The influence social problems have with violent crime and its impact on society: An investigation on the five boroughs of New York

Sean McGrory
Umeå University, Department of Human Geography and Economic History.

Supervisor: Magnus Strömgren
# Table of Contents

- **Acknowledgments** ............................................................................................................. i
- **Abstract** ................................................................................................................................. ii
- **1. Introduction** .......................................................................................................................... 3 - 6
- **2. Aim & Research Questions** ............................................................................................... 6
- **3. Literature Review** ............................................................................................................... 7 & 8
- **4. Methodology** ..................................................................................................................... 9 - 15
  - **4.1 Preparation** .................................................................................................................... 9
  - **4.2 Emerging Hot Spot Analysis** ....................................................................................... 10 - 12
  - **4.3 “Traditional” Hot Spot Analysis** ................................................................................ 13
  - **4.4 Overlay Analysis** ......................................................................................................... 14
- **5. Ethical Consideration** ........................................................................................................ 16
- **6. Results** ............................................................................................................................... 17 – 28
  - **6.1 Study Area** ................................................................................................................ 17 & 18
6.2 Identifying Violent Crime ........................................................................................................19 – 21

6.3 Identifying Social Problems .................................................................................................. 22 -23

6.4 Spatial Coincidence ............................................................................................................. 24 – 28

7. Discussion ...............................................................................................................................29 - 32

8. Conclusion ............................................................................................................................. 33

9. Bibliography ......................................................................................................................... 34 - 38

10. Appendix ............................................................................................................................. 39 - 41
Acknowledgments

I would like to take the opportunity to thank Magnus Strömgren for the support and guidance he provided me throughout this thesis. I would also like to thank my teachers throughout the year who have been part of my development. Final thanks go out to my family and friends who supported me throughout my studies at Umeå University.

Thank you.
Abstract

The purpose of this study is to show how violent crime and social problems have an impact on society. This study particularly concentrates on the five boroughs of New York. The problems associated with the five boroughs of New York are violent crime and social problems. The violent crime for the study involves; felony assaults and robberies. Whereas, the social problems for the study involves; population below the poverty line and male population who are 18-24 years with less than high school graduation. These problems were expressed through the usage of ArcGIS Pro. Using ArcGIS Pro provided an efficient way that displays spatial data. The results from this study show that felony assaults and robberies occurred in the Bronx, Manhattan, Brooklyn and the Queens. Whereas, it was also discovered that the Bronx, Manhattan and Brooklyn experienced social problems related to poverty and education. The spatial coincidence between violent crime and social problems were expressed using overlay analysis. The findings show that the violent crimes and social problems spatially coincide within the Bronx, Manhattan and Brooklyn. This study provides a way in which society can be better managed in dealing with these problems.
1. **Introduction**

Development of human society has positive and negative aspect. On the positive side, there is growth, in terms of living, communication, inventions of technology etc. However, the negative sides involve diseases and crime (Popescu et al., 2018). Seeing that crime is the main concentration of this thesis, it is seen as a problem worldwide. However, crime is such a broad word to take into consideration when studying it. Crime is known as an action carried out by an individual who breaks the law. The term crime has various types of crime, but the four main common crimes are; violent crime, property crime, inchoate crime and statutory crime. However, this thesis has a narrow focus on violent crime. Violent crime involves homicide, rape, assault, etc.

In more recent years, on a global perspective, violent crime has been quite an issue and has become alarming (Fajnzylber et al., 2002). Each country within the world experiences violent crime but at different rates. In a recent report, the United Nations released violent crime statistics for each content in the global. A type of violent crime the report included was major assaults. The highest ranked continent with major assaults was Africa. Whereas, North America was ranked second and ranked relatively lower were Europe, Asia and South America (Heiskanen & Harrendorf, 2010). Within the same report, homicide rankings for the continent was stated. High rates of homicide were accounted within Africa, South America and the Caribbean. Whereas, homicide rates were relatively lower in North America, Asia and Europe. It’s important to note from this example that various rates of violent crimes can depend on a geographical location. Each of the geographical locations with various rates have different social and cultural perspectives that can influence rates of crime. Social factors within countries can have considerable links to the violent crime rates. However, it’s important to understand the difference between developing and developed countries when studying violent crime.

There is concerns that majority of serious crimes are within developing countries (Natarajan, 2016). The causes of these crimes within developing countries are partly due to inequality and a deprived national growth performance (Bourguignon, 2000). It is difficult for developing countries to deal with such crimes as majority of the crimes is related to poverty and comes with a social cost (Sociales, 2001). For instance, two countries that are ranked with these conditions are Brazil and India. In Brazil, the highest influences of violent crime were socioeconomic statues and social structures (Peres & Nivette, 2017). On the same perspective, socioeconomic was also a high influence on violent crime in India (Mayer, 2017). Seeing that both of these countries are developing, the social and economic impacts are at a national scale, that being, this promotes crime and provides a national problem.

On the other hand, within developed countries, crime rates have been reducing over the years (Natarajan, 2016). Within these developed countries, crime is better dealt with because there is a strong political authority and there is a structure that is able to manage the social arrangements (Schultze-Kraft, 2016). Reduced crime rates provide a positive impact economically because a country has the resources, goods and services to better manage society within the country. On a national scale, most of the developed countries don’t experience violent crime because social factors are better managed that results in a healthy
economy on a national scale. However, developed countries can experience violent crime at local levels within urban areas. Within an urban area, there are two kinds of neighbourhoods to take into consideration; developed neighbourhoods and developing neighbourhoods. A developed neighbourhood is a community that is socially developing. Whereas, the developing neighbourhood is a community that is socially declining. The developed neighbourhood has a positive balance between the environment, society and economics. This positive balance provides people with an investment and an opportunity to grow and reach high expectations. The neighbourhood receives quality education, healthcare, opportunity for business growth and an environment that promotes health. On the other hand, the developing neighbourhood is a dismantled version of the developed neighbourhood. It involves a negative balance between the environment, society and economics. The disadvantaged community has social processes that influence criminal behaviour (Vogal & Van Ham, 2017). The social process is a way in which an individual socially interacts within a community. Over time, social interaction creates patterns and relationships that develop certain behaviours. However, the social process is highly linked to the social structure. The social structure is an arrangement of institutions where humans can interact and live with one another.

Studying the social structures and discovering relationships with crime within an urban area involves three levels of sociology; macrosociology, mesosociology and microsociology (Mendez & Otero, 2017). The macrosociology is more commonly associated with social institutions, where the social institutions are made of families, education, law, religion, media and the economy. Within each of these institutions are roles and fulfilsments that organise social relationships with others. In collaboration, the social relationships with mesosociology are organised in various classes, which could involve; level of wealth, education or employment. The microsociology is the analysis of the everyday social movements and patterns of humans from the social institutions within various communities.

The social processes and the links it has with social structures is particularly important to discover social implications that is possibly linked to violent crime within disadvantage neighbourhoods. However, these social implications can cause consequences to the economy for the neighbourhoods. Conceptionally, the social structures and social processes have strong connections to the economic decline or growth of a community. The economic development of a community involves spatial and non-spatial implications. In a recent journal, Shaffer et al. (2006) conducted a diagram that outlined the key components of economic growth. Three of the key components are associated with economics and the other three associated with community economic development. The three components associated with economics are market, resource and space. Whereas, the three components associated with community economic development are culture/society, rules/institutes and decision-making. Through space, people within communities decide on where to develop businesses, where to shop, where to live and where to interact. The interaction could be within the community or at a greater distance to another community. However, the decisions people make within the space depends upon the market and resources available. In terms of the market, within a community, it is known as a local market, in which it corresponds to a local business between businesses and households within that specific area (Shaffer et al., 2006).
There are two factors to take into consideration when supplying goods and services within the market, the two factors are; urban hierarchy and the socioeconomic characteristics of the community. The social institutions, as described above are focal points for social interaction within a community. However, for economical purposes the social institutions have rules that are implied for their services and goods. The performances of businesses within a community will particularly depend upon the society/culture attitude towards the business climate. The decision-making with everyone involved within the community is important. It’s important because communities will arise with problems and communities need to understand these problems in a way in which it will not spill over and have a great impact on the economic conditions within the community.

The concentration of this thesis is conducted within the five boroughs of New York in America. America is known as a developed country with one of the best economies in the world. At a local level within urban areas crime can have an impact. Most notably, in the past, America experienced its highest peaks of crime from 1970 to 1990. Although since 1990, crime within America has dramatically decreased and continues to do so. Although, within the American cities and towns, crime is still considered problematic. Of course, New York being one of these cities, still experiences crime. However, crime rates within the city decreased more rapidly than the national index crime from 1996 to 2014 (Greene et al., 2016).

Within New York, the police forces have strategies in place to identify violent crime and prevent it. A key strategy used by the police force in New York is identifying the crime hot spots within the city (Haberman, 2016). This strategy is used because it allows the police to analyse the area and provide high-controlled forces within these hot spots (Haberman, 2016). However, identifying crime hot spots also allows for understanding the social factors of a community and the implications it has on the economy. This thesis primarily concentrates on two violent crimes and two social factors. The two violent crimes are robberies and felony assaults. Whereas, the two social factors are poverty and lack of education. These two social problems were selected for this thesis because the engagements they have on violent crime. Poverty is known as people who are living in poor conditions, living in such conditions influence crime because people are more than likely to be involved in criminal activity (Webster, 2014). Whereas, lack of education also influences people to participate in criminal activity (Machin, 2011). These social problems will be expressed spatial to identify which areas within the five boroughs of New York experience these violent crimes and social problems. The approach for this thesis will provide a structure which will benefit the government, businesses and community leaders. This will allow for strategies to be put into place to improve the social and economic aspects to provide a more sustainable community.

Seeing that this thesis focuses on New York City, the government within New York recently released their visions and goals for a sustainable city by 2030. The sustainable development document highlighted that New York have four visions in place, the four visions being; growth, equity, sustainability and resilience.

Of course, these visions stated by the government involve no poverty, quality education, employment and economic growth, sustainable communities, peace and justice. Reaching
these goals requires an understanding of the relationship between social factors and violent crime and how it involves economics.

2. *Aim & Research Questions*

This thesis aims to identify violent crime and social problems within the five boroughs of New York. Identifying the violent crime and social problems will allow for analysis to be carried out. Analysing the key crime hot spots will allow for the discovery of the relationships between social factors and violent crime. Discovering the relationship between social factors and violent crime will allow for the discovery of consequences that will allow the understanding of what needs to be done in the future to help keep these communities safe. From this aim, five research questions will be answered as provided below.

- What neighbourhoods in the five boroughs of New York are deemed as crime hot spots?
- Are there signs of increased or decreased crime rates in the five boroughs of New York?
- What neighbourhoods in the five boroughs of New York have social problems?
- Does violent crime and social problems spatially coincide?
3. Literature Review

This thesis is related to determining if social problems and violent crimes have a connection and the impacts on society. Therefore, this will highly involve crime mapping and analytics to gather answers of potential issues that can be solved to prevent crime. It is perceived that place is an important concept when conducting crime analysis. Of course, the offender that commits the crime, came from a geographical location that is either within the same community as the crime is committed or from a different community. However, within various communities there is different levels of social development. Although, communities that are known as disadvantaged communities struggle to deal with the violent crime and prevent it from happening again (Johnson & Kane, 2018). From this point of view, the social disorganisation theory comes into context. The social disorganisation theory considers the condition of communities. It was described by Kubrin & Weitzer (2003) that the theory suggests that poverty, dismantled social connections, ethnic heterogeneity and residential mobility can impact the neighbourhood’s behaviour and increase crime rates. However, the social problems within disadvantaged is very broad, hence the reason for concentrating only on poverty and lack of education. A concertation by Nolan & Whelan (1996) that reduction of poverty is the core for the economy and social policy. However, the author also stated that there is no considerable measure for poverty but is indicated as being below a certain low income. The other social problem which is focused on this thesis is lack of education, lack of education was described by Pritchett (2004) as in terms of enrolments, attainments and learning achievement. The author also indicates that education provides people with competencies, that allows them to integrate within society.

The social organisation of a community is perceived as a critical aspect, where it all defines how the residents, leaders and police behave within a community, the relationships the community has within and to other communities and the strength of social networks (Sharkey et al., 2016). Consequently, in a recent article by Vogel & Van Ham (2018) that disadvantage neighbourhoods have a lack of social control, which develops crime and economic deprivation.

Although, living in such conditions within a disadvantaged neighbourhood, plays on the behaviour of individuals who carry out the criminal act. To this point, according to research, it was noted by Haines (1999) that criminals’ behaviour is all linked to their childhood, it was discovered that it’s possible that the criminal was involved in antisocial behaviour and was impacted by adult antisocial behaviour in early career. Lack of social control and low self-esteem behaviour from the criminal has its consequences on economic development within communities. According to Levin & McDevitt (2002) criminal activity provides pressure on the economy, where there is a decline in business growth and a shortage of jobs within neighbourhoods. In order to discover its linkage to violent crime, it is critical to take into consideration macro- and microsocial levels, however, also taking into consideration the accurate nature of violent crime is not known but there is a certainty that crime will always be linked to the socioeconomic conditions of communities.

Taking into consideration the methodological approach is a key component to solving crime’s relationship to social and economic aspects. Typically, the methodological approach for crime
involves the identification of a specific type of crime, furthermore, this will allow to bring in the relationships associated with crime. To this basis, Breetzke (2006) points out the importance of Geographical Information Systems (GIS) towards the National Crime Prevention Strategy. The author indicates that the strategy was taken on board by South Africa. Within the strategy, GIS was used for identifying crime hot spots, mapping priority crime and mapping the crime according to the time of day or week. This study highlights the importance of GIS, which is a powerful tool that identifies crime and establishes social and economic impacts. It was described by Eman et al. (2013) that GIS is fundamental for spatially studying crime to provide analytical techniques. GIS, as a software, is critical for manipulating high volumes of raw crime data into a spatial visualization across a geographical location to provide knowledge and provide critical decision-making (Ferreira et al., 2012). Likewise, Ferreira et al. (2012) pointed out that the importance of quality data is a key aspect in providing effective results. For instance, Nakaya & Yano (2010) conducted an effective methodological approach towards violent crime. The authors provided criminality maps that were conducted to provide a visualization of crime activities in a three-dimensional aspect through spatial and temporal patterns. Of course, when provided in the correct context the emerging crime trends will be displayed in space and time (Grubesic & Mack, 2008). Essentially, the spatial temporal is a complex set of data that provides the opportunity for researchers to analysis relationships, trends, patterns and correlations (Kraak & Van De Vlag, 2007).

Taking spatial temporal mapping into consideration will allow for the identification of crime hot spots within specific locations (Eman et al., 2013). Moreover, Filbert (2008) suggested that studying crime on GIS will allow for bringing in other factors, such as social and economic impacts. For instance, Ceccato & Dolmen (2011) used GIS to discover crime rates in Sweden and discovered that higher crime rates had a link to the younger male population and divorce rates. Whereas, Wilhelmsson & Ceccato (2015) discovered that burglary rates within an area can have a negative impact on property value. The authors employed this method by using GIS to discover spatial rates of burglary and properties within various municipalities. In terms of correlation, Kennedy et al. (2016) distinguished that there was a relationship between assaults and problematic buildings.

Studying correlations is a key aspect but there have been other studies that determined when crime patterns occur. To this point, Nelson et al. (2001) and Uittenbogaard & Ceccato (2012) were both able to show a correlation that crime had with the time of day, month and season. Firstly, Nelson et al. (2001) discovered with time graphs that crime in Cardiff City was problematic at night, particularly at weekends. Although, Uittenbogaard & Ceccato (2012) discovered that patterns of robberies occurred during the weekdays. From conducting a correlation between time of day, month and season with crime will give indications to what motivates the offender to commit a crime. The study conducted by Nelson et al. (2001) gives an indication that the offender is possibly related to crime due to alcohol or drugs. On the other hand, Uittenbogaard & Ceccato’s (2012) discovery indicates that daylight robbery is possibly linked to empty properties. Whereas, Zhao et al. (2002) created a mathematical model that demonstrates the correlation between poverty and crime and identified cost effective strategies to tackle crime.
4. **Methodology**

To answer the research questions of this thesis, a methodological approach was used. The methodological approach was primarily conducted on ESRI’s ArcGIS Platform, which involved the use of ArcGIS Pro. ArcGIS Pro was the vocal software used for this thesis because of its performance and effectiveness to deal with large formats of data. The methodology was particularly carried out on violent crime and social factors.

4.1 **Preparation**

The crime data was obtained from the NYC Open Data Portal (NYC Open Data, 2018) This portal offers a range of data on crime, sociology and economical. The crime data available on the portal was downloaded into two separate Windows Excel files. Firstly, the felony assaults that occurred in the five boroughs between 2006 – 2016. Secondly, the robberies that occurred within the five boroughs between 2006 – 2016. Whereas, the social data and economic data were collected from the American Fact Finder website (DADS, 2018). This website offered to download census data from various years. The social data was particularly concentrated on the American Community Survey from 2016 with a 5-year estimate. The American Community Survey is carried out each year by the United States Census Bureau to gather critical information about social aspects. Social aspects can involve; employment, education, residential information, etc. However, for this study the data was specifically concentrated on poverty and education. The study is concentrated on poverty and education because Webster (2014) suggested that poverty has high links to criminal activity. Whereas, education was selected because a lack of education influences criminal activity (Machin, 2011). The geographical type for this social data was census tract within New York. The social data involved two separate files; poverty status in the past 12 months and education attainment. After preparing the files, the census tract shapefile and county shapefile were downloaded from the census bureau website (Branch, 2018).

A decision was made to create a geodatabase to store all relevant data. Three feature datasets were created in the geodatabase. The feature datasets were; crime and social aspects. This geodatabase with feature datasets was created because it allows the data to be organised and easily managed. Data was downloaded and added into each of the relevant feature classes. Navigating to the geodatabase allowed for the felony assaults and robbery activities between 2006 to 2016 to be added into ArcGIS Pro and of course, the data was not on display because it is available as a table format within the software. However, the data was easily expressed as spatial data by displaying the x- and y-coordinates within the table. Moreover, this expressed all point locations of felony assaults and robberies that occurred across the five boroughs throughout 2006 to 2016. However, displaying this data as point locations was not beneficial because it was difficult to identify where crime has occurred throughout the time. Point locations was not beneficial because there were 184,177 felony assaults and 198,824 robberies that occurred throughout this time period (table 1).
Table 1: The violent crime activities from 2006 to 2016.

*2016 only includes the 1st January.

<table>
<thead>
<tr>
<th>Year</th>
<th>Felony Assaults</th>
<th>Robberies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016*</td>
<td>108</td>
<td>52</td>
</tr>
<tr>
<td>2015</td>
<td>20,374</td>
<td>16,969</td>
</tr>
<tr>
<td>2014</td>
<td>20,281</td>
<td>16,568</td>
</tr>
<tr>
<td>2013</td>
<td>20,387</td>
<td>19,172</td>
</tr>
<tr>
<td>2012</td>
<td>19,506</td>
<td>20,192</td>
</tr>
<tr>
<td>2011</td>
<td>18,607</td>
<td>19,765</td>
</tr>
<tr>
<td>2010</td>
<td>17,064</td>
<td>19,547</td>
</tr>
<tr>
<td>2009</td>
<td>16,773</td>
<td>18,613</td>
</tr>
<tr>
<td>2008</td>
<td>16,273</td>
<td>22,404</td>
</tr>
<tr>
<td>2007</td>
<td>17,488</td>
<td>21,799</td>
</tr>
<tr>
<td>2006</td>
<td>17,311</td>
<td>23,743</td>
</tr>
<tr>
<td>Total</td>
<td>184,177</td>
<td>198,824</td>
</tr>
</tbody>
</table>

4.2 Emerging Hot Spot Analysis

Within the space time mining toolbox, tools are available to statistically analysis data and patterns. Therefore, the emerging hot spot analysis tool was fundamental for this study because it displays point data more effectively across space and time. The emerging hot spot analysis is a method used by the police department, researchers and crime analytics (Levine, 2006). This tool is known as a spatial autocorrelation, which is used to determined spatiotemporal patterns within crime. Two statistical measurements are used for the process of the resultant emerging hot spots, which are; Mann-Kendall trend test and the Getis-Ord Gi*. The Mann Kendall is used for the production of the space time, whereas, the Getis-Ord Gi* is used to conduct the emerging hot spots.

Firstly, the emerging hot spot analysis can only be obtained by the creation of a space time cube. Creating the space time cube clusters points into space-time bins. The space time cube conducts the Mann-Kendall trend test. The Mann-Kendall trend test is essentially a rank correlation test that determines the rank of observation and the unique time classifications (Hamed, 2009). Therefore, the test works down through the time series available. The test compares bins down through the time period to either give a positive trend, negative trend or absolutely no trend. For example, within figure 1 it shows space time cubes created for this study area. Each of the space time cubes are at fixed locations and each represents a time series within the fixed location. Within each of these bins the points are counted and provided with trend counts over time. The trend counts are evaluated and each of these space time cubes are compared against each other to receive a +1, -1 or zero. Each of the bins within the
time period are summarised to provide a positive trend, negative trend, and no trend. Therefore, the output for the tool is a netCDF-file. This netCDF-file is the storage area for the multidimensional data.

The emerging hot spot analysis takes this netCDF-file and identifies the trends within each of the bins. Within the tool, it is essential to manually add the neighbourhood distance and neighbourhood time step to calculate the Getis-Ord Gi* Statistic. Adding these parameters allows for the Getis-Ord Gi* Statistic to identify what bins are hot and cold spots within the area. Each of the bins received a p-value and a z score from creating the space time cube. The Mann-Kendall trend test evaluates these hot and cold spots and categorises the hot and cold spots. The patterns that the hot and cold spots receive are demonstrated in table 3 within the appendix.

Figure 1: The space time cubes within a part of the study area.
For this study, the emerging hot spot analysis was used for the felony assaults and the robbery activities between 2006 to 2016. Firstly, within the space time pattern mining toolbox, the create space time cube tool was used to create a space time cube for the felony assaults and robberies. The input feature for the tool was either the felony assaults or robberies. The time space interval for the process was set to one year with the time step alignments being the end date. This suggests that the tool worked backwards from 2016 on a yearly basis until 2006. The distance interval was set to 200 metres and the aggregation shape type was set to fishnet grid. The distance interval was set 200 metres because it suggests how large the space time bin was. However, this distance interval was based on the analysis of this study. The distance interval was determined from the spatial resolution and how spatially disturbed the data was. This was an important aspect because making the intervals too small or large will provide false analysis for the data. Whereas, the fishnet grid was used for the aggregation shape type based on personal styling choice. The output for this tool was a NetCDF that clustered the points together in space time cubes.

After constructing the space time cube, the emerging hot spot analysis was used. This tool was available within the space time mining pattern toolbox. Within the tool, there was a requirement for an input for the space time cube. The input for the emerging hot spot analysis was the space time output created for the felony assaults and robberies. For this particular study two netCDF-files were created, which are; felony assaults from 2006 to 2016 and robberies from 2006 to 2016. Therefore, the emerging hot spot analysis used this netCDF-file to identify trends within the data and present them with classifications. The emerging hot spot analysis tool also required a neighbourhood distance and a neighbourhood time step. The neighbourhood distance and neighbourhood time step were provided based on the spatial disturbance of the point data. Therefore, for this study, the neighbourhood distance was set to 600 meters and the neighbour time period was provided with 1-time interval. This suggests that neighbouring bins that fall within 600 metres will be included within the analysis. Whereas, the 1-time interval indicates that within the locations there was a 1-time interval. These parameters were provided to calculate the Getis-Ord Gi* through distance and time for each of the bins. Therefore, the Getis-Ord Gi* determines if the results are statistically significant or not. For the results to be statistically significantly, the features within a bin must be high but the features within neighbouring bins must also be high. If neighbouring features are not high, the results are statistically insignificant. The resulting output for the emerging hot spot provides the trend of crime throughout a period of time. Consequently, the output for the emerging hot analysis provided the opportunity to conduct other methods that distinguished spatial coincidence with social factors.
4.3 “Traditional” Hot Spot Analysis
Navigating to the social feature dataset within the geodatabase, provided the data from the census. The Excel-file for both the poverty and education were edited. The Excel-files were edited to provide a new field for calculating the percentage of population below the poverty line and total population from 18 to 24 years that have less than high school graduation. These fields were calculated, saved and added into ArcGIS Pro. The data within these tables were joined to the census tract feature class.

The “traditional” hot spot analysis is available within the spatial statistics toolbox within ArcGIS Pro. The spatial statistics toolbox is unique because it was specifically developed for geographical data. However, within the toolbox the “traditional” hot spot analysis was used to provide the poverty and education data with hot and cold spots. This tool is quite similar to the emerging hot spot analysis, but the tool only uses the Getis-Ord Gi* statistic to provide high or low clustered values. The high or low clustered values are calculated from z scores and p-values. The high values are known as hot spots, however, to be considered as a hot spot, the feature with the high value must also be surrounded by high values. On the other hand, the low values are known as cold spots, and must be surrounded by low values to be considered as a cold spot. The calculation of the hot or cold spots is the resultant of the z score. A larger z score indicates that the result is a positive hot spot. Whereas, a smaller z score indicates that the result is a negative, which is a cold spot. For this study, the “traditional” hot spot analysis was used for the poverty and education data for the five boroughs in New York. The input for the tool was either the poverty or education data available for the five boroughs of New York. The input field for both of the social factors was the percentage field calculated. For example, the percentage of poverty and percentage of attainment for education. The output from this tool was a feature class indicating which areas have high or low poverty and education.
4.4 Overlay Analysis
Both crime and social factors have been identified but methods were also conducted to express the relationship between the two, this was done by using the overlay analysis. The overlay analysis involved two methods;

- Select by attributes
- Intersect

The select by attributes is a tool that uses Standard Query Language (SQL) to identify features. The tool allows the user to manually use SQL and it will automatically select the feature. For this study, the select by attributes was used to select increasing felony assault and robberies, and to select the hot spots for poverty and education. The SQL created for the crime was as follows “Pattern is equal to” and it included the terms within table 2 below. For example, one expression was “Pattern is equal to consecutive hot spots”. Providing these expressions allowed to select all patterns that are increasing crime. Whereas, for poverty and education the SQL was different. The SQL created for poverty and education was “GI Bin is equal to x”, whereas x is equal to 1, 2 or 3. For instance, one expression was “GI Bin is equal to 1”. These three numbers were used because they represent the hot spots for poverty and education. However, it is important to indicate the selection type when connecting the selections together. For instance, after selecting felony assault, it was important to change the selection type add to current selection when selecting a social factor.

The intersect tool was used to combine the selected crime and social factors. The intersect tool computes a geometric intersection of the selected features. It provides an output of the features that are overlapping each other. For this study, the tool was used to show the relationship between crime and social factors. The input for the feature were either the following;

- Felony Assault & Poverty
- Felony Assault & Education
- Robbery & Poverty
- Robbery & Education

The output from this tool were feature classes that showed the overlay of the crime and social factors. This output allowed for interpretation on which areas are experiencing crime and social problems.

Table 2: The pattern names used for the SQL expression for the overlay analysis.

<table>
<thead>
<tr>
<th>Crime Type</th>
<th>Pattern Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felony Assault</td>
<td>Consecutive Hot Spots</td>
</tr>
<tr>
<td></td>
<td>Intensifying Hot Spots</td>
</tr>
<tr>
<td></td>
<td>New Hot Spots</td>
</tr>
<tr>
<td></td>
<td>Persistent Hot Spots</td>
</tr>
<tr>
<td>Robbery</td>
<td>Intensifying Hot Spots</td>
</tr>
<tr>
<td></td>
<td>New Hot Spots</td>
</tr>
<tr>
<td></td>
<td>Persistent Hot Spots</td>
</tr>
</tbody>
</table>
This methodology has demonstrated a way to identify crime and social factors and an approach that shows how to express their relationship. Conducting this methodology allowed to produce maps that best outline the crime and social factors and demonstrate their relationships. The data used for this study could only be collected for the five boroughs of New York. Thus, this is why the data was only concentrated within this area. The violent crime and social problems had to be defined down because the terms are within a broad context. Moreover, there are many violent crimes and social problems that can be studied. For this study, it was expected to provide economic data to discover the economic conditions for the five boroughs, however, studying the economic conditions of the five boroughs of New York requires an in-depth study. This was not conducted because the lack of time available.
5. **Ethical Consideration**

The methodology for this study was conducted using secondary data. This secondary data was collected from NYC Open Portal and from the American Fact Finder. The crime and social data does not hold any personal data. The data that was provided from the websites is freely available for the public. The spatial resolution of the crime data is at street level; therefore, this suggests that the x and y coordinates of where the crime happened is not exactly at the location.
6. Results

This results section will firstly present key facts and a quick overview of each of the five boroughs within New York. Following up from this will be the results for identifying violent crimes, which will specifically concentrate on felony assaults and robberies within the five boroughs of New York from 2006 to 2016. Alongside this, the social problems will be expressed, which will concentrate on; population below the poverty line and male population from 18 to 24 years who have less than high school graduation. In addition, the spatial coincidence between violent crimes and social problems will be demonstrated and public houses were added to demonstrate the high clustering within these areas.

6.1 Study Area

The investigation for this study will be carried out on the five boroughs of New York. The five boroughs of New York are; Manhattan, Brooklyn, Queens, The Bronx and Staten Island. Each of these boroughs are county filled cities and each having their own governance within the broader context of New York City government. Each of the five boroughs are quite unique due to having their own cultures and reputations. Moreover, this section will discuss briefly about the history, demographics and culture for each of the five boroughs.

6.1.1 Manhattan

Manhattan is geographically smaller than the other boroughs. However, the small density area of Manhattan is known as the focal point within New York with a high-density population of approximately 1.6 million and unique tourist attractions, such as; sky scrapers, the Empire State Building, Central Park and Times Square. The rapid growth of Manhattan began in the early 20th century where social and economic development thrived. However, late into the 20th century there was a decline in population within Manhattan due to a high rise within crime. However, this didn’t stop the development and the growth of today as it is one of the most important parts of the city in the world. In terms of economic growth, Manhattan is occupied by many multinational firms, most notably, it is home to the United Nations headquarters and Wall Street.

6.1.2 Brooklyn

Brooklyn is the most populated borough in New York with an estimated of 2.6 million residents. The most iconic attraction within Brooklyn is the Brooklyn Bridge, however, Brooklyn is also filled with local parks and museums. Brooklyn saw a rapid growth in the early 21st century, where the construction of the built environment was very rapid, constructing subways and buildings. Although, in more recent years, Brooklyn has been accounted for its economic growth, where business and employment has highly developed over the years.

6.1.3 Queens

Queens has the largest area of the five boroughs with a mixture of residential and industrial areas with a population of approximately 2.3 million. The JFK airport and LaGuardia airport are located within Queens and of course are New York’s most important airports. The Queens borough joined New York City in 1898 and this saw a mass development within the area. The development of the borough saw the construction of new transportation systems allowing
for connecting to the other boroughs within New York. Since the late 20th century, Queens has experienced a high level of immigrations. Today, the economy in Queens is vibrant with the airports and immigrants playing a huge role in the growth of the economy within the borough.

6.1.4 The Bronx
The Bronx is located between Queens and Manhattan with a population of 1.5 million residents. The borough is home to the famous New York Yankee stadium and has a vast amount of nature parks within the borough. The growth of the Bronx thrived after the first world war where it saw a flock of immigrants arrive into the borough. However, in the 1960s urban renewal had taken place, which destroyed low density neighbourhoods in favour of highways and high-density housing projects. After the urban renewal, arson overtook the southern part of the Bronx. However, since 1990 the borough has been developing, although, it still harbours quite poor neighbourhoods.

6.1.5 Staten Island
Staten Island has the lowest population of the boroughs, with a population of 450,000. It is known for its historical landmarks, museums, beaches and has New York’s largest forest. Staten Island is mostly a residential area but also consists of industrial areas.

Figure 2: The population for the five boroughs of New York.
6.2 Identifying violent Crimes

Identifying the violent crime within areas of the five boroughs was fundamental. On this point, the emerging hot spot analysis tool was particularly efficient at expressing the trends and patterns of felony assaults and robberies within the five boroughs from 2006 to 2016. The felony assaults are demonstrated in figure 3. The figure shows that there are hot and cold spots of felony assaults across the five boroughs. However, from analysing the map, it indicates that Staten Island and Queens experienced low rates of felony assaults because both boroughs are dominated by cold spots. Although, The Bronx, Manhattan and Brooklyn are all dominated by consecutive and intensifying hot spots. Whereas, Manhattan and Brooklyn also experienced patches of persistent hot spots. The consecutive hot spots suggest that the felony assaults occurred less than 90% of the time intervals from 2006 to 2016. Whereas, the intensifying hot spots indicate that felony assaults occurred more than 90% of the time intervals from 2006 to 2016 but was also predicted to increase over time. The patches of persistent hot spots distinguish that felony assaults occurred 90% of the time intervals from 2006 to 2016 but at a steady rate, where there is neither an increase nor a decrease.

However, observing figure 4 shows the robberies from 2006 to 2016. From analysing the map, it indicates that Staten Island and Queens both experienced persistent and intensifying cold spots. The persistent cold spots indicate that the robberies have been particularly low for 90% of the time from 2006 to 2016. Whereas, the intensifying cold spots also suggests that robberies have been low for 90% of the time intervals from 2006 to 2016. However, robberies were high in Manhattan, Brooklyn and the Bronx. The robberies were high because there are persistent hot spots dominating these areas. The persistent hot spots across these areas indicate that robberies occurred 90% of the time intervals from 2006 to 2016. Although, across Queens and the north of Bronx there is a slight domination of oscillating hot spots, this indicates that robberies did occur across these areas, but these areas are historically known for predominately having cold spots.
Figure 3: The felony assaults that occurred across the five boroughs from 2006 to 2016.
Figure 4: The robberies that occurred across the five boroughs from 2006 to 2016.
6.3 Identifying Social Problems

Identifying the areas with poverty and lack of education was conducted by using the “traditional” hot spot analysis. Figure 5 and 6 were produced to discover what areas were considered to be in poverty and what areas had a lack of education. From figure 5, it states the population below the poverty line from 2016. The cold spots indicate the areas that are not considered below the poverty line, whereas, the hot spots are considered to be below the poverty line. By analysing figure 5, it shows that Queens is dominated by cold spots with a confidence level of 99%, whereas, cold spots also dominated the majority of Staten Island, southeast of Brooklyn and the south of Manhattan. Although, the north of Manhattan has hot spots for population below poverty line, which also runs into the Bronx. Brooklyn also encounters hot spots for population below poverty line.

On the other hand, figure 6 demonstrates the education attainment for the male population who are 18–24 and have less than high school graduation. The spatial results from figure 6 suggest that south of Manhattan and Queens experienced cold spots at a confidence level of 99%. This indicates that the male population who are 18–24 years were educated above the high school level. Although, pockets of hot spots are identified within Manhattan and Brooklyn. However, most significantly, the majority of the Bronx is covered with hot spots with a confidence level of 99%. The hot spots indicate that the majority of the male population who are 18–24 years have less than high school graduation.

Figure 5: The hot and cold spots from the population below the poverty line within the five boroughs of New York.
Figure 6: The hot and cold spots for the population that have less than high school graduation within the five boroughs of New York.
6.4 Spatial Coincidence

Figures 7 to 10 demonstrates the spatial coincidence that felony assault and robbery have with poverty and education. The red hatched areas marked within the maps indicate the spatial coincidence between the violent crime and the social problems. There is a high cluster of public houses where violent crime and social problems spatial coincide. From analysing figure 7, it shows that there is a spatial coincidence between felony assaults and poverty. This coincidence is mostly dominated across the south of the Bronx, north of Manhattan and the north of Brooklyn. It is also noticeable that there is a scatter of small patches in the south of Brooklyn. Moreover, figure 8 demonstrates the spatial coincidence between felony assault and education. The education relates to the male population who are 18 – 24 years and have less than high school graduation. The results in the map show that the spatial coincidence between felony assault and education is within the south of Bronx, north of Manhattan, northeast of Brooklyn and small patches within the south of Brooklyn.

On the other hand, figure 9 and 10 indicate the spatial coincidence robberies has with poverty and education. Figure 9 proves the spatial coincidence robberies has with poverty. The coincidence between robberies and poverty is particularly concentrated within the south of Bronx, north of Manhattan and southeast of Brooklyn. However, there are also small patches scattered across the north of Bronx and the south of Brooklyn. From figure 10 it indicates the spatial coincidence between robberies and education. The education being the male population who are 18 – 24 years and have less than high school graduation. The map suggests that there was a high concentration of the coincidence within the south of Bronx, north of Manhattan and north of Brooklyn. Also, within the south of Brooklyn there is a small patch of coincidence.
Figure 7: The spatial coincidence between felony assaults and poverty within the five boroughs of New York.
Figure 8: The spatial coincidence between felony assaults and male population who are 18 – 24 and have less than high school graduation.
Figure 9: The spatial coincidence between robberies and poverty within the five boroughs of New York.
Figure 10: The spatial coincidence between robberies and male population who are 18 – 24 and have less than high school graduation.
7. Discussion

The results have identified felony assaults and robberies through time and space. Moreover, the results have also expressed the areas that experience poverty and a lack of education for the male population. Identifying the violent crimes and social problems provided the opportunity to spatially coincide the violent crimes and social problems. Providing results in such a way is important to prevent crime within the future. To this point, Breetzke (2006) pointed out that GIS a key strategy for the National Crime Prevention in South Africa. The software is important but correct choice of methods is also fundamental within GIS. Previous studies have demonstrated crime through spatial and temporal patterns (Nakaya & Yano, 2010; Grubesic & Mack, 2008). Providing spatial and temporal patterns allowed to identify crime in a unique way (Eman et al., 2013). As demonstrated in the results, this study has also provided spatial and temporal patterns for the crime. However, the crime patterns provided the opportunity to take in the social problems, this was important to provide spatial coincidence and to analyze trends (Kraak & Van De Vlag, 2007).

Significantly, demonstrating the results in such a way would not be possible without ArcGIS Pro. ArcGIS Pro had the ability to take in high volumes of raw data and convert it to spatial visualization across geographical locations (Ferreira et al., 2012). Within ArcGIS Pro, the emerging hot spot analysis and “traditional” hot spot analysis were effective in displaying spatial visualization across geographical locations. This study took advantage of these statistical tools to provide spatial temporal data. Spatially displaying results provides more opportunities compared to non-spatial results. Other studies have used the approach by demonstrating geographical data as non-spatial data. For instance, Wang et al. (2013) used non-spatial data to identify crime. The non-spatial data was included as time of the day profiling for house break ins between a yearly time period. Compared to this approach, spatial temporal data provides the opportunity to discover trends, patterns and relationships (Kraak & Van De Vlag, 2007). The two statistical tools proved to be the focal point in providing these trends, patterns and relationships. As it was demonstrated in the methodology, the emerging hot spot involved two statistical measures; Getis-ORD GI* and Mann-Kendall trend test. Whereas, the “traditional” hot spot analysis involved one statistical measure; Getis-ORD GI*. These statistical measures proved to be quite significant in the production of the results for this study. It proved to be significant because it identified the crime and social aspects through space and time. The significations of identification were through the statistical measures. The statistical measures are advantageous for this study because the Getis-ORD GI* was able to identify the crime and provide trends, whereas, the Mann-Kendall trend test provided these trends with patterns.

Comparing this approach to other studies show how beneficial it is to identify violent crime efficiently. For instance, Chainey et al. (2008) and Leigh et al. (2016) used the Kernal Density Estimation to produce spatial maps that identify crime. However, the patterns for both maps only ranged from high to low. The Kernal Density Estimation provides maps that show where crime occurs as hot spots. However, for this study, Getis-ORD GI* and Mann-Kendall trend test were able to provide hot spots with more detailed patterns. When referring back to figure 3 and 4, it is obviously noticeable where the crime is occurring, but the crime is identified with
detailed patterns. These detailed patterns are extremely important for policing certain areas because it allows the police authority to control certain areas and concentrate on these hot spots for crime prevention efforts (Braga, 2005). However, the police authority can also identify if crime is spilling over to other areas by analysing the crime patterns. For instance, in figure 4 it demonstrates that oscillating hot spots surround persistent hot spots in the Bronx, Manhattan, Brooklyn and Queens. The oscillating hot spots indicate that robberies are starting to occur in more recent times, and thus police authorities can concentrate on this before it starts to develop.

However, producing these violent crime hot spots also allows the opportunity to identify spatial coincidence with social aspects. For this study, the opportunity was provided by using the “traditional” hot spot analysis. Once again, this tool used the Getis-ORD GI* to demonstrate where hot spots of social problems were occurring. When referring to figure 5 and 6, it demonstrates the education attainment and population below the poverty level. Identifying these social problems proved to be fundamental to demonstrate the spatial coincidence with the violent crime. Of course, from this study the spatial coincidence was demonstrated by using the overlay analysis. The overlay analysis was quite an efficient way to display spatial coincidence.

The results for this study don’t suggest that there is a correlation between the violent crime and social problems selected. However, it clearly states that violent crime and social problems coincide each other. Previous studies have expressed correlations instead of spatial coincidence between social problems and crimes. Investigating the previous studies shows that Ceccato & Dolmen (2011) indicated a correlation between young male population in rural areas and crime rates by using non-spatial statistic measures and graphs. Whereas, Wilhelmsson & Ceccato (2015) were able to indicate that burglary rates were having a negative impact on property values in Sweden by using quantile regression and spatial analysis. These studies prove that there is a correlation between the crimes and social problems but the spatial coincidence for this study is still quite unique because it shows where crime and social problems occur spatially. Referring to figure 7 – 10 demonstrates the spatial coincidence. From figure 7 and 8 it suggests that male population who are 18-24 have less than high school graduation occur where there is felony assaults and robberies. The findings from these two figures show that dropping out of high school occurred where there was felony assaults and robberies within the Bronx, Manhattan and Brooklyn. A lack of education influences the occurrence of these violent crimes. The influences education has on violent crime has been expressed by Lochner & Moretti (2004). Within this study, the authors suggested that not completing high school influences crime rates. However, it was also noted by the authors that finishing high school influences lifestyle, opportunities and residential locations, which helps reduce the amount of crime. To back this up, Lochner (2004) suggested that high school drop outs are more than likely to take part in criminal activity compared to a high school graduate. Referring to the results for this study, clearly shows this discovery. Dropping out of essential education and interacting with crime reduces the opportunity for young people to develop skills and gain knowledge. Moreover, it also develops criminal behaviour because a young population dropping out of essential education develops antisocial behaviour, which influences criminal behaviour (Haines, 1999). Nevertheless, with
this criminal behaviour, a lack of skills and knowledge reduces the chances of employment for these individuals.

Being unemployed with a lack of education increases the rates of poverty. Of course, this study has demonstrated that the Bronx, north of Manhattan and Brooklyn experience poverty. Consequences also come with poverty, as there is an occurrence of violent crime where poverty was demonstrated. As demonstrated in the results, the spatial coincidence between violent crime and poverty occurred in the Bronx, Manhattan and Brooklyn. The results also indicated that areas with this coincidence also had a high cluster of public houses. Poverty influences violent crime within these areas because of public housing. According to statistics, all these boroughs have public housing with low income residents (see Capperis et al., 2014). The reason for this is that public housing is designed for low income individuals and families. Therefore, these public houses create communities of individuals and families with low incomes. These individuals and families within the communities fail to oblige within society due to social problems. Of course, these communities within poverty areas have issues related to resource deprivation. Resource deprivation has it impacts on these communities because individuals and families within the communities fail to interact within the social structure.

Poverty being the masosociology within the social structure, fails to interact with the macrosociology and the microsociology. Poverty fails to interact with the masosociology because there is a lack of skills and knowledge to be implied and from this, there is a lack of income to provide sufficient health care and education. On the other hand, the microsociology is impacted because there is a struggle to meet daily needs, difficulties participating in social activities and social interactions. This dismantled connection within the social structure has an influence on violent crime. For instance, struggling to make these connections within society encourage the community to get involved in violent crimes. Therefore, this dismantled version of the social structure provides a lack of social control, which influences violent crime and causes an economic downfall (Vogel & Van Ham, 2018).

The economy is an important factor when crime and social problems occur within areas, as it was noted by Vogel & Van Ham (2018) and Mulok et al. (2017). Of course, economic growth requires a strong social structure where all age groups should have free access to low cost education to improve their skills and knowledge. Improving skills and knowledge for all age groups open doors to employment opportunities. However, employment opportunities should provide a wage rate that is sufficient for individuals to survive (Mulok et al., 2017). Above all, this will help reduce violent crimes within these areas because individuals have few motives to carry out such crime.

Significantly, the methodology of this study provides a demonstration to reduce crime, where the usage of ArcGIS Pro was fundamental to spatially identify crime and social problems. The way these results were conducted and displayed, can further act as a platform for carrying out statistical tests. For instance, other studies have conducted statistical tests that provide correlations. Kennedy et al. (2016) demonstrated that there was a correlation between assaults and problematic buildings. Whereas, Uittenbogaard & Ceccato (2012) indicated that daylight robbery and empty properties have connections. Bringing these statistical tests into
the methodology used within this study will allow the government, community leaders and police authorities to identify the problems and improve communities. Moreover, the government and the United Nations are working towards goals set for 2030 (NYC, 2015). Of course, some of the goals set are no poverty, economic growth and peace and justice. To meet such goals, it is recommended to use this methodology and take it further by conducting statistical tests where there is a spatial coincidence between violent crime and social problems. A big advantage for New York is the wealth of data available. As noted in the methodology, this data was gathered from the New York Open Portal. For future studies of the five boroughs it is recommended to use this portal for crime data. On the other hand, it is also recommended to gather census data from the American Fact Finder. Discovering patterns, trends and relationships in the future will allow for making comparisons with this study and determine if violent crime and social problems are decreasing.

Nevertheless, crime and social data is not only limited to New York. Major cities across America have their own city portals, with crime data available. Studying other cities can be compared to the five boroughs of New York to discover which city has the least impact from violent crime and social problems. This will allow for bringing up questions as to how these cities deal with crime and social problems. However, it must be taken into consideration that violent crime is not only a problem in America but across the globe. Although, when studying crime within another country, it must be taken into consideration as to what type of crime these countries face, because one must remember that violent crime is only one type of crime within the broader term of crime. Different countries experience various types of crimes. These types of crimes come in at various geographical levels. For instance, when studying crime within a country it is essential to understand if the country is developing or developed. Although, tackling crime and improving societies is governed by the United Nations and it is therefore recommended to follow the goals that they have set for the country or city at hand.
8. Conclusion

To conclude, this thesis has presented a way in which violent crime and social problems can be identified. Identifying these factors spatially across a geographical location is an important consideration. However, providing this spatial data within ArcGIS Pro proved to be beneficial because the software had the ability to deal with a large quantity of data. The tools within ArcGIS Pro were efficient to demonstrate the violent crime and social problems across the five boroughs of New York. Demonstrating the violent crime and social problems provided the opportunity to show spatial coincidence between violent crime and social problems. Demonstrating this data in such a way allows for the government, community leaders and police authorities to understand how violent crime and social problems is impacting their areas.
9. Bibliography


10. Appendix

Table 3: Definitions for the hot and cold spots.

<table>
<thead>
<tr>
<th>Pattern Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Pattern Detected</td>
<td>No hot spots or cold spots identified.</td>
</tr>
<tr>
<td>New Hot Spot</td>
<td>Location has never been statistically significant hot spot in the past but in more recent times it has become a statistically significant hot spot.</td>
</tr>
<tr>
<td>Consecutive Hot Spot</td>
<td>Within the final time step intervals, there is an uninterrupted of statistically significant hot spot bins. The final hot spot run has made the location statistically significant. Overall, less than ninety percent of the bins are statistically significant hot spots.</td>
</tr>
<tr>
<td>Intensifying Hot Spot</td>
<td>Ninety percent of the time intervals within the location has been statistically significant hot spots. The clustering of the high counts within each bin is statistically increasing.</td>
</tr>
<tr>
<td>Persistent Hot Spot</td>
<td>Ninety percent of the time intervals within a location are statistically significant hot spots with the trends having no increase or decrease in the clusters over time.</td>
</tr>
<tr>
<td>Diminishing Hot Spot</td>
<td>Ninety percent of the time intervals within a location are statistically significant which includes the final time intervals. Within each time step, the intensity of clustering is decreasing and</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sporadic Hot Spot</td>
<td>A location that receives on and off hot spots. The location time intervals that have received less than ninety percent statistically significant hot spots. The time intervals within the location have never been statistically significant cold spots.</td>
</tr>
<tr>
<td>Oscillating Hot Spot</td>
<td>A location that has statistically significant hot spots for the final time step interval but also has a history for statistically significant cold spots. Less than ninety percent of the time step intervals have statistically significant hot spots.</td>
</tr>
<tr>
<td>Historical Hot Spot</td>
<td>The most recent time within a location is not hot but at least ninety percent of the hot spots are statistically significant.</td>
</tr>
<tr>
<td>New Cold Spot</td>
<td>Location has never been statistically significant cold spot in the past but in more recent times it has become a statistically significant cold spot.</td>
</tr>
<tr>
<td>Consecutive Cold Spot</td>
<td>Within the final time step intervals, there is an uninterrupted of statistically significant cold spot bins. The final cold spot run has made the location statistically significant. Overall, less than ninety percent of the bins are statistically significant cold spots.</td>
</tr>
<tr>
<td>Intensifying Cold Spot</td>
<td>Ninety percent of the time intervals within the location have been statistically significant.</td>
</tr>
</tbody>
</table>

the decrease is statistically significant.
significant cold spots. The clustering of the low counts within each bin is statistically increasing.

<table>
<thead>
<tr>
<th>Persistent Cold Spot</th>
<th>Ninety percent of the time intervals within a location are statistically significant cold spots with the trends having no increase or decrease in the clusters over time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diminishing Cold Spot</td>
<td>Ninety percent of the time intervals within a location are statistically significant cold spots which includes the final time intervals. Within each time step, the intensity of clustering is decreasing and the decrease is statistically significant.</td>
</tr>
<tr>
<td>Sporadic Cold Spot</td>
<td>A location that receives on and off cold spots. The time intervals that have received statistically significant cold spots that are less than ninety percent. The time intervals within the location have never been statistically significant cold spots.</td>
</tr>
<tr>
<td>Oscillating Cold Spot</td>
<td>A location that has statistically significant cold spots for the final time step interval but also has a history for statistically significant hot spots. Less than ninety percent of the time step intervals have statistically significant cold spots.</td>
</tr>
<tr>
<td>Historical Cold Spot</td>
<td>The most recent time within a location is not cold but at least ninety percent of the cold spots are statistically significant.</td>
</tr>
</tbody>
</table>