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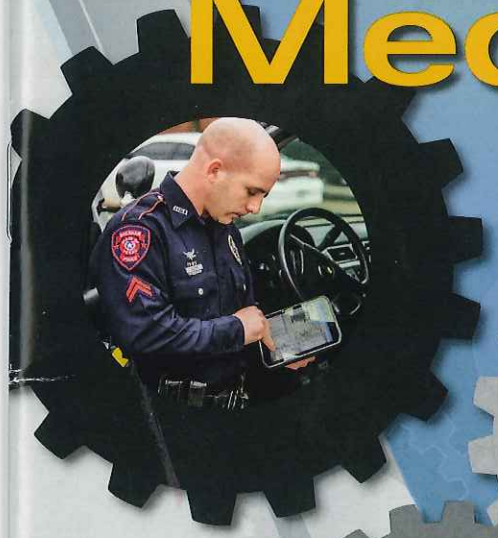
Technology and Social Media



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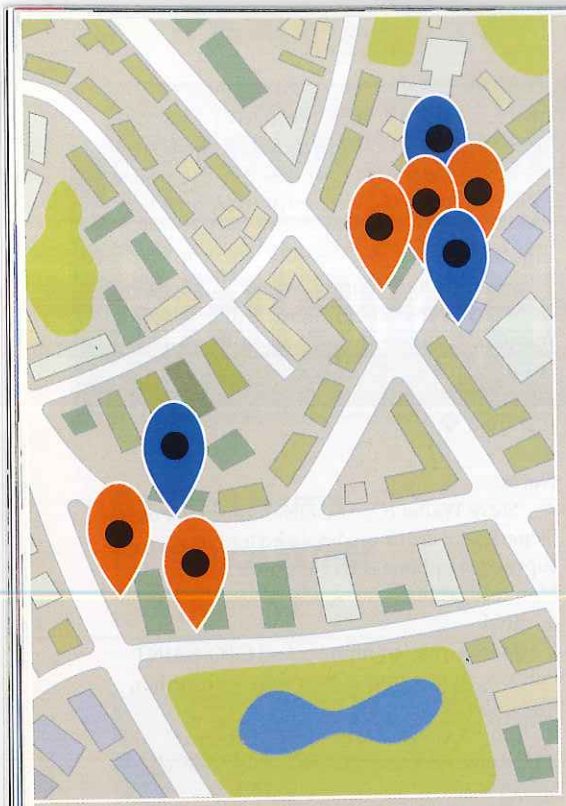

Police Implications Associated with Identifying Micro-Hotspots

By Thomas Chengchun Gao; Sungho Ken Park; Jeremy Yablon; and Mark Iris, PhD, Northwestern University, Evanston, Illinois; and Timothy N. Oettmeier, PhD, Executive Assistant Chief, Houston, Texas, Police Department

Policing hotspots has long been considered a valuable tactic to help management direct scarce police resources. The effective implementation of responses to "hotspots" requires police department personnel to analyze mountains of data they routinely gather; however, there is a key obstacle: police departments typically do not have enough skilled personnel or sufficient resources to perform advanced statistical analysis of the gathered data.

The Houston, Texas, Police Department (HPD) has found a creative solution by partnering with Northwestern University (NU). That institution has a highly competitive undergraduate program, Mathematical Methods in the Social Sciences (MMSS), consisting of students possessing strong statistical and analytical skills. An NU faculty member, Dr. Mark Iris, who has a background in policing (retired civilian Executive Director of the Chicago, Illinois, Police Board), realized the potential to solve the issue of insufficient resources—match police agencies with high volumes of data in need of analysis with students having strong quantitative analytical skills who are in need of data for their senior year theses.

Dr. Iris began to serve as a matchmaker in 1997, linking interested students with police agencies. Since then, students have completed more than 30 projects, initially in Chicago, Illinois, and more recently in Los Angeles and Long Beach, California; Philadelphia, Pennsylvania; and Houston, Texas.

Establishing the Protocol

The typical protocol begins with a police department identifying research questions in need of answers that can be developed from data the agency has or can readily generate. Interested MMSS students, in the spring of their junior year, commit to a full academic year–long project, typically working as a team of three students per project, with Dr. Iris as their academic advisor. Each team begins intensive reading on pertinent aspects of policing to become familiar with issues they will need to address.

The entire team flies to the host city and meets with key police managers, technology staff, and crime analysts to begin the process of securing the necessary data from the police agency.[1] The winter is devoted to intensive data analysis, followed by drafting the actual report. In the spring, the team returns to the host agency to present its report to the command staff.[2]

For the 2011–2012 project, the HPD opted to build upon research done by students in the previous academic year. For the 2010–2011 year, the students had been asked to determine the overlap between on-duty officer time and crime activity. The team examined crimes, calls for service, and officers' self-initiated activity, which were aggregated by police patrol division. "Heat maps" were created to demonstrate if officers were focusing their self-initiated discretionary efforts (when not responding to calls) in those areas where concentrations of crimes and calls for service were greatest.[3] In short, were the cops on the dots? The answer was in general, yes. That analysis was valuable to HPD management, confirming that for most patrol units, crime and discretionary activity were generally well aligned, while highlighting those in need of change.

The Utility of a Micro-Hotspot Grid

The 2011–2012 project, conducted by MMSS students Thomas Chengchun Gao, Sungho Ken Park, and Jeremy Yablon, extended that analysis.[4] Building on the established concept of hotspots, defined as specific locations for disproportionately large numbers of crimes, Police Chief Charles A. McClelland Jr. tasked the students with examining these trends, not by patrol division, but by identifying definitive micro-hotspots.[5] The team was also asked to profile these hotspots using a categorization system and, finally, to analyze whether officers' self-initiated activities aligned with the locations and profiles of the micro-hotspots.

The team divided the city of Houston into a grid of small cells, each measuring 700 feet by 700 feet, roughly equivalent to an area of two city blocks by two city blocks. Given Houston's large area (well over 600 square miles), this resulted in a grid of approximately 40,000 cells. The grid was created using a beta version of the Geospatial Modeling Environment developed by Spatial Ecology LLC.

The software package combines components from R, ArcGIS, and Python, and allows sophisticated geospatial analyses to be conducted in an automated fashion and superimposes the geographical distribution of activities (crimes) onto the grid. Thus, the number of activities per cell could be easily counted, rather than relying on a visual measurement and estimate. This analysis also included different charts describing the numbers and types of crimes in each cell and maps showing the geospatial distribution of crimes per cell. Using these

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The next step was to superimpose this grid on the citywide distribution of crimes and officers' self-initiated (SI) activities. The project started with approximately 3 million crime and 2.3 million SI activity records in Houston spanning seven years, from 2004 to 2011. Data files were cleaned by removing unreasonable records (such as non-existing addresses) and crime types (such as those with too few records for meaningful results). Also eliminated were artificial hotspots, created, for example, when numerous police crime reports were taken at a police station or hospital emergency room, and the address of the police station or hospital was listed as the crimes' location.

The research team calculated the numbers of crimes per cell for 2011, the most recent year for which full-year data was available. Over 19,000 cells—47.7 percent of the total—had zero reported crimes that year.[6] At the other extreme, one cell had 671 reported crimes. The arbitrary decision to focus on the top 100 cells meant the threshold for inclusion in that list was 114 or more reported crimes occurring in 2011. The hotspot concept was again validated: The top 100 cells—one fourth of one percent of the total cells in Houston—accounted for 10 percent of the total reported crimes.

While this analysis focused on overall crime, the same methodology could be used to identify crime-specific hotspots. For example, the first and third hotspots were shopping malls, and their very high total crime counts overwhelmingly comprised various types of theft offenses. If an agency wanted to do so, it could filter the data to identify the top hotspots for violent crimes (murders, assaults, robberies, and rapes). The analysis of crimes by type and by time of day for individual areas provided significant insight on crime trends, both for the city in general and each particular zone. In terms of the overall city, the analysis confirmed the hotspot concept: crimes are distributed disproportionately both geographically and temporally.[7]

Significantly, this disproportionality has increased from 2004 to 2011. In other words, in Houston, the hotspots are getting hotter! This underscores the increasing importance of pinning down hotspots so more effective anti-crime tactics can be implemented.

In addition, the analysis showed that different crime types have different disproportionality characteristics. For example, theft activities related to motor vehicles are most concentrated in the afternoon, whereas robbery is reported most commonly during evening and night. Another noteworthy observation was that hotspots do not

exist in a clustered fashion; they are distant from each other. In fact, it is frequently observed that a block has an excessive number of crime records, whereas the surrounding blocks have almost zero crime; this observation emphasizes that identifying micro-hotspots for which the size is block-scale (rather than neighborhood-scale) is crucial in ensuring the effectiveness of implementing policing tactics.

Next, the team examined officers' SI activity to evaluate how well SI activities align with hotspot locations. Thus, maps in this analysis documented not just micro-hotspots, but the distribution of SI activities per cell, as well as the correlation between crime activity count and SI count within a cell. Sorting the records into these cells, the authors noted the type of crime or officer activity, as well as time of day, so they could compare them within each of the 40,000 individual areas.

In addition to analyzing the SI distribution, the team assessed how well SI activities matched with crime levels by calculating correlations of the two across the grid of cells. The correlations are calculated within a range from -1 to 1, where 1 represents the strongest correlation.

Of course, the effectiveness of officers' SI activities is not solely defined by a simple count of SI activity and crime in a cell. Nonetheless, these calculations, based on a large data set, suggest how relatively well officers are locating themselves on the dots across years, times of day, and crime types. For instance, the highest correlations occurred during 2008 and 2009, implying that the SI activities were the most in alignment with crime events during those years. The analysis also provided an additional observation on how many SI activities occur in zero-crime areas. About half the city's cells have no crime, and SI activities were minimal in those areas.

Moreover, the analysis showed that some crime types are better covered by SI activities than others. Drug crimes and simple and aggravated assaults tend to have high correlations with SI activity counts, whereas theft from motor vehicles showed lower correlations. Furthermore, the SI activities seemed to align with crime events better during night and evening than during morning, as evidenced by decreased correlations across almost all types of crimes during that time of day.

The nature of crimes and reporting should be taken into account in interpreting tendencies. For example, the high correlation between SI and drug crimes arises from officers' direct actions, not by crime victims' reports to the police.

Overall, from HPD's management perspective, the correlations were reassuring. Officers, on their own initiative, were clearly investing their discretionary time in fairly close synchronization with levels of reported crimes in individual cells. Intuitively, officers sensed where crime problems were and acted accordingly. This speaks well of the "street smarts" of front-line patrol officers.

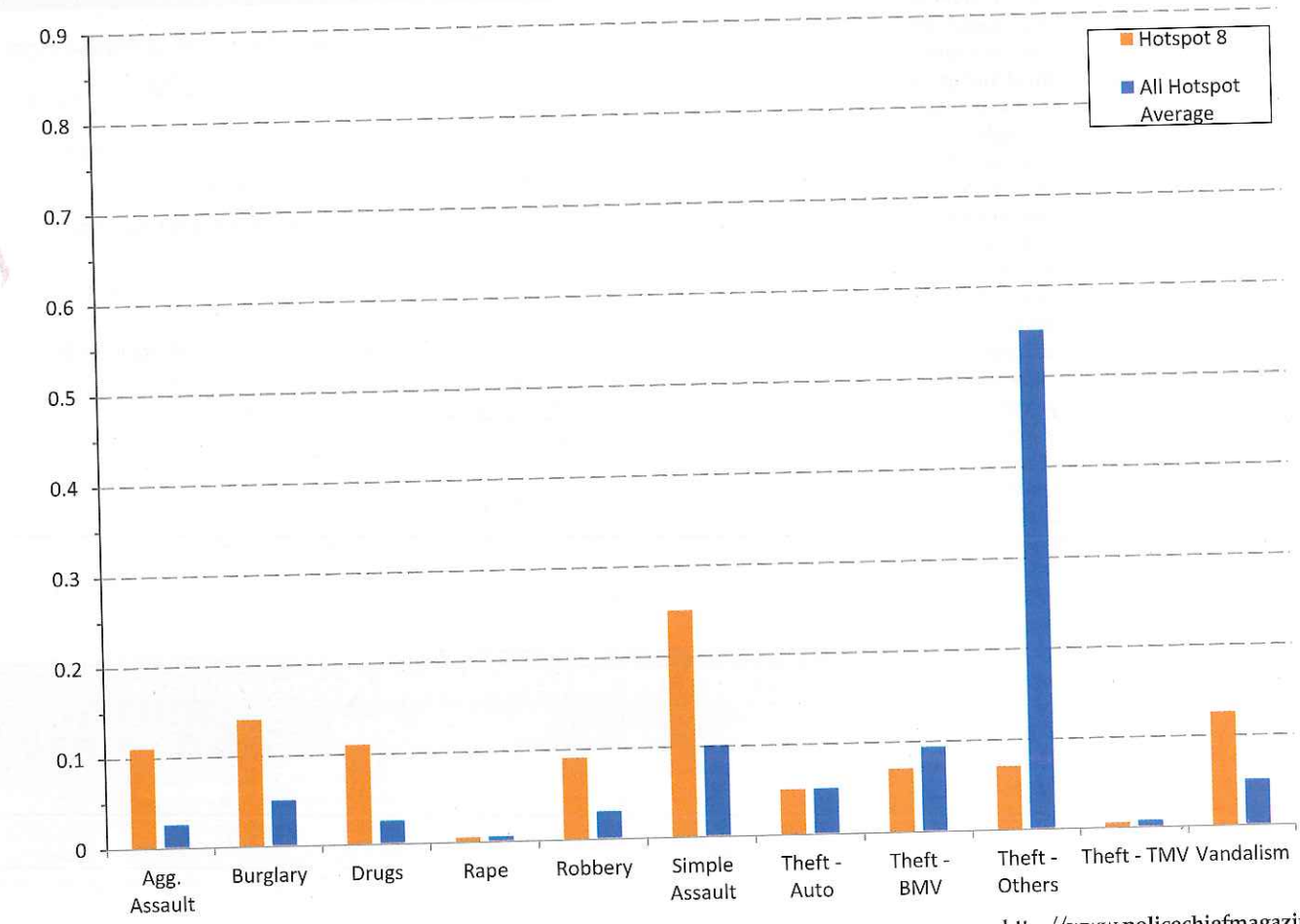
Example: Micro-Hotspot 8

This example focuses on the Number 8 micro-hotspot in Houston for 2011, defined as the intersection of Sugar Branch Drive and Forum Park Drive. Satellite photos reveal it is a residential area and shadows suggest the presence of high-rise apartment buildings.[8]

Two key graphs profile this cell. Figure 1 shows 2011 crimes by type of crime; Figure 2 shows crime distribution by time of day. Within each graph, the orange bars show the number for that specific cell; the bars in blue show the averages for the top 100 micro-hotspots.

In Figure 1, by comparing the number of crimes to that of the average for the top 100 micro-hotspots, one observes that assault,

Figure 1: Relative Histogram of 2011 Crime Counts by Type: Sugar Branch Drive and Forum Park Drive



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In Figure 1, by comparing the number of crimes to that of the average for the top 100 micro-hotspots, one observes that assault, burglary, and drug crimes happen relatively more in this area. In fact, assaults are two to three times more prevalent here than the average for the top 100 micro-hotspots in Houston (and vastly higher than the average for all cells). This cell, while eighth overall in the micro-hotspot rankings, was the number one micro-hotspot in Houston for violent crimes, with 39 aggravated assaults and homicides, 1 rape, and 32 robberies in 2011 in the 700 feet by 700 feet area.

Overall, this one cell had 350 reported crimes in 2011. The average for the top 100 cells was 184.86. The city-wide average was 4.56 reported crimes per cell; the number of crimes in this one cell was 77 times that.

In contrast to the large number of violent crimes in this cell, a similar plot of the Number 1 micro-hotspot, by a shopping mall, showed very high disproportionate spikes in the theft categories, but very low counts for all other categories.

In Figure 2, crimes are plotted by time of occurrence. In the Number 8 cell, crimes are disproportionately high during the night hours of 7:00 p.m. to 2:00 a.m. Conversely, the Number 1 micro-hotspot (not shown) has a distinctly different pattern, with reported crimes disproportionately occurring from 1:00 p.m. to 7:00 p.m.

Finally, Figure 3 shows types of officer SI activities in this particular area, with each type of activity as a proportion of all officer SI activities in that cell. SI patrol investigation is by far the most common type of activity, accounting for half of all SI activities in that cell for that year. Officers were very active in this cell; the actual number of SI events covered in Figure 3 was 217. By contrast, the average for the top 100 cells was 146.26 citywide; the average per cell was only 4.43 activities.

Implications of the Project

The project's methodology and results are pertinent to police personnel in multiple ways, including the following:

1. Many police agencies use crime density mapping to identify hotspots. Typically, this effort provides information on the location of hotspots, the crime types associated with each hotspot, and the time in which the crime incidents are occurring. The difficulty with this approach is the use of algorithms used to create the density map. One cannot always tell where in a particular hotspot a crime(s) is occurring. The "grid system" allows one to pinpoint crime within the actual hotspot cluster (referred to as a micro-hotspot).
2. The grid system can be used to guide and direct the allocation of officers to address call response management. It is not uncommon for officers to observe, over a period of time, the volume and types of calls that emanate from neighborhoods within a community. To the extent that calls and crime are occurring in certain grids, deployment of officers should be able to prevent some of that activity from occurring.
3. This project delineated ways to create quantitative metrics in measuring macro-level trends of crimes disproportionality across locations and the correlation of officers' activities with crime events. These metrics, which can also be measured by time of day, type of crime, and SI activity, can provide insight on how crime patterns are changing and suggest ways to monitor police resources. The project's methodology allows an agency to see how disproportionality is changing over the years, across crime types, and by time of day.
4. The project demonstrates a way to identify micro-hotspots that are only a

Figure 1: Relative Histogram of 2011 Crime Counts by Type: Sugar Branch Drive and Forum Park Drive

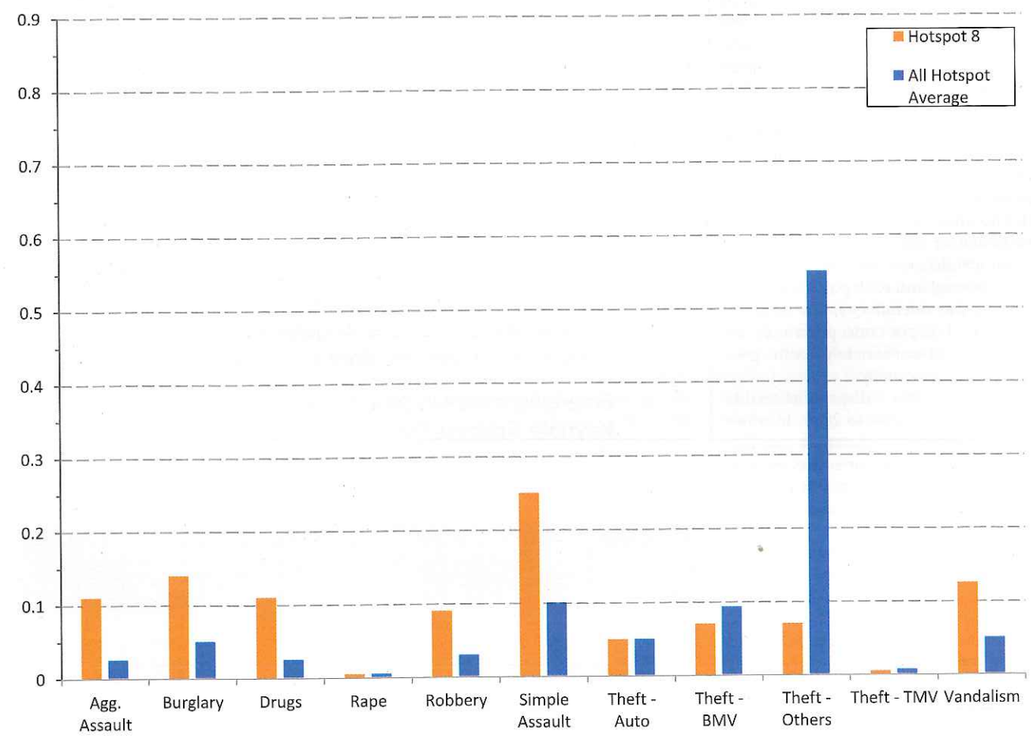


Figure 2: Relative Histogram of 2011 Crime Counts by Hour: Sugar Branch Drive and Forum Park Drive

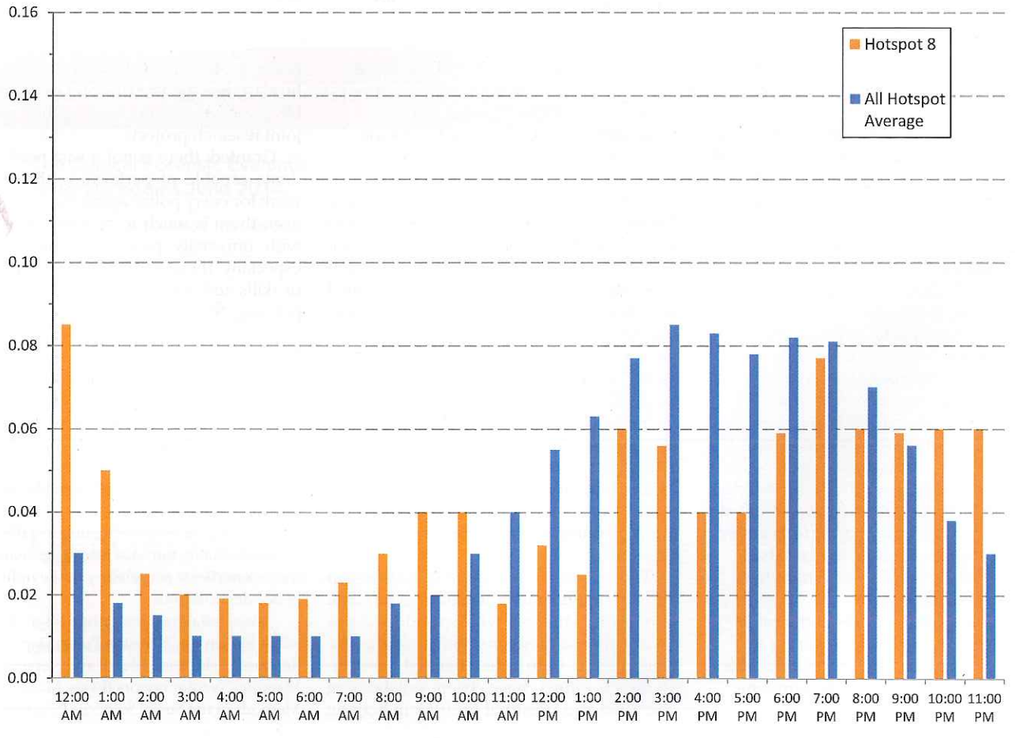
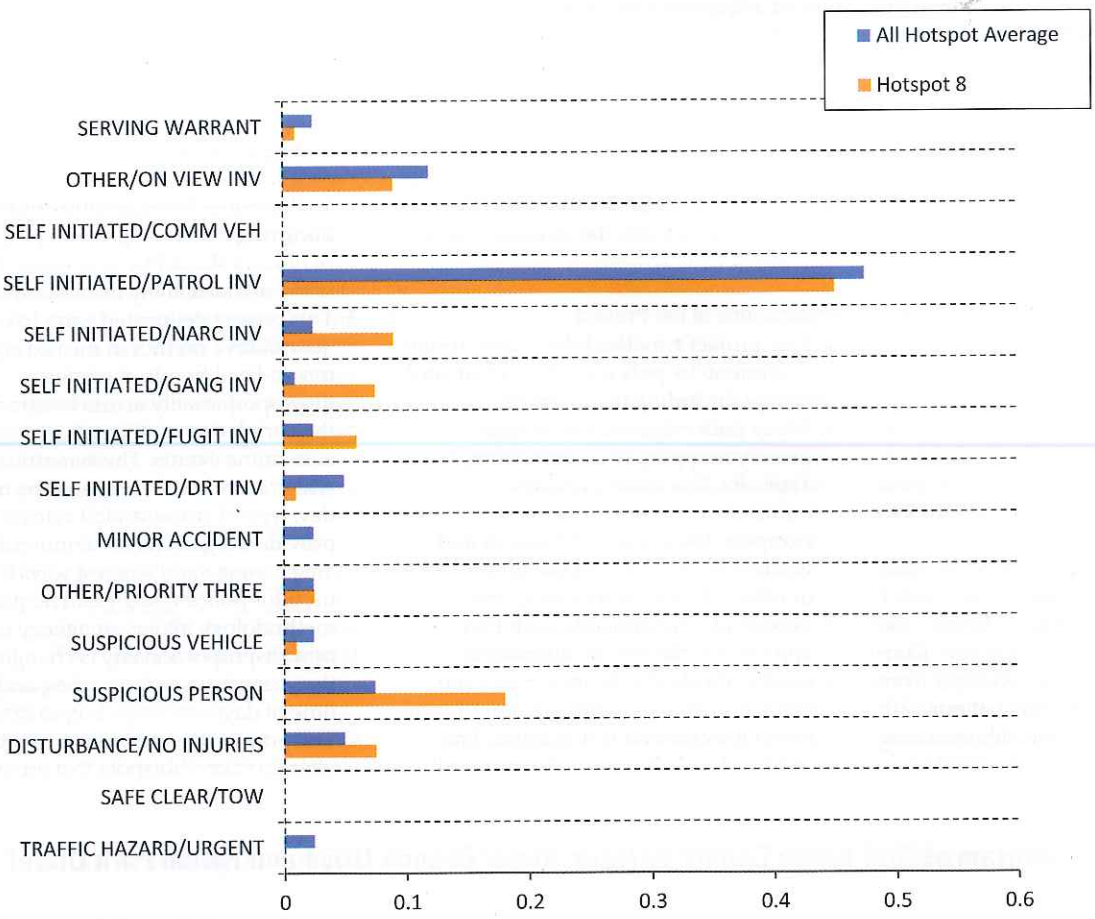


Figure 3: Relative Histogram of 2011 Self-Initiated Activities: Sugar Branch Drive and Forum Park Drive



few square blocks in size. This unit of measurement allows police leaders to utilize their policing resources more effectively by placing officers precisely on the most problematic areas. In short, a police agency can not only identify hotspots in its jurisdiction at a micro-level, but can get a nuanced profile of each hotspot to determine what types of crime are most prevalent in the hotspot and when these crimes are occurring.

5. Given the extraordinary difficulty of hiring personnel to "expand" one's operation, one of the few viable alternative options is to recoup and redistribute "uncommitted time."[9] Once time is acquired, it becomes the purview of patrol lieutenants and sergeants to manage how officers use that time. Whether officers are directed via their supervisors or they self-initiate, it is far easier to measure effects within a micro-hotspot using the grid than using amorphous density maps that lack specificity.
6. Much has been said about the value of predicting activities requiring a police response. The grid system adds a degree of precision in determining if crime is moving and in what geographical direction and the degree of intensity occurring within any given cell (how much and what type of crime), both of which might provide insight as to why such activity is occurring.

Currently, the HPD is working on Phase Three of this research initiative. A third wave of students has been tasked with the challenge of creating an instrument to facilitate the "predictive mapping" of criminal activity using the grid system as the tracking device. This research can be extended further, possibly even creating a predictive model of future crime amount and composition. For instance, it was noted that a presence of vandalism signifies imminent coming of other crimes such as burglary. There are mathematical models for predicting burglary counts, on the assumption that a burglary in a neighborhood increases the probability of subsequent burglaries in close proximity.

This has been a wonderful partnership for both organizations, illustrating the value of allowing students with specific skills to assist police as they constantly strive to provide citizens with much-needed services. Students' efforts have been outstanding and serve as a breath of fresh air in helping police professionals think differently about how to manage their resources. Currently, HPD and MMSS are planning their seventh joint research project.

Granted, there is not a vast pool of students capable of performing this type of work for every police agency in need. However, there is much to be said for working with university professors and students, especially those who bring a unique set of skills and determination to the world of policing. ❖

Notes:

[1]Travel costs for these trips have been generously supported by the Weinberg College of Arts and Sciences at Northwestern University, and (for Los Angeles projects) grants from the Los Angeles Police Foundation. No police or other public funds are used in these projects.

[2]Students and their advisor normally sign a confidentiality non-disclosure agreement; these reports are proprietary to the individual police departments.

[3]Wajeeh Bakhsh, Johnathan Hsial, and Miles McGinley, "Houston Police Department: Resource Allocation Model and Hotspot Mapping" (senior honors thesis, Mathematical Methods in the Social Sciences Program,

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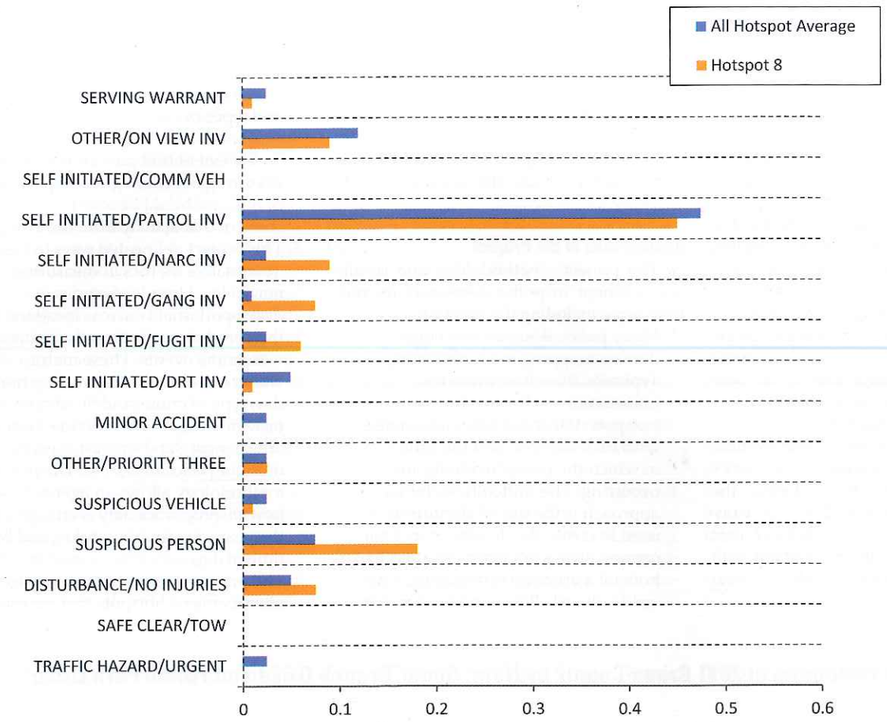

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[4]Thomas Chengchun Gao, Sungho Ken Park, and Jeremy Yablon, "Houston Police Department: A Study in Hot Spot Identification and Profiling" (senior honors thesis, Mathematical Methods in the Social Sciences Program, Northwestern University, 2012).

[5]For a general overview of the concept of hotspots in policing, see Lawrence Sherman, "Hot Spots of Crime and Criminal Careers of Places," in *Crime and Place*, Crime Prevention Studies (4th edition), eds. John Eck and David Weisburd (New York, NY: Willow Tree Press, 1995), http://www.popcenter.org/library/crimeprevention/volume_04/02-Sherman.pdf (accessed May 7, 2014); and Lawrence Sherman and David Weisburd, "General Deterrent Effects of Police Patrol in Crime Hot Spots: A Randomized Controlled Trial," *Justice Quarterly* 12, no. 4 (1995): 625–648.

[6]The large number of zero crime cells is partially explained by the fact that Houston's many waterways account for many cells—not many assaults or auto thefts occur in the middle of a lake or bayou.

[7]M.B. Short et al., "A Statistical Model of Criminal Behavior," *Mathematical Models and Methods in Applied Sciences* 18 Suppl. (2008): 1249–1267, http://www.math.ucla.edu/~bertozzi/papers/M3AS-final.pdf (accessed May 7, 2014).

[8]This aerial photo–driven description of the area was subsequently confirmed through direct observation by HPD personnel.

[9]Houston uses multiple approaches to "free up time" for patrol officers. Three tactics are used within the Emergency Communications Division (Dispatch): Teleserve, Webcop (computer reporting for citizens), and the Patrol Desk (calls are handled over the phone by police officers). Personnel working in the Investigative First Responder Division handle violent crime incidents. Members of the Mental Health Unit handle a significant number of complex crisis intervention calls for service.