

Exploratory Spatial Analysis of Type I Crimes in Puerto Rico

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Abstract — *Criminal activity has a spatial and a temporal component. Police investigations have long relied on maps for a better understanding of criminal activity patterns. Monitoring crime statistics by entering paper forms into a computer database or sticking pins on a paper map is a static process of historical data collection, where the results might not be available for months after a criminal incident. Combining the use of different readily available technologies like GIS, GPS and Relational Databases, among others can provide police departments with near real-time tools to better document and reference crime incidents in their jurisdiction. The visual aspect of GIS can sometimes reveal patterns and relationships that could be buried deep inside the data. This article explores the potential tools that a well-organized police department could use for fighting crime. Using GIS spatiotemporal analysis along with other technologies we are able to better understand the behavioral patterns of crime.*

Key Terms — *Crime Mapping, Criminal Statistics, Law Enforcement GIS, Spatiotemporal Analysis*

INTRODUCTION

“If you know your enemies and know yourself, you need not fear the result of a hundred battles; if you know yourself but not the enemies, for every victory gained you will also suffer a defeat; if you know neither the enemies nor yourself, you will succumb in every battle” [1] said Sun Tzu in his treatise *The Art of War*. Information is power. The more we know about our enemy, in this case crime, the better decisions can be made toward our safety and wellbeing.

In a simplistic point of view, in order for a crime to happen, three components are necessary: a likely offender, a suitable target and the absence of

a capable guardian. All of these components must meet in time and space in order to create the proper environment for crime. Many countries and communities around the world are exploiting the gamut of Geographic Information System (GIS) tools that are available to them in order avoid the meeting of these components.

In Puerto Rico there are 3 levels of police jurisdiction, federal, state and municipality. This study will focus on the state level, analyzing their use of information towards the fight against crime. In 1929 the International Association of Chiefs of Police created the Uniform Crime Reporting Program, it divides offences into two groups Type I and Type II. Type I offences include Murder, Rape, Assault, Robbery, Breaking & Entering, Grand Theft Auto and Illegal Appropriation. This study will analyze the occurrence of Type I offences in Puerto Rico.

Objectives

Using the data available to for Type I Crimes in Puerto Rico, maps and analysis tools will be generated to help evaluate the behavioral patterns of crime. Spatial analysis will be used to determine if crime occurs in geographical patterns, in order to better understand the behavior of criminal activity. These analysis will include animations, hot spot analysis and heat maps.

EXISTING MAPPING TECHNOLOGIES

Now more than ever, there are many technologies that would be of great use in the fight against crime. GIS, Global Positioning System (GPS) and Relational Databases on their own, have proved to be insufficient for effective crime mapping, however implementing them as part of a system could build a series of very powerful tools for law enforcement.

GIS

GIS is a system that combines geographical features like points, line and polygons to tabular data, in order to be able to analyze these spatially. Pioneered mostly for military, planning and engineering applications, the use of GIS in law enforcement is relatively new. GIS can integrate massive amounts of location-based information to generate maps and spatial analysis data for many application including law enforcement. According to the International Association of Crime Analysts, its member are mapping crime and related statistics in law enforcement departments all throughout North America.

GPS

GPS is a series of satellites that emit a signal of its position along with a very accurate time stamp. A GPS Receiver is capable of receiving this information from multiple satellites at the same time, and with it, it can calculate a position (Latitude, Longitude and Elevation) at any location on Earth.

On the earlier days of GPS a receiver was quite inaccessible, they were expensive and large; nowadays they are as common as a mobile phone. Most if not all modern smartphones have a GPS receiver inside of them, along with modern data capacities and internet access; this makes them a very accessible potential tool for use in crime mapping.

Relational Databases

Relational Databases are extensively used in GIS and many other applications. They are defined by a series of tabular data sets that share a primary key between them. This primary key can be used to relate the contents of one table to another. They are capable of managing huge amounts of information, which becomes useful in law enforcement for large areas or when we want to analyze other aspects of crime like:

- The relationship between the offender and the victim.
- Costs of crime and law enforcement.

- Tracking arrested offenders
- Use of weapons

LAW ENFORCEMENT APPLICATION

Merging these technologies, can give way to an infinite number of analysis tools that could provide a better understanding of how crime develops in communities. Here are some of the most common applications.

Response Time and Opportunity Reduction

When GIS, GPS and an emergency response system are linked, there is a reduction on dispatch time and error which could lead to shorter response times and a reduced criminal opportunity window. Systems such as Automatic Vehicle Location (AVL) along with a GIS Network Analysis can not only compute the shortest route between a patrol car and a crime location, it can calculate the fastest route, by considering traffic speeds and road conditions; this would offer the dispatcher the capability of sending the patrol that can be there faster, instead of the one closer to the scene.

Suspect and Asset Tracking

During police investigations, the need to track a vehicle suspected of wrong doing, might arise. These technologies could provide the ability to track suspicious vehicles. A discreet GPS receiver with a transmitter could easily be mounted on a suspect's vehicle, offering law enforcement the ability to track his movements anytime. In the same way, a system could track the location of officers, vehicles and others assets; giving the dispatch system a better understanding of their available resources during an emergency.

Proactive Law Enforcement

Using the proper data and analysis, police departments could define the areas where crime incidents are more common (Hot Spots) and where they are less common (Cold Spots). This type of system could be easily automated with the appropriate tools. If police officers were able to create their reports electronically at the scene, using

GPS enabled computers, tablets or even smartphones; all of the required data could be sent through the internet to a centralized GIS system. Using this information officers could offer the hot spot areas more patrolling, therefore proactively reducing crime opportunity.

CRIME MAPPING IN PUERTO RICO

The Puerto Rico State Police Department (PRPD) is divided into 13 regions, these regions are themselves divided into precincts. With the exception of San Juan, all regions watch over multiple municipalities. See Figure 1 below.



Figure 1
PRPD Regional Map [2]

From what this investigation could acquire, the crime incident data handling in Puerto Rico's police department is a paper based manual process. A police report is handwritten by an officer in a notebook. He receives a unique police report number from a centralized call center. The precinct generates a weekly paper report which includes the type of crimes that were committed, the amount of each, and region where it happened. This report is sent to the region who compiles all the information into one single report, and this report is sent to Police Headquarters where it is entered into a data base to handle the statistics. These statistics are currently being used to evaluate human resources demand and to plan patrol routes.

After all of this process, the precinct is the smaller geospatial unit on which crimes are being recorded. Later reports compile the crimes separating them by municipality. After numerous attempts to receive more precise geospatial information on the criminal offences, the data we could acquire are monthly cumulative reports

stating the amount of incidences of each Type I crime per municipality from 2009 to 2013. These reports are in an Excel Spreadsheet format and were found in the Puerto Rico Statistics Institute website.

Even though the access to local data was limited, it was understood, that the PRPD is actively using GIS to some potential. There was mention of an apprehended serial rapist that was caught in Rio Piedras after the police entered the location and times of rape incidents with similar methodologies in the area close to The University of Puerto Rico campus. They were able to determine not only a spatial pattern but a temporal one as well. With this information they were able to forecast the dates and places of possible rape incidents, and decided to upgrade their patrol efforts, resulting in the perpetrator being arrested.

METHODOLOGY

Preparing the data

One of the data sets available through the Puerto Rico Statistics Institute Website were Excel spreadsheets posted monthly with an accumulative total of each Type I crime reported for each city. These were compiled yearly. Elaborate Excel formulas were created in order to separate the quantities per month per crime. The formulas subtracted the accumulated amounts with the accumulated amount for the previous month, giving us the amount for the current month. Enabling the organizing of the data using yearly files, which included monthly spreadsheets, in which the cities were displayed in rows and the crimes were displayed in columns. Due to the amount of data, a quality check system was created, by constantly verifying the data by adding the different series and checking the totals with the original sources. From these data sets animations will be created using thematic maps, displaying a comparison of the amount of Type I Crime incidents for the 60 months of data, in every municipality in Puerto Rico

Another available data set, came from Primera Hora, a local newspaper; that publishes on their

website a map for reported murders. This data contains coordinate data which is needed to generate Hot Spot and Heat maps. At first there were doubts in using this data, due to the fact that there was no reference information mentioned on the website. However the reports has the coordinates and an address, so the location was verified for accuracy; through a statistical sample of data. Since the focus of the study is the whole island and then the Metropolitan Area, locations established within 100m of their reported address would be considered correct. The sample size was calculated for a 95% confidence level and 10% margin of error. The sample showed that the data satisfied the established parameters.

Hot Spot and Heat Maps

There are various ways to create Hot Spot maps, the Optimized Hot Spot Analysis and the Hot Spot Analysis (Getis-Ord G_i^*) available on ArcMap. The Optimized Hot Spot Analysis is a user friendly version of the Getis-Ord G_i^* analysis, where most settings are calculated automatically, this tool will be used to analyze murder hot spots in the island. To go more into detail the Hot Spot Analysis (Getis-Ord G_i^*) will analyze the same data but focused on the Metropolitan Area of Puerto Rico.

A Heat map, where the hot spot values are interpolated in order to predict “hot areas”, will be generated using the Kernel Density tool. An analysis of whether police presence affects the occurrence of murder in these hot areas. PRPD’s Stations will be located with a buffer of 1 Km around them, overlaying these buffers over the Heat maps.

Data for Animation

Even though the data seemed to be in a reasonable format for statistical analysis, there had to be some reformatting, in order to enter it into our GIS software. ESRI ArcMap 10.1 was used to analyze the data. When using temporal data on ArcMap the date has to become a time stamp, therefore the format had to change, so that the cities

would have a crime incident amount and a time stamp tied to that amount. Once the time stamped tables were ready, a layer was loaded into ArcMap with the city boundaries and they were joined with the tables. The municipalities were colored according to the crime incident amounts, using the Symbology tab in ArcMap. Due to the large differences in incident amounts, the color ranges were classified using 5 classes of quantiles or quintiles.

Enabling time on each layer, activates the Time Slider tool, which allows a frame by frame view for each month of data. Time Slider also allows to export a computer animations of how the amount of criminal incidents changed in the 60 months of data.

Data Analysis

Playing the animations for each crime, shows how crime incidence changes for one city and on its bordering cities. In order to better compare the patterns graphs were created, using Excel, totaling the yearly amounts of each crime per city.

Hot Spot Analysis tools look at each feature considering the value of its neighboring features. A feature with a high value is important but may not be as significant, statistically, when determining a hot spot. Statistically significant hot spot has a high value and is surrounded by other features with high values. The distance between these high values also plays a critical role in this analysis, the closer the incidents are the more effect they will have on one another; as the distance increases their values will have less effect.

The Kernel Density tool creates a raster bell-shaped surface over every crime location. With the bell’s highest point directly over the incident location, other incidents that are close will contribute a considerable amount to the sum while more distant incidents will contribute much smaller amounts. The resulting surface changes smoothly over distance, showing higher points where crime clusters exist. An analysis of whether police presence affects the occurrence of murder in these hot areas will be made.

RESULTS

By examining the animations of the 7 Type I crimes, one is able to observe that not all of them behave in same manner. For this reason, our findings will be discussed one crime at a time. One of the most notable issues found affecting all crimes, is that for June 2011 none of the crime statistics had values, they were all 0. However on the next month values seemed to be approximately double of what the usual values are.

Rape Animation

Even though it was expected for larger cities like San Juan and Ponce to have a higher number of incidents, these two cities seem in the same range. Surprisingly, Ponce has a slight lead especially in the earlier months of study. Other large cities like Mayagüez and Arecibo show very little amount of incidents. It is also noticeable how some inland municipalities have a higher tendency towards this crime than others, for example Cidra and Cayey.

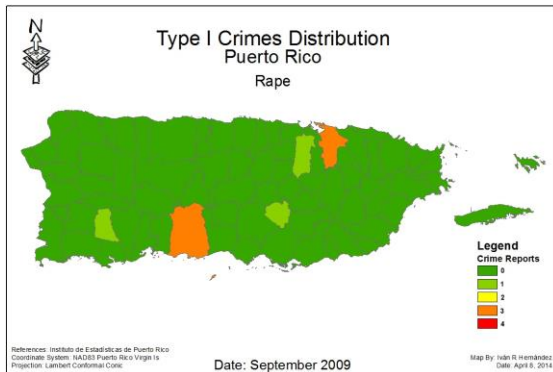


Figure 2
Rape Sample Map

Assault Animation

According to observations of the animation assault seems to have a tendency to be higher in the cities with higher population. San Juan, Ponce, Mayagüez, Carolina, Bayamón, Humacao and Arecibo are always in the higher ranges. Even though they were not without incidents the lower ranges went towards the smaller cities like Las Marias, Florida, Culebra, Quebradillas, and Rincón.

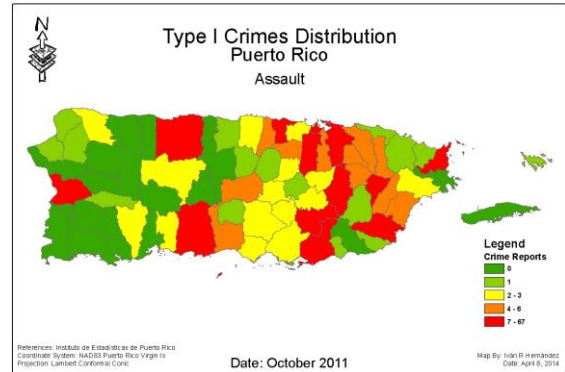


Figure 3
Assault Sample Map

Breaking and Entering Animation

As in most of these crimes San Juan claims the highest number of incidents throughout the time sample, with Bayamón at a not too far second place. The next level belongs to Caguas, Carolina, Humacao, Mayagüez and Ponce. The rest of the cities are pretty well spread out over the ranges, except for Culebra, Maricao and Maunabo that showed the lower levels of incidents.

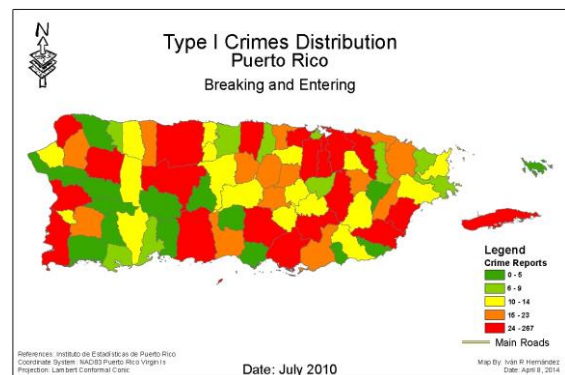


Figure 4
Breaking and Entering Sample Map

Grand Theft Auto Animation

Grand Theft Auto has higher levels of incident on the larger cities, like San Juan, Caguas, Ponce and Mayagüez. However, there is a very noticeable spatial pattern on the northern coast cities. Almost all cities from Barceloneta to Rio Grande show to be in the higher ranges of incidents.

On the contrary, a lower range spatial pattern can be found, towards the central and southern parts of the island.

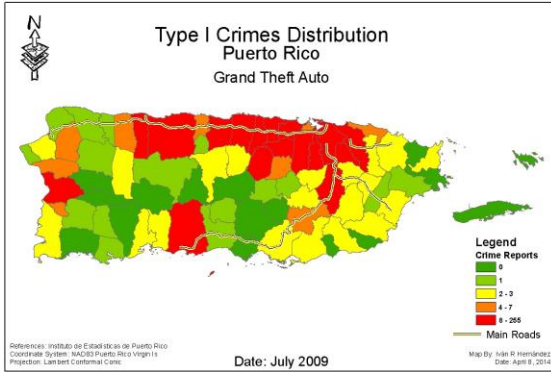


Figure 5
Grand Theft Auto Sample Map

Illegal Appropriation Animation

Larceny-theft as it is also called refers to taking, carrying or riding away of property from the possession of another. Perhaps this is why, there is a tendency to higher levels of incidents in cities with direct access to highways. This especially the case in cities crossed by Highway 52, like Caguas, Cayey and Salinas. The larger cities also showed a high number of incidents.

Only remote cities stayed towards the lower levels of the scale. Places like Maricao, Las Marias, Jayuya and Villalba were among those cities.

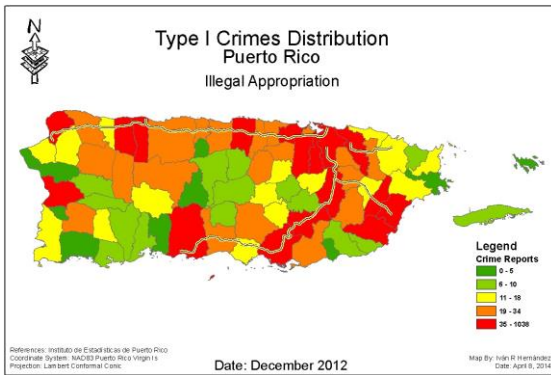


Figure 6
Illegal Appropriation Sample Map

Robbery Animation

Is defined as the taking of anything of value from a person, by the use of force or threat of force or violence and/or by putting the victim in fear. So even though the amount of incidents is approximately 1/4 of amount for Illegal Appropriation, the spatial patterns are very similar; remaining in the high ranges for cities with better

access to highways. However in the case of robbery, cities intersected by PR30, like Gurabo, San Lorenzo, Juncos and Las Piedras reach higher ranges than Illegal Appropriation.

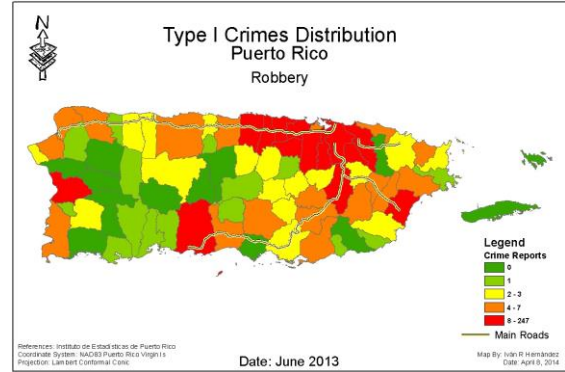


Figure 7
Robbery Sample Map

Murder Animation

Most notable during the murder animation is that out of the 60 months of study San Juan is in red 57 of them and that includes the month without data. Cities close by which compose the Metropolitan Area like Bayamón and Carolina have a tendency to high ranges but are seldom in red, however that cities like Guaynabo, Cataño, and Trujillo Alto manage to stay at lower ranges than its Metropolitan neighbors.

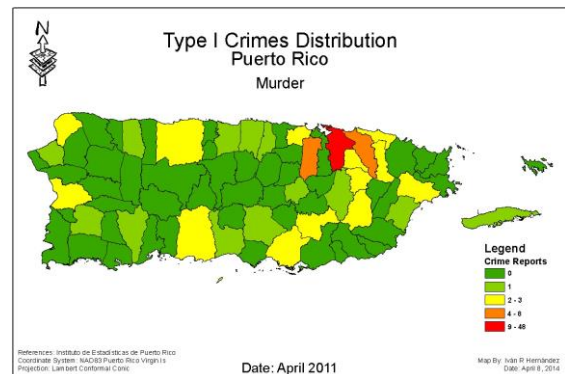


Figure 8
Murder Sample Map

Large cities outside the metro area, like Mayagüez, Arecibo and Humacao have a tendency towards the lower ranges. Ponce however, although it does not reach the San Juan levels, tends toward the higher end of the scale. The rest of the island cities remain mostly on the lower ranges, rarely

reaching the higher levels, they show no noticeable pattern.

Murder Hot Spot Analysis

Using georeferenced data a “pin map” for all murders reported in Puerto Rico from 2010 – 2013 (Figure 9) can be created. This map includes 3,122 georeferenced murder incidents. Areas with high concentration of incidents can be easily recognized.

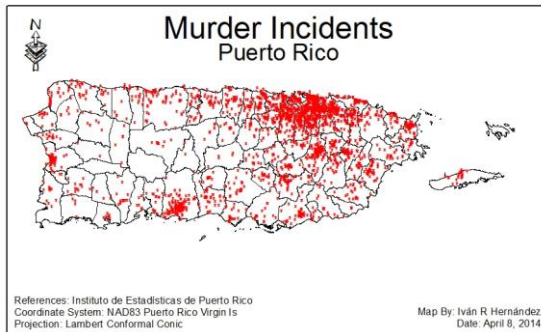


Figure 9
Puerto Rico Murder Pin Map

By looking at the Optimized Hot Spot Analysis map, shown in Figure 10, one can immediately notice that the Metropolitan Area is almost entirely colored red marking it as a statistical hot spot for murder. Some other smaller areas appear in the Caguas-Juncos area, Cayey, Dorado, Fajardo, Ponce and Mayagüez. Comparing it to the pin map shows that the areas with really high murder rates concur; but some areas that seemed dense on the pin map, do not appear to be statistically significant.

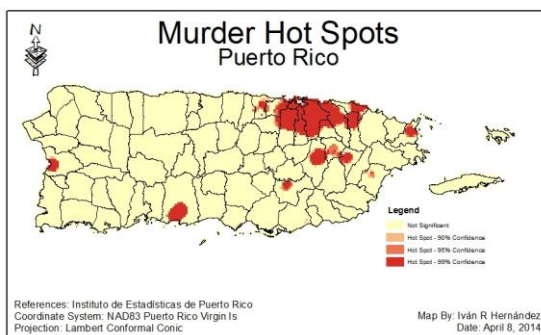


Figure 10
Puerto Rico Murder Hot Spots Map

Focusing on the Metro Area with a Getis-Ord Gi* Hot Spot Analysis map (Figure 11), which statistically analyses each incident location and

assigns it a “temperature level”; one can see higher level of detail with specific locations of previous incidents have occurred and that statistically show high levels of probability of re-incidence.

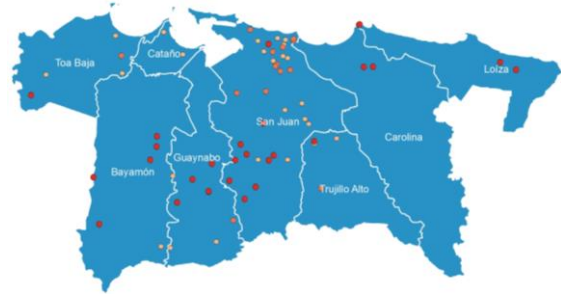


Figure 11
Metro Area Murder Hot Spot Map

However the most benefit a police department could get out of these analyses would be to determine areas where to upgrade patrolling efforts, this is where the heat maps are useful. As we can see in Figure 12, the areas of higher probability (hot) are colored in red, diffusing into yellow colors and then blue to depict the colder areas.

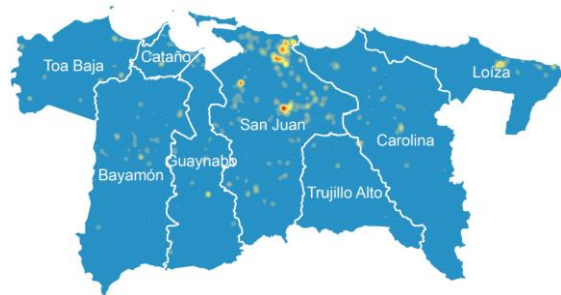


Figure 12
Metro Area Murder Heat Map

These red areas are near the urban areas of Rio Piedras, Puerto Nuevo and Barrio Obrero; also Public Housing Developments like Nemesio Canales and Luis Llorens Torres seem to have a strong influence in the high murder incidence.

If we compare the locations of the areas of higher murder probability (Figure 13), these show that they all have 1 or more police station less than 1 Km. away. As a matter of fact police presence seems to be higher at the hotter areas of the map.

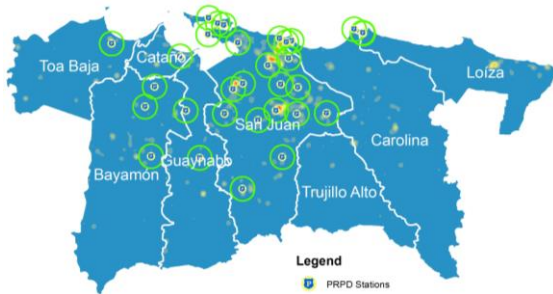


Figure 13
Metro Area Murder Heat Map and Police Stations

CONCLUSIONS

Definite spatial patterns were found in the behavior of some of the Type I crimes. These include:

- First the obvious, high crime rates on the larger cities, especially San Juan and Ponce.
- A great difference in amount of incidents for Grand Theft Auto between the north and south areas of the island.
- The tendency to stay close to the main highways for robbery and illegal appropriation.
- Hot Spot Maps proved to be an excellent tool to analyze crime incidence of an area.

Regarding how crime behaves in the Metropolitan Area one could conclude that the current hot areas that our study shows are similar to what common sense and a little bit of history could predict. However, there are very similar places to those found to be “hot” that showed much less murder incidence. If one combines this fact and the fact that the study clearly shows that police presence has very little effect in preventing murders from occurring in nearby areas; then an analysis of what is different about these areas compared to homogeneous ones that have lower crime rates, would be in order.

There is a lot of work to be done regarding Information Technology, including GIS. The need to create a database that includes historical information is imperative. It would constitute the base to study the reality of the environment with better tools, and to be able to better predict future phenomenon. Having full knowledge of current

situations and knowing the enemy, in this case crime, is equally important. The sooner Puerto Rico starts, the closer it is to being able to offer better solutions to its problems.

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