RUTGERS Center on Public Security

BRIEF

Risk Clusters, Hotspots, and Spatial Intelligence: Risk Terrain Modeling as an Algorithm for Police Resource Allocation Strategies

Eric L. Piza | Leslie W. Kennedy | Joel M. Caplan :: *June 21, 2010*

Introduction

There has been an increased interest in developing techniques using spatial analysis programs to identify and target areas where crime concentrates. The most popular approach has been hotspot mapping based on high spatial crime density to direct police attention to certain locations to suppress crime and deter offenders[1]. Sherman[2] (1995) examined the ways in which different types of crime concentrate in hotspots and concluded that what is important in understanding crime outcomes are onset, recurrence, frequency, desistence, and intermittency, in the context of how these processes influence the concentration of crime. This perspective, drawing together routine activities, rational choice, and crime careers approaches has been the gold standard of crime analysis for years. However, while hotspot mapping has allowed police to address the concentration of crime, it has generally turned attention away from the social and structural contexts in which crime occurs. Predictions about crime occurrence are then based on what happened before in locations rather than on the behavioral or physical characteristics of places within communities.

As better data and more sophisticated mapping techniques have come available, opportunities have emerged to move beyond approaches that rely on mapping past incidents to empirical and evidence-based strategies that forecast where crime will emerge in the future. Caplan, Kennedy and Miller[3] (see also Risk Terrain Intro Brief.pdf) have proposed that risk terrain modeling (RTM) offers a way of looking at criminality as less determined by previous events and more a function of a dynamic interaction between social, physical and behavioral factors that occurs at places. They suggest that the ways in which these variables combine can be studied to reveal consistent patterns of interaction that can facilitate and lead to crime. This analytical strategy more directly addresses the role of place-based context in crime forecasting, tying back to the basic premises in environmental criminology that social and physical characteristics of communities influence how crime emerges, concentrates and evolves[4].

The study briefed here examined how the RTM approach to spatial risk assessment can be implemented into police operations by addressing three important issues that address the validity of RTM that sets it apart from current approaches to spatial crime analysis. First, it addressed the selection criteria used in determining which risk layers to include in risk terrain models. Second, it compared the “best model” risk terrain derived from the analysis to the traditional hotspot density mapping technique by considering both the statistical power and overall usefulness of each approach. Third, it tested for “risk clusters” in risk terrain maps to determine how they can be used to target police resources in a way that improves upon the current practice of using density maps of past crime.

Setting

Newark is the largest city in the State of New Jersey, covering 26 square miles, with an estimated 2009 population of over 280,000 persons (U.S. Census Bureau) and the largest municipal police force in the state, with more than 1,300 sworn officers as of 2009. The City has a long standing reputation as a tumultuous urban environment. The new millennium saw both murders and non-fatal shootings increasing every year from 2000 to 2006, according to police department figures. But under the direction of newly appointed Police Director Garry F. McCarthy, formerly the lead crime strategist at the NYPD, the mission and structure of the department changed and an intelligence-led policing mantra was adopted.

Since these initiatives went into effect, Newark experienced a significant reduction in violent crime. According to department figures, overall crime decreased 19% from 2006 through 2009, with murders and shootings decreasing 28% and 40% respectively. While some may instinctively think otherwise, cities experiencing reductions in violence such as Newark can benefit from analytical methods like risk terrain modeling as much as jurisdictions facing crime increases or stagnation. As violent crime trends downward, so does the margin of error for police (especially police with limited resources). Public desire for crime reduction is ever-present, as is the political motivation for maximizing public safety. For these reasons, a technique that accurately forecasts the locations of future incidents (not just future totals) can be a valuable tool for agencies looking to build upon their recent successes.

Here, we focused our attention on gun violence due to the obvious seriousness of the offense and its (still) high level of occurrence in Newark. Despite ending 2008 with its second lowest murder total since 1965 (67), Newark's murder rate of 23.9 (per 100,000 residents) more than doubled the national average (11.5) for cities with populations greater than 250,000 (UCR, 2009). Firearm usage directly dictates the murder rate in Newark, with police data showing 84% of the city's murders resulting from gun shot wounds from 2007 through May 2010. While recognizing recent successes in violent crime reduction, city officials and residents consider current levels of gun violence to be unacceptable and rank violent crime along with the related issues of gangs and drugs as the most serious issues facing the city.

The Newark Police Department maintains an extensive Geographic Information System (GIS) which contains numerous data layers. Such a system presents a unique situation: The abundance of data allows one to configure numerous risk models, each utilizing a different combination of data layers. At the same time, the analyst faces the daunting task of identifying the "best" combination that produces the model with the strongest predictive capabilities. The more layers accessible within a GIS, the more frustrating this situation can be.

Given the size of Newark PD's GIS (as of the date of this study 50 separate layers appeared in the system) we first attempted to get a general sense of the place-based factors related to shootings in the city. The professional insight of experienced police officers in conjunction with a review of relevant empirical research led us to identify seven risk factors that we believed would accurately forecast the locations of shooting incidents in Newark: (1) locations of drug arrests, (2) proximity to "at-risk" housing developments, (3) "risky facilities," (4) locations of gang activity, (5) known home addresses of parolees previously incarcerated for violent crimes and/or violations of drug distribution laws, (6) location of past shooting incidents, and (7) locations of past gun robberies. These risk factors were operationalized into separate risk map layers in a manner consistent with the steps detailed in the *Risk Terrain Modeling Manual* (www.riskterrainmodeling.com).

Research Objective 1: Select the Best Risk Terrain Model

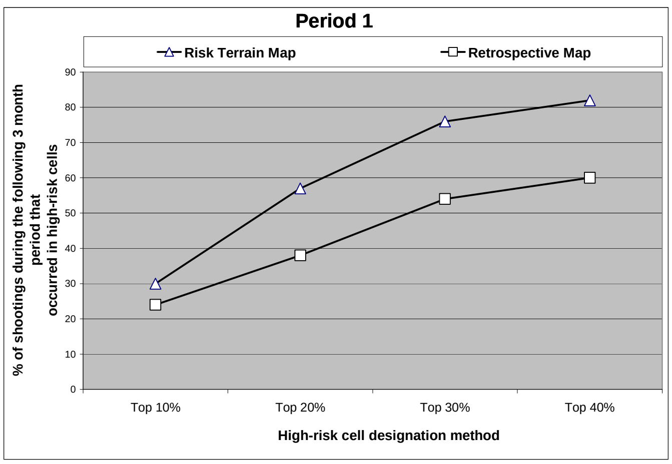
Although seven risk factors were initially identified to be correlated with shootings, we sought to select only those that were most significant and influential. Chi-Squared tests were conducted to identify the place-based risk factors most significantly associated with shooting locations and to develop four models: Model 1 included all of the seven risk factors; Model 2 included risk factors that were significant at $p<0.05$ (Drug Arrests, Gang Territory, At-Risk Housing, Risky Facilities, Shootings, and Gun Robberies); Model 3 included risk factors that were significant at $p<0.01$ (Drug Arrests, Gang Territory, At-Risk Housing, and Risky Facilities); Model 4 included risk factors that were significant at $p<0.01$ and whose proportions of cells experienced 20% or more shootings at places with each risk factor, respectively (Drug Arrests, Gang Territory, and At-Risk Housing).

Model 4 proved to be the best model, as results of binary logistic regression showed consistently higher odds ratios compared to the three other models and across four consecutive three-month time periods. For every increased unit of risk in a 140'x140' cell (i.e. place) in Newark, the likelihood of a shooting occurring there within the next three months increased by more than 48%, with a 95% confidence interval of 38%-60% (N=17,524; $p<0.001$). As hypothesized, including only the risk factors with relatively high and significant correlations to the outcome event produces the best place-based risk assessment of future events.

Research Objective 2: Compare Risk Terrain Maps to Retrospective Hotspot Maps

The Model 4 risk terrain was compared to retrospective density maps of past shooting incidents because if RTM does not outperform retrospective hotspot maps then its operational value to police is negligible and, thus, not worth the effort that the production of "best model" risk terrains mandates. Retrospective mapping was defined by using the locations of past events to predict locations of future similar events. To make this comparison, separate retrospective maps were created for Periods 1 through 4 (three months each from July 1, 2008 through June 30, 2009) in the same manner that the Model 4 risk terrain maps were produced. Then, consistent with the approach used by Caplan, Kennedy & Miller[5], four categories of "high risk" cells were designated for each map and tested: The top 10 percent (n=1,752), top 20 percent (n=3,504), top 30 percent (n=5,262) and top 40 percent (n=7,009). This allowed for a numerically equal comparison of cells designated as "high risk" between the two methods—retrospective density maps and risk terrain maps. It also added pragmatic operational value to the results by identifying the coverage area (10 percent through 40 percent of the city) needed to maximize any observed benefits so that finite police resources can be allocated most efficiently.

As exemplified in the chart below, the risk terrain maps outperformed retrospective maps across each high risk cell designation method and across all time periods. As much as 36 percent more shootings occurred in high-risk cells identified by the risk terrain model compared to the retrospective map.

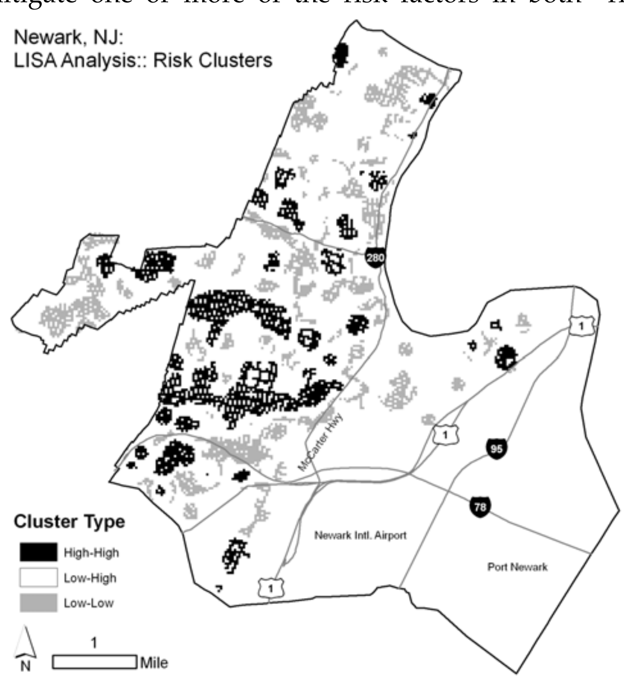


Research Objective 3: Use Risk Terrain Maps for Spatial Intelligence

With nearly 300 shootings annually in Newark, even a small five percent improvement over existing analytical practices equates to 15 shootings that will probably occur within known 140'x140' places. In the context of shootings, which run a high risk of fatality, there could be a significant dividend if police take adequate preemptive measures to mitigate one or more risk factors in these places. Herein lies the leading question for Objective 3: How can the intelligence produced by RTM be communicated in a meaningful way to police and used for strategic decision-making and tactical operations?

If police want to target areas with existing high crime, then using simple retrospective density maps of these events will show the general areas where crime is most concentrated and suitable for common suppression methods (e.g. increase police patrols, ordinance enforcement, curfews, zero-tolerance enforcement of ordinances and misdemeanors, knock & talks). The challenge that police agencies have is to allocate resources to areas with high crimes in order to suppress them, and also to areas that pose the highest risk for crimes to occur in the future[6]. Risk terrain modeling especially permits the latter. This encouraged us to think more about using "risk clusters" instead of crime hotspots to allocate police resources, and we used Local Indicators of Spatial Autocorrelation (LISA), or Local Moran's I, to test whether RTM could generate this type of information. LISA can distinguish between statistically significant clusters of high values surrounded by high values (HH), low values surrounded by low values (LL), high values surrounded by low values (HL), and low values surrounded by high values (HL). This kind of information can be especially useful to police strategists within the context of risk terrain modeling because it allows for categorizing (and ultimately prioritizing) the most risky, most vulnerable, or least risky places.

The map below shows results of a Local Moran's I test performed on the period 1 Model 4 risk terrain map with all zero-valued cells excluded. It is apparent from this map that risk can, in fact, cluster and that the nature of these clusters can better inform plans for police response. For example, officers might seek to leverage the social and human capital and other strengths of low-risk places that are nearby high-risk places in their efforts to mitigate one or more of the risk factors in both "risk



cluster" spots. Or, because lower-risk clusters still have some criminogenic risk factors in them, police can monitor these places as they target nearby high-risk clusters to preempt any displacement or dispersion of risk factors (or new crime incidents) that could occur.

Conclusion

The computation of the conditions that underlie crime patterns is a key component of risk terrain modeling (RTM), with the ability to weigh the importance of different factors at different geographic points in enabling crime events to occur. These attributes themselves do not create the crime. They simply point to locations where, if the conditions are right, the risk of crime or victimization will go up. Risk terrain modeling offers an approach that provides a means of testing for the most appropriate qualities of space (i.e. risk factors) that contribute to these outcomes through a statistically valid selection process. It also promotes the idea of the concentration of risk leading to these problems, in a way that these "risk clusters" can be used to help forecast future crime and direct interventions, such as police patrols, to these high risk locations.

Information from risk terrain maps can also be used to support the resiliency and expansion of the mitigating attributes that are in the low risk areas. The risk clustering approach can direct police to anticipate crime problems early and address the correlates of crime outcomes (note that these can vary by the type of crime being studied). Since risk can cluster in meaningful ways, RTM can ground risk-based policing much more into the contexts in which police operate rather than concentrating police on behavior that they are trying to control.

This study offers a number of advances to thinking about spatial analysis of crime. It serves as replication of risk terrain modeling from what was offered by Caplan et al., but improves on it by addressing both the analytical and practical aspects of this approach. This study identified a procedure for selecting some variables out of many to include in the risk terrain model; it compared RTM to hotspot mapping and suggested a way to utilize both in concert—rather than the need to have RTM replace density mapping; and it considered how risk clusters can be used in strategic decision-making in police organizations. See the full manuscript for a more detailed presentation and discussion of the results in which we concluded with an in-depth exploration of how one might develop strategies for incorporating risk terrains into operational policing.

"Since risk can cluster in meaningful ways, RTM can ground risk-based policing much more into the contexts in which police operate rather than concentrating police on behavior that they are trying to control."

"While some may instinctively think otherwise, cities experiencing reductions in violence such as Newark can benefit from analytical methods like risk terrain modeling as much as jurisdictions facing crime increases or stagnation."

Endnotes

[1] Lawrence W. Sherman, Patrick R. Gartin, and Michael E. Buerger 1989 " Hot Spots of Predatory Crime: Routine Activities and the Criminology of Place." *Criminology*, 27, 27-55.
[2] Lawrence W. Sherman 1995 " Hot Spots of Crime and Criminal Careers of Places." pp. 35-52 in John E. Eck and David Weisburd, eds., Crime and Place. Crime Prevention Studies, Vol. 4. Monsey, NY: Criminal Justice Press.
[3] Caplan, J. M., Kennedy, L. W., Miller, J. (in press). Risk terrain modeling: Brokering criminological theory and GIS methods for crime forecasting. *Justice Quarterly*.
[4] Brantingham, P.L., and P.J. Brantingham. (1995). Criminality of place: Crime generators and crime attractors. *European Journal on Criminal Policy and Research*. 3: 1-26.
[5] Caplan, J. M., Kennedy, L. W., Miller, J. (in press). Risk terrain modeling: Brokering criminological theory and GIS methods for crime forecasting. *Justice Quarterly*.
[6] Personal communication, Jonas Baughman, May 20, 2010 [Kansas City, Missouri Police Department].