Chennai is investigated with the help of ArcGIS, employing both qualitative and quantitative techniques. This approach would undoubtedly change our thinking mode from technological and methodological to spatial awareness and thinking, and utilizing GIS for improving analysis and decision making. Findings of the investigation include: (1)the People's Square is found to the "crime hot spot" of Chennai, and crime density decrease gradually with distance away from the city center increase; (2) six Areas: Indra Nagar , Korattur, Aminnijikari, Bharathipuram, Chromepet, Ennur suffer serious crime; (3) New houses are more likely to lie under more property crime than that of old houses, Apartments and natural villages; and (5) there is a close relationship between permanent or transient population, land use type and Chennai crime. In spite of limited knowledge and capabilities of the police, they can only fight or take precautions against the symptoms of crime actively. Our findings imply that crime treatment and prevention strategies should be re-examined carefully in "hotspots" areas. Moreover, the result can be used as a useful reference for policy makers and police departments for crime prevention. At last we have to emphasize that the long-term solution to the crime problem rely on the reduction of poverty.

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