The Edge Effect:

Exploring High Crime Zones near Residential Neighborhoods

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***Abstract*—Crime Pattern Theory offers a theoretical framework for a micro level explanation of the dynamics of crime in an urban environment. The research focuses on the novel use the concept of boundaries or edges to analyze micro level differences in crime in various urban neighborhoods. Edges are identified where there is dissimilarity between adjacent areas. Crime is more likely to occur along edges. Edges can be physical, social, temporal and economical or a product of these dimensions. This study compares crime data from the Municipality of Burnaby in British Columbia, Canada with patterns in land use data. Single family residential neighborhoods are constructed by joining adjacently zoned single family areas. The edges of these neighborhoods are the areas where the single family zoning changes to commercial, parks and higher density residential zoning The results finds crime is sixty four percent higher in these edges than in the interior of the neighborhoods. The results are discussed and future research proposed to repeat and enhance the model.**

Keywords: crime-pattern recognition – GIS techniques – crime analysis

I. Introduction

Crime Pattern Theory [1], [2] is tested using computational criminology, an emerging multidisciplinary field that uses criminology, geography, computer science and mathematics to better understand patterns of criminal events, offender target choices and social networking of co-offenders. Analysis is frequently done through spatial-temporal algorithms developed to describe the city's environment and, using these backcloth structures, identify features to predict where crimes are likely to occur [3].

Crime pattern research has found that offenders appear to navigate through an urban setting between crime attractors and along major roads. There are basic routine travel patterns that develop between home, work or school, shopping and entertainment. These locations and the routine pathways between these locations form an awareness space. Crimes mostly occur in these awareness spaces or at the attractors [1], [2], [7], [9].

Research has also found that people in general and offenders tend to find routine navigation routes along major roads or public transit routes. Crime tends to be highest along these routes or at, or near, common destination points like shopping areas, large schools, parks, or clusters of working locations. In turn, zoning patterns for land uses associated with higher use tend to be placed near major travel routes, that is areas that are easily accessible. Commercially zoned areas are near major streets or transit; industrially zoned areas are easily accessible; large senior level schools serve multiple neighborhoods and frequently are in high access locations. The high access attribute continues for drinking establishments, movie theaters, shopping malls and high use parks. With that crime concentrates near these high access locations [1], [2], [8], [9].

An important question is whether these crime concentrations expand or permeate into the surrounding, less accessible areas. This paper presents the results of a computational criminology approach to explore this micro level crime spread from high activity areas to surrounding ones. This is not done through a diffusion model but through the use of knowledge about human navigation in the urban environment and the cognitive images created for urban environments [5], [6].

The permeability of the edge or boundary of single family residential areas is the focus of the research. It is expected that crime will move from higher concentrations of crime along major access routes, but not far beyond the edge into the surrounding area and less towards the interior of the surrounding neighborhoods. Edges from spatially distinct single family dwellings are identified for a major suburb of the City of Vancouver, Canada. Buffers of varying sizes are used to test the permeability of the single family areas to crime.

The purpose of this study is to explore in some detail the differences in the edges based on land use classifications. While there are many other types of edges based on socio-economic or even architectural design that could impact their behavior, the first iteration of this type of research focuses on the dynamics of land-use changes, a highly visible change within a city. Future studies will bring in other dynamics into play within these spaces to explore core attributes.

II. Theoretical Review

A. Crime Pattern Theory

In 1993, Crime Pattern Theory [2] was formalized through four assumptions about crime. In a first instance crime events are described as complex requiring various elements to occur. Second, crime is not random due to the non-uniform spatial and temporal distribution of motivated offenders and targets. Third, offenders and victims use the environment as anyone else does and develop routine movement patterns. Through this routine activity they develop an awareness space of limited parts of a city. Motivated offenders are more likely to commit crime within the sphere of their normal activity space. Finally, motivated offenders, through daily routines and activities combined with their social and physical interactions with the environment, over time will develop a stable offending template.

B. Structual Elements in Urban Environment

In the *Image of the City,* Lynch [5] describes how cognitive images of the city are created and related to way-finding. Images are developed through an interactive process between the individual and the environment. These images of the city are individual, but can resemble the image of other people who may share experiences of the environment, live in similar areas or are attracted to similar activity areas. The city image is structured through constructed using major or minor elements: paths, edges, nodes, districts and landmarks.

Paths: These channels designed for movement such as streets, sidewalks, bike paths, or transit lines. Major paths would carry large numbers of people whereas minor ones have lower flow of people.

Edges: These are barriers between two places and vary in how penetrable they are. For instance, a river is very impenetrable whereas a change in land-use is less of a physical barrier, but may create a mental barrier.

Nodes: These are geographic points where activity concentrates. Nodes can be the crossing of two paths or large people attractors in a city. Nodes are connected to paths and are generally predominant features in perceptual images of the city.

Districts: These are sections of the city and each one has its own identifying character. Cities are structured through districts and while these districts hold similar geographical definitions from a general perspective, each individual person will place these in a different hierarchical order depending on their own personal experience.

Landmarks: These are reference points that are physical objects such as large building or mountains in the environment. These can be well-known landmarks and can symbolize a direction.

Couclelis, Golledge, Gale and Tobler [6], build the anchor-point theory on these elements established by Lynch [5] to show how space is conceptually clustered, and guides judgment about space. Individual cognitive maps evolve according to Lynch's principles. However, where landmarks are both individually and collectively experienced, anchor-points are only found in individual cognitive maps. These are places like home or work and are unrelated to the collective because these would be specific to the person forming the cognitive map.

Brantingham and Brantingham [2] use the geographical concepts of nodes, edges, paths and anchor-points to explain, in part, the occurrence of crime events. Offenders, in the sense of learning about space and developing routines, follow similar functions to non-offenders. And most offenders spend a large portion of their time in non-offending activity. Space in these theoretical approaches is structured in such a way that crime can be analyzed and predicted both at the individual and aggregate level. Cognitive image-making ties into Crime Pattern Theory as activity spaces follow these geographical principles [7], [8].

C. *Edges and Crime Occurrences*

Edges occur between two distinct spaces defined by a variety of characteristics including physical, social or economical attributes. The temporal and physical permeability of these edges also vary depending on a number of factors. Edges also range from sharp and well defined, to diffused and progressive.

For example, a river running through a city creates a very defined edge between two shores. Whereas a commercial strip which transitions to mixed-use structures to multiple dwelling residential buildings to single family dwellings represents a more progressive transition. Furthermore, major pathways such as major roads, highways or mass transportation networks, such as light rail systems, form edges that can either bisect neighborhoods or define communities.

From a perceptual perspective, edges emanate territorial cues that reduce spatial ownership, increase potential conflicts and decrease feelings of safety. For these reasons, crime events are more likely to occur in these areas. Furthermore, edges often contain a variation and concentration of criminal opportunities.

D. *Summary of Theoretical Framework*

Crime Pattern Theory provides an environmental context for crime events. The non-uniform distribution of crime is connected to the physical and cognitive structure of the urban domain. Physical, social and economical factors guide how people interact within the urban setting. In particular, the dynamics of edges can create high crime areas. Therefore the continued exploration of edges is an important contribution to the theoretical understanding of these spaces.

III. Methods

A. *Data*

Four data sources are integrated in this study: Police Information Retrieval System (PIRS), Land use data, British Columbia Assessment Authority (BCAA) data, and GIS Innovation data.

PIRS: Crime Data-Warehouse (CDW) is a collection of datasets located at the Institute of Canadian Urban Research Studies (ICURS) at Simon Fraser University. PIRS contains officially reported crime dataset events for Royal Canadian Mounted Police (RCMP) jurisdictions in British Columbia. This dataset contains about 4.4 million crime events. There are 43,225 crime events from the middle of 2001 to the middle of 2006 in the city of Burnaby, the study area in this study. These data contain attributes about the crime event such as date, time, location, offender, and specific crime type. This data does not contain attributes of residents of the locations victimized.

Land use Data: In 2001, Metro Vancouver published the land use dataset used in this study. It is classified as 14 land use categories: Agricultural, Commercial, Commercial – Residential Mixed, Industrial, Institutional, Lakes and Water Bodies, Open and Undeveloped, Recreation and Protected Natural Area, Residential – High Rise Apartments, Residential – Rural, Residential – Single Family, Residential – Townhouse and Low rise Apartments, and Transportation, Communication and Utilities.

In this study, the Residential – Single Family class is analyzed in detail. The area of this land use type is 33.6 square kilometers and covers 33.6 % of the study area.

British Columbia Assessment Authority (BCAA) data: 32,375 single family dwelling addresses were used to identify the exact x, y coordinates of those dwellings. They were used to calculate the crime density (crimes per dwellings).

GIS Innovation data: The 2006 road network data from the GIS Innovation was used to geocode crime event locations. This road network data was also used to visualize the output results.

B. *Geocoding*

Crime events records retrieved from PIRS have an address field that includes the street address of the crime location. The street addresses are converted to geographic coordinates through Geocoding. For example, a street address, 1020 North Road, could be geocoded somewhere at the road segment with the starting and ending house numbers of 1000 and 1098 respectively. The exact location is therefore determined through the interpolation of house number and street address. The side offset option in geocoding was set to five meters.

C. *Identifying the Edge and the Interior*

Land use type classified as "Residential - Single Family" was extracted and defined as either interior or edge. The edge was identified within each Residential – Single Family zone and was a buffer area with a width of 0 to 100 meters inward from the outer boundary of the Residential – Single Family zones. The interior was the complementary area not part of the edge buffer.

Once the interior and the edge were identified, the edge was defined more thoroughly to determine the relationship between the edge type and adjacent land use type. Edge – adjacent to Commercial zone, Edge – adjacent to Residential Multiple Family (Residential – Townhouse and Low rise Apartments), Edge – adjacent to Institutional, Edge – adjacent to Natural area (Open and Undeveloped, Recreation and Protected Natural Area), and Edge – adjacent to Industrial are defined by their adjacent land use zone. For example in figure 1, the Edge – adjacent to Commercial was identified in relation to the residential interior area and the adjacent commercial zone.

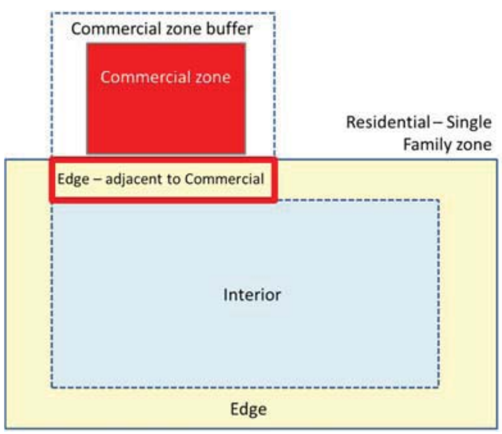

Figure 1: Identifying Interior and Edge

This process was replicated over the entire study area with both the interior residential areas identified and the edges to each of these interior spaces defined. The map of the study area in figure 2 shows the interior areas as light blue with the edges as white bands surrounding these residential interiors.

Figure 2: Study Area with Edges and Interior (100 meters Buffer)

D. *Crime Density Calculation*

The BCAA data was used to calculate the crime density. BCAA data is point data representing each lot. Once the buffer zone was established, including the interior and exterior boundaries, the housing unit density count for BCAA data was calculated. Crime count data was then divided by this BCAA data in order to establish data crime density value.

E. *Iterative Process – Re-defining the Buffer Zone*

The experiment was run to clarify crime patterns in residential neighborhoods, and more specifically compare crime density in the edge of single dwelling neighborhood compared to the interior aspect of these areas. Therefore, defining the edge and interior is a critical aspect of this experiment.

To further identify the characteristics of the edge, a crime density decay graph was used. First, the shortest distance between the crime location and the boundary of the Residential Single Family zone was calculated for each crime occurred in the Residential Single Family zone of the study area.

The distance between a point (*c*) and a boundary set (B) is the infimum of the distances between the point and the polygon that forms the boundary of the set.

$$d(c, \mathrm{B}) = \inf \{d_i(c,b)\},\ where\ b \in B$$

A polygon is a collection of finite polylines; therefore, the distance between a point (c) and a polygon could be written as the minimum of the distances between a point (c) and a collection of finite polylines.

$$d(c, B) = \min \{d_i(c, b)\}, \text{ where } b \in B$$

If the perpendicular line is within the polyline, as shown on the left in the figure 3, the shortest distance between the point c(x_1, y_1) and the polyline is the perpendicular distance. If a perpendicular line is outside of the polyline, as shown on the right in the figure 3, the shortest distance is the distance between the point c(x_1, y_1) and the closest vertex. [4]

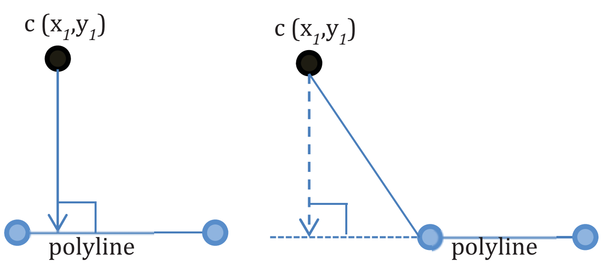

Figure 3: Distance Between a Point and a Polyline

After the distances between the crime point and the boundary was calculated, crime density was calculated every five meters in the buffer zone from the outer boundary of the Residential - Single Family zone inward. The circles in figure 4 show the location of dwellings and the red circles indicate the crime locations.

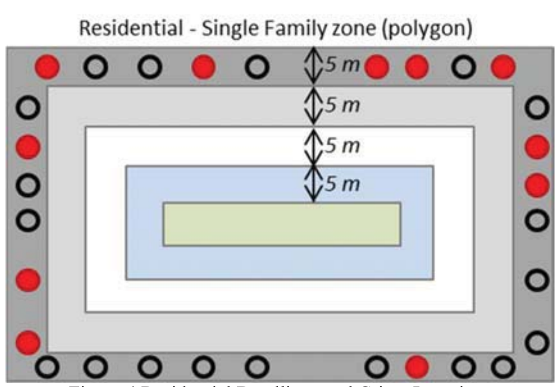

Figure 4 Residential Dwellings and Crime Locations

In order to calculate crime decay, the crime density for each successive five meter buffer zone was calculated for the number of crimes per the number of dwellings and plotted as shown in figure 5.

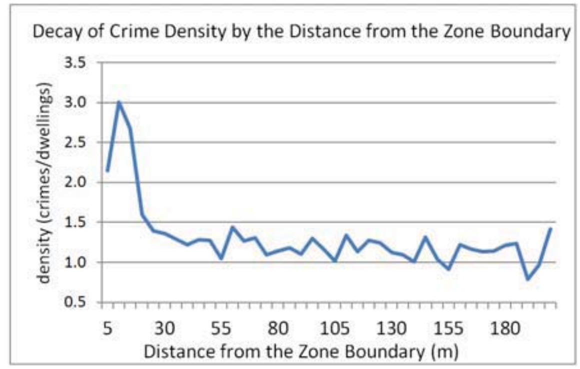

Figure 5 Crime Decay

The peak value of crime density was found around the 10 meters from the outer buffer boundary and drops rapidly at 30 meters. Also, the density value found steady after 30 meters. The results of this experiment are taken from within the 30 meters buffer zone.

IV. Results

The crime density in the homogenous interior and the 30 meter edge were calculated by crime/dwelling density. Table 1 shows how the crime density in the edge is higher than that of homogenous interior with a 64% difference.

Table 1: Interior and Edge Comparison

Residential (Single Family)	Dwellings	Crimes Count	Crime Density (crimes / dwellings)
Interior	26,110	30,931	1.18
Edge	6,264	12,173	1.94

Further analysis was conducted to determine how the interior area interacts with different types of land use. The edge where there was the highest crime was the Utility area with crimes being 187.9% higher in the edge that in the interior. Conversely, the edge with the lowest impact is Multiple Family edge which was only 20% higher than the interior. The Commercial edge contained 45.6% more crime than the interior, the Institutional edge, 105.6%, the Industrial edge contained 127.7% and the Natural Area edge 69.2% more crime than the interior. Table 2 displays the crime distribution in these areas.

Table 2: Crime in Edges

Edge	Dwellings	Crimes Count	Crime Density (crimes / dwellings)
Edge - Commercial	3,410	5,676	1.66
Edge - Multiple Family	5,010	7,885	1.57
Edge - Institutional	5,197	8,464	1.63
Edge - Natural Area	6,215	8,492	1.37
Edge - Industrial	1,199	2,485	2.07
Edge - Utility	1,016	1,716	1.69

V. Discussion

The results of this experiment support the Crime Pattern Theory in a number of ways. First, crime events are complex as these relate to urban dynamics. Second, the crime events explored here are not uniformly distributed in the edges. Some edges have significantly higher levels of crime. This could be attributed to both the distribution of targets and the specific nature of the edge. Third, the variation in crime distribution may be attributed to the movement patterns within these edges. Finally, the daily routines that occur in these edges may be extremely varied both physically and temporally.

This research further supports the edge theory, with crime higher on the border/edge than the interior. The results show that there is 64% higher crime in the overall edge area compared to the interior. Furthermore, the variation of the edge comes to the forefront. In this research, the highest crime edge is the Industrial one and the lowest is the Multiple Family edge. This initial research combined crime types. Future research into edges will concentrate on the variation by crime type that occurs in these spaces (eg: property crime, violent offenses or public disorder). Similarly this initial study focused on the difference in edges by land use and attributes available in the data sets. Future analysis will include, with the acquisition of the population data, even greater distinctions including factors such as income, education levels and ethnicity.

This study is limited to one jurisdiction in metropolitan Vancouver as such these results cannot be generalized to all jurisdictions. However, this research does explore the intricacies at play within edges with strong results encouraging future research in other jurisdiction to verify whether land-use impacts edges in a similar manner.

Research on edges is important to civic agencies engaged in crime prevention. While calibration would be necessary in a different city, should the pattern be repeated in a similar form, it would outline the importance of considering and focusing physical crime prevention in the possibly narrow high crime buffer zones surrounding residential neighborhoods. Resources could be maximized in these edges to reduce crime opportunities while maximizing offender apprehension. Future land use decisions could also be calibrated to incorporate these concepts and reduce high crime edges through alternate development decisions. Future research will concentrate of delving further into these edges to discover the intricacies of the edge effect.

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