The Haryana Police Journal
Vol.2 | 2019

AN EVALUATION OF VARIOUS TECHNIQUES OF MEASUREMENT OFHOT SPOTS OF CRIME

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Abstract

That crime is non randomly distributed has long been known. However, the measurement of crime hotspots and its application to crime control strategies is fairly new. Especially, the sue of GIS and other software for mapping and plotting of hotspots has given a new dimension to crime prevention. This paper reviews the various issues in defining hotspots with a view to make preventive strategies for handling of crime events. We also look at the methods used at presentfor measurement of hotspots of crime. It is highlighted that the hotness of the crime spots can be measured in multiple ways and each of them results in a specific recommendation to formulate an effective response to crime events.

Key Words: hotspots, crime prevention, crime control, cluster analysis

Introduction

Police officers have long recognized the importance of place in crime problems (Braga, A. A., Weisburg, D. L., & Waring, E. J., 1999). However, until recently, crime prevention strategists have not systematically analyzed crime hot spots. Similarly, they have not addressed the underlying conditions that give rise to high activity crime places. However, a Police Foundation report found that 7 in 10 police departments in the United States used crime mapping to identify crime hot spots (Weisberg et al., 2001). Recent research suggests that focused police interventions such as directed patrols and proactive arrests can produce significant gains in crime prevention at high crime spots (Eck, 1997, 2002; Braga, 2002; Weisburd and Eck, 2004).

Criminology has traditionally focused on two main units of analysis: individuals and communities. They often speculate as to why certain individuals or communities are prone to commit more crime. However, some criminologists have focused their attention to the context of crime and the opportunities presented to the potential offender. For example, Ronald Clarke has used situational crime prevention to analyze crime in public transport. (Smith Martha J, Clarke Ronald V, & Michael T., 2000). The implication of this perspective is that high crime areas are an important focus of inquiry.

This change has come about in part due to the rise in empirical work on how and why crimes happen. Ronald Clarke's (1983) work on situational crime prevention showed how small changes in situational opportunities could affect crime. For example, a law that requires riders to

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wear helmets compulsorily could reduce motorcycle theft. The potential thieves would find carrying helmets difficult. Cohen and Felson (1979) suggested a theoretical approach to situational and spatial aspectsof crime in their work on routine activity theory. They suggested a crime triangle with one side representing the target, the second offender and the third place. All three must come together for a crime to happen. Guardianship protects targets from offenders. Later, Felson (1986) spoke about handlers, who when present will prevent offenders from deviating. Finally, Eck (1994) suggested a third class of crime controllers. These people manage places – store clerks, lifeguards and the like. They control crime by regulating the behaviour of place users.

This approach requires victims, offenders and guardians to converge in space and time for a crime to happen. A change in any one side of the triangle causes a change in the risk of a crime occurrence. Thus, a criminally inclined individual alone is not enough to cause crime.

A number of research studies reinforced this view of crime in the late 1980s and early 1990s. These studies indicated that crime clusters in very small places or hot spots generate a disproportionate number of criminal events (Pierce et al., 1988; Sherman, Gartin, and Buerger, 1989; Weisburd et al., 1992). In Minneapolis, for instance, only 3 percent of the city's addresses accounted for 50 percent of calls for service to the police (Sherman, Gartin, and Buerger, 1989). Similarly, in Jersey City only 4% of streets generated nearly half the city's narcotic arrests (Weisburd and Green Mazerolle, 2000). Many police departments use crime hot spots analysis as a common crime prevention strategy.

WHAT ARE HOT SPOTS

Hot spots are geographical areas of higher than average crime or disorder, relative to the distribution of crime and disorder across the whole region of interest. However, there is no unanimous definition of hot spots. One definition is that hot spots are small places in which the occurrence of crime is so frequent that it is highly predictable, at least over a one-year period (Sherman, 1989). Weisburd has defined hot spots operationally as small clusters of addresses with frequent 'hard' crime call activity, which also has substantial 'soft' crime calls for service. Eck et al. (2005) describe hot spots as areas of concentrated crime. These areas may be addresses, blocks, clusters of blocks, neighbourhoods or larger areas such as cities.

Eck et al., (2005) have expanded the place definition into five categories. These categories are defined by crime concentrated at places or specific addresses, among victims, streets or in an area. Each category has a specific geometric dimension such as a point, line or area. Different theories explain crime causation for each category and different crime control strategies are required for each kind. However, defining a hot spot is not easy.

There are three difficulties in terming an area as a hot spot. One is the nature of human techniques and practices that assign activities to addresses in official records. For example, the data entry operator enters the callers' location and not the location of the crime. Many callers belong to the low-income neighbourhoods and do not have personal phones. They frequently rely on public phones to call the police. Many times, these phones are located up to six blocks away from the scene of crime. The patrol cars also reach this location in order to contact the caller. The researcher frequently records this address, incorrectly, as the crime location. This has the effect of concentrating crime spread over a geographic region to a single point. However, this can issue be addressed once the patterns are identified.

Second is the question of crimes that take place in the public space, which does not have a specific address. Crimes occurring on streets and alleys have to be attributed a particular address. Such an instance of crime has harmful effects in a wider area, and this calls for an inclusive definition of hotspots. If crime occurs in a private enclosed space, one only needs to include the actual address. It is also debatable whether police can prevent indoor crimes.

The third is the issue of boundaries between two areas which seems clearly demarcated on the map, but is not so in the real world. The area of a hot spot can be imagined as the area, which a patrol officer can observe while on a hot spot patrol. However, the deterrent effect of police presence depends more on visibility of the officer by the residents rather than on what the officer can observe. Over time, this specific deterrence aggregates into a general deterrence due to continual police presence. Experiments in hot spot policing support this inference (Sherman and Weisberg, 1995).

Brantingham (1976) has talked about spatial analysis of crime using crime maps. He uses a "cone of resolution," which moves downward from national to city-block level analysis. The appearance of hot spots at national levels is different from the one at state level and so on down to block level. This suggests that hot spots will be a relative term to scale of analysis.

MEASUREMENT OF HOT SPOTS

A number of techniques help in crime mapping and analysis. Areas of crime were highlighted using coloured pins by police agencies. As technology advanced, computer- based techniques for representation and explaining crime have evolved. One of the powerful tools for spatial exploration of crime has been Geographic Information Systems (GIS). The ability to combine spatial and other data makes GIS a powerful tool. The information available to crime analysts is so huge that it becomes necessary to use an intelligent computational system, which is able to integrate a wide variety of data, and can help identify patterns.

The Crime Mapping Research Centre at the National Institute of Justice, United States, has categorized hot spot detection and analysis techniques. They are visual interpretation, chloropleth mapping, grid cell analysis, and spatial autocorrelation and cluster analysis. Twelve different variations on these five classes have been documented and evaluated. The study suggests that though there are a variety of methods used to detect hot spots, no single approach is superior.

Visual Interpretation

Hot spots are mapped many times using visual interpretation. Sherman and Weisberg describe the process of creating a hot spot thus:

We defined hot spots operationally as small clusters of addresses with frequent 'hard' crime call activity, which also had substantial 'soft' crime calls for service... We then limited the boundaries of each spot conceptually as being easily visible from an epicentre.

… A computer-mapping program, MAPINFO was then employed to locate most of the addresses, so that visual inspection of the computer printouts for each map grid could identify what appeared to be visually connected clusters of these addresses…

These addresses were generated from an archive database of Minneapolis 911 calls maintained by the crime control Institute. A criterion for hot spot identification was the categorization of crimes as hard or soft as proposed by Reiss (1985).

Spatial Autocorrelation

A study by CMRC (1998) suggests that a good approach for detecting hot spots is tests of spatial autocorrelation. Software packages such as CrimeStat 1.1, SpaceStat or SPlus Spatial Statistics conduct these tests at the local or global level. The Getis-Org statistic (Gi statistic) in SpaceStat provided a very good measure of crime hot spots for Baltimore County in study by Szakas (1998). The work of Craglia et al. (2000) has further supported the utility of spatial correlation and the Gi statistic.

Cluster Analysis

Gordon (1999) suggests that cluster analysis is one of the most useful methods for exploratory data analysis. However, cluster analysis, which is a well-established statistical test, is generally viewed to be less useful as compared to the Gi statistic for spatial autocorrelation (Chainey and Cameron, 2000). Software packages such as SAS, SPSS and SPlus can implement statistical approaches for cluster analysis. However, the cluster analysis algorithms, particularly non-hierarchical versions commonly used in crime analysis such as k-means are not clear nor do they give direction for useful application (Murray and Estivill-Castro, 1998). Perhaps the fault lies in the way these software packages analyze hot spots. Hot spots are spatial phenomena. Therefore, in order to identify high concentrations of crime, tools that treat space appropriately are critical. The existing approaches for cluster analysis are not necessarily ideal when applied to spatially referenced data.

Cluster analysis is a method of classification that places objects in groups based on the characteristics they possess. Clustering algorithms break observations into groups, linking the most similar observations into clusters. This allows analysts to examine the concentration of crime events in small geographical areas as also the links between crime cluster hierarchies. Hierarchical clustering procedures frequently generate local rather than global optima. Levine (1999) suggests that crime distributions with many incidents, such as burglary, have lower threshold distances than distributions with fewer incidents, such as murders. This means different crimes would have different criteria for clustering. Another grey area is the decision on how many points would constitute a meaningful cluster. The definition of cluster varies between individual analysts thus introducing subjectivity.

The analyst can specify the number of clusters for a given set of crime events. This is an important shortcoming of non-hierarchical techniques for hot spot detection. User defined parameters such as k groups build significant subjectivity into analysis. There are many methods for determining the number of clusters. One effective method is the cubic clustering criterion (CCC). CCC is the test statistic obtained by the SAS software package. Another approach used by Milligan and cooper (1985) was the Calinski and Harabasz (1974) index. The Calinski and Harabasz (1974) index performs better than CCC for varying cluster group simulation. Milligan and Cooper (1985) assessed the ability of thirty different stopping rules to predict the correct number of clusters in randomly generated data sets. Some rules performed poorly, others performed quite well. Thus, one may conclude that there are no established methods for determining the optimal number of clusters (Levine, 1999).

Cluster analysis thus presents many problematic aspects for crime hot spot detection. More research is required to adapt the existing statistical and other techniques to crime analysis.

Chloropleth Maps

When hot spots cover wider areas such as neighbourhoods, they can be shown using ellipses and chloropleth maps. In case of gangs, one could create a map of the gang areas and shade the areas according to the robbery frequency within each (Eck, 2005). However, there are limitations of such hot spot maps. If the risk of victimization is geographical, even in a small part, then maps are useful. Some analytic technique other than maps may be more useful, if the population of victims is not concentrated along streets or neighbourhoods and is spread out throughout the area. In case of taxicab robberies, which are spread out thinly across the city, police would find bar charts showing characteristics of victims and non-victims more useful than maps (Eck, 2005).

Spatial ellipses

Spatial and temporal Analysis of Crime (STAC) is a spatial tool to find and examine hot spots. It fits a "standard deviational ellipse" to each dense concentration of crime. The size and alignment of the ellipse indicate the underlying crime clusters. Martin et al. (1998) have used STAC in their study of how to reduce incidents in Detroit's infamous "Devil's Night" period and several other studies.

One of the advantages of STAC is that it does not rely on defined boundaries such as Census boundaries or police administrative divisions., requires few parameters and is compatible with most GIS applications (Martin et al., 1998). One of the problems is that the availability of choice in choosing parameter values leads to ambiguity and variability in results (Eck et al., 2005). Another is that crime hot spots do not naturally form into ellipses, thus STAC ellipses do not represent the actual spatial distribution of crime. The last difficulty associated with STAC is that visualization of ellipses negates any comparison with events that do not fall into the spatial ellipses (Eck et al., 2005)

Thematic mapping of geographic boundary areas

Police beats, census blocks or wards are arbitrarily defined for administrative use in case of thematic mapping of geographic boundary areas. Such maps are also called chloropleth maps. The geographic areas are shaded in accordance with the number of crimes that fall within them. A handy feature is that such maps allow the user to zoom in a particular area of interest. They can also be linked with other data sources such as population – increasing their versatility for analysis. However, this method is not without its disadvantages. The varying size and shapes of areas can beguile the analyst in identifying the highest concentrations of crime (Eck et al., 2005). The Modifiable Areal Unit problem (MAUP; Openshaw, 1984) produces further complications. A change in the boundaries of areas directly affects the patterns on the map in this case.

Grid Thematic mapping

The use of uniform grids in a GIS as a layer over the study area can overcome the problems associated with unequal sizes and shapes. All areas used for thematic shading are of consistent dimensions and allow quick identification of hot spots. LeBeau has used this technique to map the volume of emergency calls and violent offenses per square mile in North Carolina. One problem associated with this approach is that it restricts how the hot spots are displayed. Spatial detail within each quadrant is lost. Its blocky appearance has also been seen as a problem (Home Office, 2001; Chainey and Ratcliffe, 2005; Eck et al., 2005), which is affected by the grid cell size. Reducing the grid size can destroy the resolution of the thematic map by making it look "speckly". Grid thematic mapping also suffers from the same MAUP problems as mentioned above (Bailey and Gatrell, 1995).

Kernel density estimation (KDE)

This is an increasingly popular method and is widely regarded as the most suitable spatial analysis technique for visualizing crime data (McGuire and Williamson, 1999; Williamson et al., 1999, 2001; Chaineyet al., 2002; Chainey and Ratcliffe, 2005; Eck et al., 2005). It is accurate and its maps have a better aesthetic look. Crime is represented by means of a continuous surface that represents the density or volume of crime events across the desired area. A smooth surface map is produced with no need to conform to any fixed geometric shape such as an ellipse. One problem is the choice of thematic range to use. Police agencies are caught in the lure of the visual image and do not question the validity or statistical robustness of the map (Eck et al., 2005). There is no universal doctrine to use in setting parameters such as grid cell size and bandwidth (search radius). This gives rise to variability in maps produced from the same statistical data. However, the KDE technique is in widespread use because of its visual impact as well as its capability to analyze hot spots through a statistically robust methodology (Williamson et al., 1999; Chaineyet al., 2002; Chainey and Ratcliffe, 2005; Eck et al., 2005).

APPLICATIONS OF HOTSPOTS ANALYSIS USING VARIOUS TECHNIQUES

Several authors have used he above mentioned methods for hotspots analysis. These are presented in the form of a table as below.

S No.	Author	Data to analyze	Method Used	Assessment
1	Braga, Anthony A and Brenda J. Bond (2008)	a. Citizen's call for service b. Observed Disorder c. Displacement/ Diffusion Effects	SARA (Scanning, Analysis, Response and Assessment) Geospatial analysis	Consistent results were obtained
2.	Martin et al. (1998)	Instances of crime	STAC (Spatial and temporary Analysis of Crime)	No need of reliance on defined boundaries such as census units or police unit boundaries. However, user needs to be well versed in software. Also, hotspots do not naturally fall into ellipses
3.	Hirschfield (1999)	in a study of links between crime and disadvantage in NW England	-do-	-do-
4.	Ratcliffe and Mc Cullagh (2001)	Vehicle Theft	Thematic Mapping	Requires little expertise, enables quick determination of high crime areas. User can zoom in desired areas. However, due to varying shapes of boundaries, identifying areas of high crime concentration can be misleading. Thus, patterns within boundaries are not revealed.
5.	Harries (1999)	Repeat burglaries across	-do-	-do-
6.	Le Beau (2001)	a. Volume of emergency calls b. Violent offenses per square mile	Grid thematic mapping	All areas are of consistent dimensions and comparable, so easy identification of hot spots. However, no detail within grids is available and it has a 'blocky' appearance.
7.	Bowers et al.,(2001)	Vulnerable residences where target hardening was later implemented	-do-	-do-
8.	Chainey, Tompson, Uhlig (2008)	A comparative analysis of various techniques such as point mapping, thematic mapping of geographic areas (e.g. Census areas), spatial ellipses, grid thematic mapping and **kernel density estimation** (KDE)	Kernel density estimation	Accuracy of identification and aesthetic look of map. It produces a smooth surface map, with no restriction on shapes such as ellipses. Its flexibility is a problem as there is no universal doctrine on how to set parameters for grid size etc.
9.	Lavery, Schuck (2009)	Analysis of violent crime locations of Chicago	-do-	-do-

HOTSPOTS CRIME ANALYSIS IN INDIA

Many police agencies are trying to develop a hotspots analysis strategy in India. Cluster analysis has bene used to identify hotspots and safe zones of crime in Uttar Pradesh using a geo spatial approach by Kumar et al. (2012). Delhi Police has obtained a software called CMAPS (Crime Mapping Analytics and Predictive System). It uses the Delhi Police's Dial 100 call data and ISRO's satellite imagery. The system attempts to locate the telephone calls which are received on Number 100 and visualizes them as clusters to identify hotspots.

Jharkhand police has partnered with Open Group on E governance (OGE). This group is attempting to develop capabilities in hotspots and predictive policing. Maharashtra plans to have a Computer Emergency Response Team (CERT), which will work on social media and crime hotspots. The National Crime Records Bureau (NCRB) has partnered with Advanced Data Research Institute (ADRIN) at Hyderabad to develop a software to utilize crime data for analytics including hotspots analysis. Maddlipatla, Qureshi and Verma (2018) have used official crime data of Faridabad district in Haryana to generate maps of crime hotspots of vehicle theft, Excise Act and fatal accidents using Q-GIS (9an open source software). However, the application of any form of hotspots analysis has so far not been implemented at the district level in the country so far. Other hotspots to reduce crime-future directions.

A longitudinal relationship between adolescent day time sleepiness and criminal offending in adult life has been established (Raine & Venables, 2017). It is reported that sleepy adolescents are more likely to be antisocial during adulthood and are 4.5 times more likely to commit crime by the age of 29. It has been demonstrated that association of social adversity with adult crime is partly explained by sleepiness. Low self-control mediates the relationship between sleep deprivation and delinquency (Meldrum, Barnes, & Hay, 2015). Disturbed sleep has been reported as an associated factor of aggressive behavior in 19 male prisoners in the Netherlands (Meijers, Harte, & Scherder, 2015). Sleep deprivation has also been suggested as a causal factor for domestic violence (Hoshino et al., 2009). Potential mechanisms mediating the relationship between sleep deprivation and aggressive behavior are reduced prefrontal cortex functioning, increased emotional instability and altered serotonin levels (Kamphuis, Meerlo, Koolhaas, & Lancel, 2012).

A geographic hotspot map of insufficient sleep has been generated (Grandner et al., 2015). They used data from 424,989 respondents of 2009 Behavioural Risk Factor Surveillance System by the Centres of Disease Control and Prevention. This contained information from 2231 counties in the US. Spatial concentrations of insufficient sleep were generated using Getic-Ord G* statistics of local spatial concentration. They found 84 hotspots and 45 coldspots of insufficient sleep in the US.

Treatment of sleep disorders has been proposed as aggression reducing and crime preventing treatment program (Kamphuis et al., 2012). The comparison of sleep hotspots to crime hotspots would be a pertinent research focus. If found overlapping, an experimental interventional strategy to reduce crime by reducing sleep deprivation and treating sleep disorders may be of use in crime prevention strategy.

CONCLUSIONS

Hot spot analysis is a powerful tool to isolate areas of high crime incidence. There is a variety of methods available to be used. The rapid advancement in computer technology, particularly GIS, has made the mere representation of crime hot spots on maps earlier to much more intuitive and analytical representations today. However, different kinds of hot spots require different kinds of tools to detect and represent them. Cluster analysis and Kernel Density Estimation have emerged as powerful tools for measurement of hot spots, but there are other techniques available too. It is important to understand the limitations and assumptions of each method before thinking of using them to implement crime prevention strategies.

The reasons for the occurrence of crime have to be determined and appropriate action taken, after identification of crime hot spots. One can look at hot spots as the starting point in the overall crime control strategy. Stopping analysis at the stage of discovery of hot spots would lead to implementation of ineffective responses. Moreover, hot spot mapping has little utility if there is no geographical component to the problem. Such cases require the use of other analytical approaches.

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