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VULNERABILITY AND EXPOSURE TO CRIME: APPLYING RISK TERRAIN MODELING TO THE STUDY OF ASSAULT IN CHICAGO

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Full Article:
Kennedy, L. W., Caplan, J. M., Piza, E. L. & Buccine-Schraeder, H. (2015, online first). Vulnerability and Exposure to Crime: Applying Risk Terrain Modeling to the Study of Assault in Chicago. *Applied Spatial Analysis and Policy*. Link

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Introduction
This study addressed which factors relate to crime outcomes; considered the importance of crime risk factors relative to one another and weights them; suggested how these factors, when they overlap, created vulnerable (i.e., risky) places; and then isolated the catalyzing effect of crime events on new crime incidents at vulnerable places (Kennedy and Caplan 2013). The three key propositions of the theory of risky places are as follows:

1) All places are at risk for crime, but because of the spatial influence of certain criminogenic features of a landscape, some places are riskier than others;

> This proposition addresses the direct spatial influence (Tobler 1970) that risk factors, as studied in previous literature, have on assaultive behavior. This current study advanced what has been done previously as we look at the relative importance of these factors when considered together, rather than single effects. We can add to this consideration of risk a suggestion that certain types of facilities, known to be stronger attractors of crime, will be where we will find the most crime.

2) Crime emerges at places when there is high vulnerability based on the combined spatial influences of multiple criminogenic features at said places;

> Vulnerability comes from the emergence of settings that, because of the presence of a combination of risk factors' spatial influences, enhance the likelihood of illegal behavior. The resulting spatial inference acquired from this analysis addressed interactions that occur among risk factors to support aggravated assault behavior and ultimately crime incidence, which can be mapped and used as reference points for intervention and crime suppression activities.

3) The overall effect of risky places on crime is a function of differential vulnerability and exposure throughout the landscape.

> We can say that a place is vulnerable based on the co-location of criminogenic features, but this is not solely important if there are no recent nearby exposures to crime. But, if crime occurred at the place before and if the place is spatially vulnerable, then the likelihood that crime will occur in the future increases. This framework operationalized the vulnerability-exposure analytical approach that looks at the joint utility of hot spots, environmental risks, and near repeats (Caplan et al. 2013a). We characterized insights from the vulnerability-exposure analysis as spatial intelligence, suggesting that differential effects of vulnerability in the context of exposure provide actionable evidence for place-based policing efforts.

For the purposes of testing these propositions, we studied aggravated assault in Chicago, IL. We identified the environmental factors for this crime type and applied a series of tests to demonstrate how the vulnerability-exposure framework can be operationalized consistent with the assumptions about crime concentration.

Study Setting and Data Sources

Chicago is one of the major cities in the United States and the largest city in Illinois, with a long history of serious crime problems. In 2012 Chicago suffered a spike in homicides and gun violent incidents. The dramatic jump to 500 homicides in the city – a 16 % increase compared to 2011 - prompted city officials to rethink policing strategies. Lax gun laws in jurisdictions outside of the city border, feuding gangs and delinquent groups, drugs, and dispersed clusters of poverty seemed to have fueled violence in Chicago. Although Chicago now appears to be following a trend of decreasing rates of aggravated assaults (as similarly experienced across the country), the rates seem to be approximately double that of the rest of the US between 2005 and 2008, and approximately 150 % higher between 2010 and 2012. Violent crime is an ongoing problem in the city. Aggravated assault covers a wide range of criminal behaviors, from shootings to beatings in which victims sustain serious injuries. In Chicago, aggravated assault is defined as an illegal attack by a person where the offender displays a weapon in a manner that is threatening (Chicago Police Department). In Chicago there were over 12,000 aggravated assaults in 2012, giving us a large number of incidents to examine across the large expanse of the city.

Methods and Analysis

Testing Proposition 1:

In conducting the analysis, we used the RTMDx Utility, developed by the Rutgers Center on Public Security (Caplan et al. 2013b). The Utility applies a precise set of statistical tests, to be explained in the following discussion, in evaluating the relative importance of risk factors in influencing crime outcomes.

Thirteen risk factors were found to have significant spatial associations with aggravated assault incidents according to their spatial influence. In order of their relative risk values, the factors are: problem buildings, gang hot spots (i.e., known gang territories), foreclosures, bus stops, liquor stores, bars, grocery stores, gas stations, schools, 311 service requests for street lights all out, apartment

complexes, 311 service requests about abandoned vehicles, and variety stores. The most meaningful operationalizations and spatial influential distances of each risk factor are presented in Table 1. The relative risk values can be easily compared. For instance, a place influenced by problem buildings has an expected rate of crime that is twice as high than a place influenced by grocery stores (RRVs: 2.84 / 1.42=2). Accordingly, as posited in Proposition 1, all places may have some risk of crime occurrence, but because of the spatial influence of certain criminogenic features, some places are riskier than others. In particular, we find that problem buildings, drug hot spots and foreclosures have the strongest influence on locations for aggravated assault.

Table 1. Risk factors, spatial influence, and relative risk values for risk terrain model.

Risk Factor	SI	CO	RRV
Problem Buildings	426ft (P)	1.0458	2.84
Gang Hot spots	852ft (P)	0.92848	2.53
Foreclosures	852ft (P)	0.92104	2.51
Bus Stops	426ft (D)	0.57046	1.76
Liquor Stores	426ft (D)	0.52086	1.68
Bars	426ft (D)	0.41855	1.51
Grocery Stores	852ft (D)	0.35358	1.42
Gas Stations	1278ft (P)	0.25476	1.29
Schools	1278ft (P)	0.23762	1.26
311 Requests For All Street Lights Out	852ft (P)	0.22555	1.25
Apartment Complexes	1278ft (P)	0.16805	1.18
311 Requests for Abandoned Vehicles	1278ft (P)	0.16764	1.18
Variety Stores	1278ft (P)	0.1504	1.16
Intercept	--	-4.1625	--

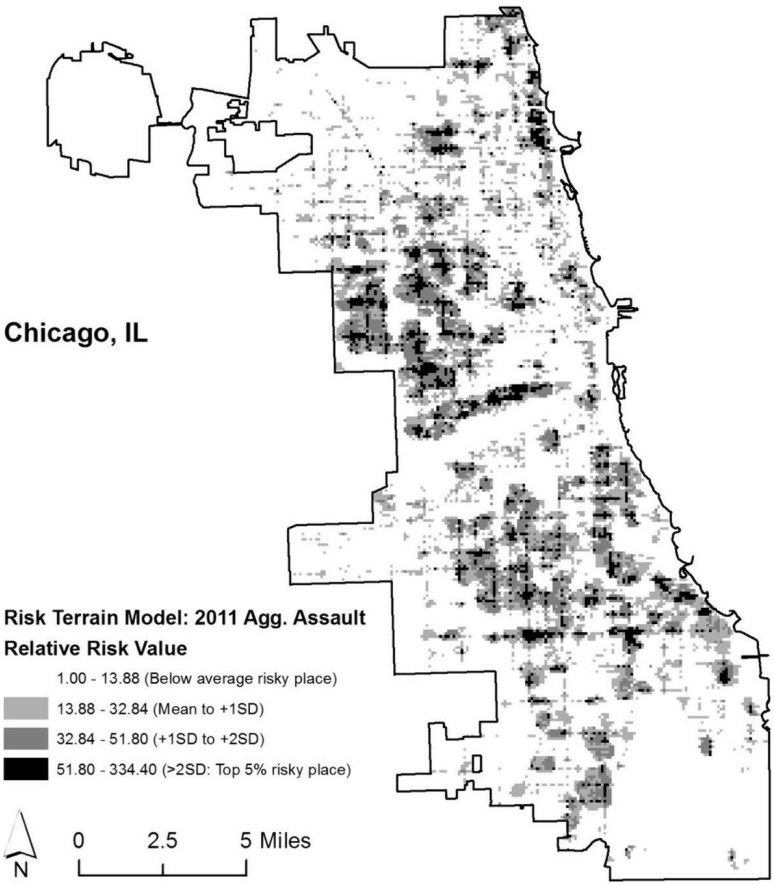
SI: Spatial Influence (Operationalization)
P: Proximity
D: Density
CO: Coefficient
RRV: Relative Risk Value

Testing Proposition 2:

The second proposition, "crime emerges at places when there is high vulnerability based on the combined spatial influences of criminogenic features," can be tested with a risk terrain model for aggravated assaults in Chicago. Places in Chicago with higher risk values should have greater expected aggravated assault counts than places with low risk values. Risk map layers of the 13 risk factors specified by the RTMDx Utility were combined through map algebra (Tomlin, 1994) using ArcGIS for Desktop's Raster Calculator, to produce a risk terrain map.

Proposition 2 was tested through a negative binomial regression model with the count of 2012 aggravated assaults as the dependent variable and a cell's Risk Value as the independent variable. In addition, a spatial lag variable was included as an independent variable in order to control for the observed presence of spatial autocorrelation. The Incidence-Rate Ratio (IRR) from a negative binomial regression suggests that the aggravated assault count increases 2% (IRR= 1.02) for every unit increase of

risk at a 426 ft cell. The mean and standard deviation of risk values are 13.88 and 18.96, respectively. So, a cell (i.e., a place approximately the size of a street block) with a risk value above the mean has an expected aggravated assault count that is at least 29% greater than that of cells with a risk value of 1 (1.02^12.8=1.29). Places with risk values equal to or greater than one standard deviation above the mean (31.84) have aggravated assault counts at least 88% greater than that of cells with risk values of 1 (1.02^31.84=1.88), while places with risk values two standard deviations above the mean (i.e. the top 5% of high-risk cells) have counts nearly three times as high as cells with risk values of 1 (1.02^50.80=2.73). These probabilities are statistically significant at $p<0.001$ and empirically support Proposition 2. Higher risk (i.e., spatially vulnerable) places have an exceptionally strong likelihood of experiencing future crime incidents.



To summarize, the risk terrain map in Fig. 1 articulates environmental contexts of places that are most likely to attract or enable aggravated assaults as a function of the combined influences of criminogenic features within Chicago. These results suggest that the risk terrain map produced to articulate the environmental backcloth for aggravated assaults in Chicago was statistically valid for forecasting purposes. The empirical predictive validity of the risk terrain model supports Proposition 2 because places that appear to be the most vulnerable on the map are also places where future aggravated assaults occurred most often (beyond random chance).

Figure 1. Risk Terrain Model for Chicago 2011 Assaults

Testing Proposition 3:

To further explore the relationship between spatial risk and Near Repeat crime occurrence, we conducted a logistic regression model with the individual assault incidents as units of analysis. The dependent variable was a binary measure of whether the incident was an instigator event (1) or not (0). The independent variable was the average risk value of the cells falling within the incident's aforementioned buffer area. The Average Cell Risk was statistically significant ($p<0.001$) with an odds ratio of 1.01. This suggests that with each 1-unit increase in Average Cell Risk, the odds of the incident generating additional near repeat assaults increases by 1%. As previously mentioned, the average risk for all buffers was 32.56 with a standard deviation of 19.76.

Based upon the odds ratio, an aggravated assault within a buffer greater than 1 standard deviation above the mean has 22 % higher odds of generating near repeat incidents than an assault within a buffer with a mean level of risk (1.01^[52.32–32.56]=1.22).

Cumulative results of t-tests and logistic regression models demonstrate that aggravated assault incidents become instigators for near repeats when they occur at places surrounded by higher levels of risk. These findings suggest that the overall effect of risky places on crime is a function of vulnerability and exposure throughout the landscape, and lends strong support to Proposition 3.

Summary and Conclusions

This study offers a way of improving on the spatial study of crime through the application of a vulnerability-exposure framework that considers how risky places are formed and sustained. The risk that comes from increased vulnerability tied to features in the environment, and the exposure that derives from crime incidents, concentrates at micro places and influences the new crime patterns that occur throughout an area. The stochasticity or fluctuations in criminal behavior may be the seeds from which new problem areas nucleate and grow. But, if places are not ideally suited for crime events and near repeat incidents, then they may never fully mature to be labeled "hot spots". The vulnerability-exposure framework helps to articulate such probabilities.

So, for aggravated assault in Chicago, we find that the most important predictors of occurrence are locations in which there are problem buildings. Next in importance is gang hot spots followed by the nearby presence of foreclosures. While significant, the locations that we normally associate with assaults, as reported in the previous literature, represented by bars, liquor stores, and schools are much less likely to be associated with assaults within the Chicago context.

This research demonstrates the tight connection between exposure to crime and vulnerability. The usefulness of hot spot analysis is enhanced, as shown here, by knowledge of the vulnerable locations in which the high risk factors prevail. So, plotting assaults and then looking to see where problem buildings, drug hot spots, and foreclosures locate, will provide the police with an effective tool in identifying where assaults are likely to take place in the future.

Extending beyond the confines of this Chicago study, using the vulnerability-exposure framework for crime analysis provides insights for a holistic response to crime problems. This approach is flexible in that it allows analysts to consider the characteristics of the landscape that may be emerging as problems within a jurisdiction and account for their influence and unique combinations while still taking account of what are known to be important correlates of aggravated assault. It offers a step-by-step guide for producing spatial intelligence applied to locating, anticipating, and preventing violent crime. As an applied strategy for crime control: It tells you, first, what to look for. Then, it tells you where to go to find it. Finally, it offers clues about the triggers to crime that come with previous offending and what to do about crime based on the important factors that create vulnerability in that location. The vulnerability-exposure approach provides an evidence-based method that encourages problem-oriented policing, focusing on how to change places to make them less conducive to crime

(Mastrofski et al. 2010). By articulating the environmental context of crime incident locations, the framework demonstrated here can help guide analyses that identify and prioritize specific areas and features of the landscape that should be addressed by a targeted intervention. It also provides an extension of solutions for response that go beyond what has been discussed related to hot spots policing, although could include some of the strategies that have been adopted there (Koper 2014). The vulnerability exposure approach to crime analysis not only tells police and other stakeholders where to go based on past crime occurrences, but how to prioritize new crime incidents and what to do about the places to make them less vulnerable. Investigating how such things as directed patrol or saturated policing would work in concert with crime prevention and community improvement offers a way forward in addressing vulnerability and exposure (Caplan et al. 2012).

Many crime incidents at the same location create hot spots. Hot spots may expand, contract, or move over time. The evolution of hot spots depends on the actions of offenders, the interventions of police, and the changing opportunities for crime that are influenced by prevention activities. For example, we have seen that violent crime in some locations subsides because of police presence, but also because of the follow-up actions of enforcement and responses to reported crime incidents. Hot spots can appear elsewhere from where they once did, but this will most likely be the case when the host areas are most vulnerable according to the risk terrain model (i.e., spatial influence).

When crime disappears from vulnerable places, should these places still be considered unsafe or suitable areas for crime to occur again? The answer based on findings of predictive validity of the risk terrain model (discussed above) is yes. Vulnerability does not change unless one or more factors that comprise the risk terrain model are mitigated. The spatial-temporal context for crime is merely exacerbated when vulnerable places are located near recent past crime incidents. Given the current thinking about crime vulnerability based on concentration and spatial influence of features and events, this paper offered an analytical strategy to model risky places that combined the conceptual insights of crime emergence and persistence, advances in geo-spatial analytical techniques, and micro-level data.

See also: Caplan, J. M. & Kennedy, L. W. (Forthcoming, 2016). *Risk Terrain Modeling: Crime Prediction and Risk Reduction.* Berkeley, CA: University of California Press. Link

References: See full article for complete list of reference citations.